[EHNUR WP 10]

WHAT WOULD BE NECESSARY FOR A SMALL AUSTRIAN NUCLEAR POWER PROGRAM: ACTIONS, NUMBER OF UNITS, TIME TABLE & COSTS

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EXECUTIVE SUMMARY

A thought experiment has been conducted concerning four questions for a theoretical small nuclear power program for Austria:

- What would be necessary in order to establish a nuclear power program in Austria?

  Austria would have to:

  - Pass a constitutional amendment rescinding the ban on nuclear power.
  - Pass a nuclear law (enabling legislation).
  - Pass legislation establishing liability for nuclear accidents.
  - Establish and staff an independent Nuclear Regulatory Authority (NRA) and its Technical Support Organization (TSO).
  - Establish regulation for nuclear powered electricity costs (either under the current E-Control or in another regulatory regime).
  - Establish a nuclear constabulary or an equivalent organization to provide external security for four nuclear power plant sites and a geological repository, as well as spent fuel and radioactive waste shipments from power plant sites to the repository.
  - Upgrade emergency planning and response capabilities for responding to nuclear accidents inside Austria and for providing assistance to neighboring transboundary countries in such an event.

- Approximately how many nuclear units of what size would make sense for Austria, given a particular framework for reducing Austrian electricity imports, and for reducing generation of electricity from carbon intensive sources?

  Given the size of the Austrian grid and the likelihood of considerable resistance at siting nuclear power plants and radioactive waste repositories, a total of four nuclear power plants and a single geological repository for low and intermediate level radioactive waste and spent fuel are suggested. Only a limited number of advanced reactor designs fit the Austrian grid situation, and the choice of technology would likely be from among the AP1000 and the VVER-1200/491 pressurized water reactors, the KERENA and ESBWR boiling water reactors, and the EC-6 pressurized heavy water reactor. The latter would require four pairs of units in order to have approximately the same generating capacity as four units of the other designs.

- How much time would be required for implementation of the assumed nuclear power program?

  Assuming an immediate start with passage of a constitutional amendment allowing a nuclear power program, the first reactor would be unlikely to begin operation before 2028. It is assumed that the next three units would follow at two-year intervals (i.e. in 2030, 2032, and 2034). Assuming 60 years of operation for each unit, the last unit would shut down for decommissioning in 2094. Assuming 10 years for decontamination, spent fuel shipment (after five years of cooling in the spent fuel pool), and dismantlement, and assuming all shipments to the geological repository are completed 10 years after the shutdown of the last unit, the closure of the geological repository could begin in 2104 and be completed 5-10 years later (i.e., not later than 2114).

- Approximately how much would the assumed nuclear power program cost, including regulation and government costs; plant construction, and operation; decommissioning; and radioactive waste storage & final disposal?

The grand total estimate for a 4-unit nuclear power program is €147 billion. This estimate is based on: (a) a per unit cost of €10 billion (as an all-in estimate, including overnight costs, owner's costs, connection of the plant to the grid, escalation, inflation, and interest on construction loans); (b) operations and maintenance (O&M) expenses – including fuel – of 3 Eurocents per kilowatt hour; (c) 93% plant availability, as predicted by the designers; (d) decommissioning costs of €1.5 billion per unit; (e) a single radioactive waste and spent fuel repository at a cost of €15 billion; and (f) lifetime governmental costs of €7 billion (over 110 years). This is a relatively optimistic estimate in that:

- It does not account for cost increases over time (except very crudely for the regulatory authority cost);
- It does not account for possible cost increases in nuclear fuel (which are very possible since easily accessible uranium ores will likely be exhausted during the lifetime of the assumed nuclear power units);
- It does not account for profit for the owner/operator utility (but note that the current industry average return on equity is about 5% or less, so such a profit level would not dramatically disturb the results reported here);
- It does not account for lower than projected (by the designers) plant availability or for lengthy shutdowns for correction of possible generic issues arising during the course of operation of the units over their planned 60-year service lifetime); and
- It does not account for higher than normal accident liability costs, which are plausible following on the experiences with the 1986 Chornobyl and 2011 Fukushima Daiichi accidents (both of which had cost consequences in excess of €200 billion)[2].

[2] The cost of the Chornobyl Unit 4 accident in 1986 is cited as $451 billion in Wikipedia (about €356 billion Euro at current exchange rates). The cost within Japan of the Fukushima Daiichi nuclear accidents in 2011 vary from $137-650 billion (about €105-500 billion), which spans costs estimated by TEPCO as of November 2012 to the high end of estimates by Physicians for Social Responsibility. This range spans estimates by the Japan Center for Economic Research, experts at the Stanford Department of Economics, Greenpeace, and a Commissioner of the Japanese Atomic Energy Commission, although most estimates do not exceed €250 billion.

Recent nuclear accident cost estimates prepared by IRSN (France) have included an estimate of €120 billion for a "*representative severe nuclear accident in France*", and an estimate of €430 billion for a "*representative major nuclear accident in France*". Note that the so-called representative accident involved core melt followed by radioactive releases that are "*more or less controlled*" and therefore not "*massive*". The major nuclear accident release is termed "*massive*", resulting in higher costs (Pascucci-Cahen & Patrick, 2012).

It is also noteworthy that on-site costs are calculated as €6 billion and €8 billion in the two cases. These estimates are far greater than the oft-cited cost of €1 billion for the on-site costs of the 1979 Three Mile Island Unit 2 accident (these costs did not include replacement power costs for the loss of generation from the 906 MWe net reactor; such losses, judged with a 75% capacity factor and considering five years to build a replacement combined cycle gas turbine (CCGT) plant, amount to about 30 trillion kWh). If one costs out this lost generation at 5-10 cents U.S. per kWh, the additional losses were $1.5-3.0 billion, plus the cost of the replacement unit (in 2002, such units cost about $800/kWe, or about $725 million for a 906 MWe unit). Thus, the total losses were about $3.25-5 billion for a severe accident in which the containment did not fail.

A more pessimistic estimate considers a €15 billion per unit cost, O&M costs of 5 Eurocents per kilowatt hour, and 50% plant availability. In this more pessimistic case, the cost increases to €170 billion.

Excluding utility profits and other factors identified above, these two cost estimates amount to 7 Eurocents per kilowatt hour and 15 Eurocents per kilowatt hour, respectively, spread over the 60-year operating lifetime. (Typically the costs are higher for 15 years or more since the lending institutions for construction loans require repayment of the loans much faster than 60 years. Once the capital cost and construction loans are paid off, the cost of operations drops to the differential O&M and fuel costs, plus utility profit.)

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INTRODUCTION

This chapter of the EHNUR report consists of a thought experiment (*Gedankenexperiment* in German) in which it is a working assumption that the Austrian government and population have decided to abandon the current anti-nuclear position and establish a modest nuclear power program for electricity generation. The purpose of a thought experiment is to think through its consequences. The purpose of this thought experiment is not to recommend a change in the Austrian position, but rather to explore the consequences of such a change which is assumed (irrespective of its plausibility) to nonetheless occur.

METHODOLOGY

The methodology for the EHNUR thought experiment is three-fold:

- Using the International Atomic Energy Agency (IAEA) guidance for establishment of a nuclear safety infrastructure, (International Atomic Energy Agency, *Establishing the Safety Infrastructure for a Nuclear Power Programme*, SSG- 16, December 2011), define a nuclear safety infrastructure for a hypothetical Austrian nuclear power program. Since SSG-16 does not extend past the completion of startup testing for the first nuclear unit in a country, IAEA requirements documents are used to define additional measures needed in the operation, decommissioning, and radioactive waste repository closure periods.
- The nuclear safety infrastructure needs are based on SSG-16 is conditioned on relevant Austrian conditions (e.g. a nuclear skeptical population and Parliament, Austrian grid conditions, and Austrian siting limitations for nuclear facilities), Austrian international treaty and convention obligations, and European Council requirements.
- The cost of the hypothetical small Austrian nuclear power program is coarsely estimated considering government costs (including regulatory oversight), capital cost and interest on construction loans for four nuclear units, operations and maintenance (O&M) costs – including nuclear fuel – for four nuclear units, and the costs associated with decommissioning four nuclear units and emplacing radioactive waste and spent fuel in a geological repository. Utility profits are not included in the cost estimate, nor are cost increases over time due to inflation. A more pessimistic case (involving higher unit construction costs, lower plant availability, and higher O&M costs) is also considered. The objective of the cost estimate is not precision, but rather an order -of-magnitude estimate.

LIMITATIONS

The results represent a particular point-of-view concerning regulatory matters and responsibilities for costs (i.e. in most cases the owner/operator utility would be responsible for the costs, which would be passed on to ratepayers at a profit). One could structure the case differently, and obtain somewhat different results, but ultimately the small nuclear power program would require most of the features described herein in one form or another. Regardless of whether the costs are charged to ratepayers or taxpayers, the costs <u>will</u> be paid. The difference with the positions taken here is that those who obtain electricity from the power plants would pay, be those ratepayers in Austria or abroad in case of nuclear-generated electricity exports.

Also, the cost estimates for the program (base case and more pessimistic) are very general, yielding only order-of-magnitude results. Given the uncertainties and the long time period over which a small nuclear power program would be carried out of more than a century, we consider the estimates to be broadly reasonable. With different assumptions, of course other estimates could be made, however we do not believe they would be different in order-of-magnitude from what we have described here.

1. BACKGROUND, PRINCIPAL THESIS, AND QUESTIONS TO BE ANSWERED IN THE THOUGHT EXPERIMENT INFRASTRUCTURE

This chapter of the EHNUR report consists of a thought experiment (*Gedankenexperiment* in German) in which it is a working assumption that the Austrian government and population have decided to abandon the current anti-nuclear position and establish a modest nuclear power program for electricity generation. The purpose of a thought experiment is to think through its consequences. The purpose of this thought experiment is not to recommend a change in the Austrian position, but rather to explore the consequences of such a change which is assumed (irrespective of its plausibility) to nonetheless occur.

In 1979, Austria decided against allowing construction and operation of nuclear power plants within the country. In 1999 constitutional prohibition to this effect was enacted.

A decade later Austrian citizens remained nuclear skeptical. In a 2010 opinion survey conducted by TNS Opinion & Social at the request of the EC Directorate General for Energy and Transport, it was found that two-thirds of Austrians believe that the risks of nuclear power outweigh its benefits, and also believe that the current level of reliance on nuclear power within the EU should be reduced (EC, 2010). Thus, an *entirely theoretical* change of position (as assumed in the thought experiment herein) does not constitute a recommendation for an *actual* change in position. Any such change is up to the Austrian population and the Austrian Parliament.

It is nonetheless useful to understand the requirements, time frame, and costs of a small nuclear power program for Austria. Accordingly, the main questions of the current thought experiment are four in number:

- What steps would be necessary in order to establish a nuclear power program in Austria?
- Approximately how many nuclear units of what size would make sense for Austria, given a particular framework for reducing Austrian electricity imports, and for reducing generation of electricity from carbon intensive sources?[3]
- How much time would be required for implementation of the assumed nuclear power program?
- Approximately how much would the assumed nuclear power program cost, including regulation, construction, operation, decommissioning, and radioactive waste storage and final disposal?

A nuclear power plant (Kraftwerk Union BWR/69, 692 MWe net) was constructed in Austria at Zwentendorf[4] however it never entered operation as a result of a national referendum on 5 November 1978 which went against startup of the plant by a narrow margin[5]. A nuclear power plant

[3] It must be recognized that even if Austria embarked on a nuclear power program, such nuclear units are base load power plants, and that peaking power units powered by natural gas would likely continue to be necessary.

[4] The Zwentendorf nuclear power plant was built by Gemeinschaftkernkraftwerk Tulnerfeld GmbH (GKT), of which 50% was owned by Verbund and the remainder by a number of Austrian regional utilities.

[5] The actual vote was 50.5% against operation of Zwentendorf and 49.5 in favor. Upper Austria, Salzburg, Tyrol, and Voralberg had more than 50% opposed. Burgenland, Carinthia, Lower Austria, Styria, and Vienna had more than 50% in favor. The results by Austrian province are available at the website of the Austrian

at St. Pantaleon-Erla/St. Valentin, on the border between Lower Austria and Upper Austria near the confluence of the Enns River and the Danube River near Linz, about 100 km west of Zwentendorf) had also been planned (presumably also the same plant design as Zwentendorf), as had a reactor at a site in Carinthia near St. Andrä[6], northeast of Klagenfurt.

According to EVN, a total of six nuclear power plant sites had been discussed[7], but all plans were cancelled after the 1978 referendum (we could not identify the other three sites in time for inclusion in this report).

Notwithstanding an eventual constitutional amendment prohibiting nuclear power within Austria, about 12% of Austria's electricity consumption is estimated to come (as of 2012) from nuclear power plants outside Austria (primarily in the Czech Republic and Germany) (ENS, 2012). Legislation passed by the Austrian Parliament in mid-April 2012 represents an attempt to ban (by the end of 2014) electricity imports resulting from nuclear power generation. Starting on 1 January 2015, Austrian utilities will be required to provide certificates of origin for power imports[8], and imports from nuclear power sources will be prohibited under the Parliamentary legislation.

Even if Austria were to decide to permit construction and operation of nuclear power plants, there would be some very difficult issues with which to contend for the Austrian population, the Austrian Parliament, the Nuclear Regulatory Authority, and the prospective constructing/operating utility:

- The extent of liability coverage for nuclear accidents – Austria is not currently a party to any international convention concerning liability for damages from a nuclear power plant accident (Austria signed but did not ratify the Vienna Convention and Paris Convention). There is unlimited liability were such an accident to occur in Austria. It is considered extremely unlikely that any prospective utility wishing to construct a nuclear power plant in Austria would do so facing unlimited liability in the event of an accident (particularly for a utility with significant foreign government ownership involvement such as, for example, ČEZ and EdF which are majority government owned, or SE/ENEL, which is nearly two-thirds owned by the Italian and

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Interior Ministry, http://www.bmi.gv.at/cms/BMI_wahlen/volksabstimmung/Ergebnisse.aspx. Extremely detailed results by election district are also available at http://www.bmi.gv.at/cms/BMI_wahlen/volksabstimmung/files/volksabstimmung.pdf.

6 No record of the proposed location could be found online. We assume that the plant would have been constructed near the Drava River (known as the Drau in Austria), about 10-15 kilometers south of St. Andrä, since the town itself is located at the foot of mountains, and there is no water supply there which would be adequate for cooling purposes for a 700 MWe nuclear power plant. The Lavant River flows through the town, but the average discharge of the river is only 12.5 m^3/s (45,000 m^3/h). The condenser cooling water flow from the Elbe River for the 771 MWe net Brunsbüttel nuclear power plant in Germany (nominally identical to Zwentendorf but somewhat larger) was 120,000 m^3/h for once-through cooling (no cooling tower) (Nonbøl, 1994). The Lavant River's entire average discharge is thus less than half of what would have been required for a repeat of the Zwentendorf plant on the Lavant River near St. Andrä.

7 Energie Versorgung Niederösterreich (EVN), *Zwentendorf atomic power plant*, http://www.zwentendorf.com/en/geschichte.asp?index=7. Some other sources cite seven eventual units, but whether the number was six or seven is of little import here.

8 This is not so radical an idea as it may initially sound, since European Commission Directive 2003/64/EC already established labeling provisions for electricity supply. See, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:176:0037:0037:EN:PDF and http://ec.europa.eu/energy/gas_electricity/interpretative_notes/doc/implementation_notes/labelling_en.pdf for details. The prohibition against importing nuclear-generated electricity is a unique feature of the Parliamentary legislation.

Slovak governments through their holdings in the two companies). It is also unlikely that Austria would charter its own nuclear power plant construction and operating company in such circumstances (a significant nuclear accident at a nuclear power plant in Austria could produce damages of the order of €200 billion or more, which is a sum that represents more than half of the country's GDP). Some sort of compromise position would have to be developed to limit liability for nuclear accidents, or a nuclear power program in Austria would simply not develop irrespective of a government decision to allow nuclear power in Austria. What such a compromise would entail is difficult to forecast, and is anyway beyond the scope of the current assessment. We simply assume that a compromise would be reached in the nuclear power enabling legislation.

- The level of safety required for a nuclear power plant – It is considered likely that the nuclear skeptical Austrian population and Austrian Parliament, and therefore the eventual Austrian Nuclear Regulatory Authority would require a very high level of safety for nuclear power plants and the necessary low and intermediate level radioactive waste (LILW) and spent fuel storage and disposal facilities. Insofar as nuclear power plant designs are concerned, it is considered unlikely that a nuclear power plant in the 700-1500 MWe class (see below) without a double containment, a robust containment filtered venting system, and state-of-the-art accident prevention and mitigation systems would prove acceptable in Austria under the best of circumstances. This limits the potential nuclear power plant design choices as indicated below.

- Siting of nuclear power plants and radioactive waste management & disposal sites – Given the current views of the Austrian population, the geomorphology of the country, and the prevalence of forest and other lands that are protected nature reserves, siting of nuclear power plants and radioactive waste management & disposal facilities would be difficult at best. This would necessarily limit the number of such sites, bearing in mind as well the limited capabilities of the Austrian electricity grid to support nuclear power units larger than 700-1500 MWe range. At the upper end of this range, condenser cooling water potential may also limit siting possibilities.

- Anti-terrorism protection and security requirements for the power plant and radioactive waste management & disposal sites – It is considered very likely that the Austrian population, the Austrian Parliament, and the eventual Austrian Nuclear Regulatory Authority would require significant protection of nuclear power plants and radioactive waste management & disposal sites against hypothetical acts of sabotage and terrorism. Given current Austrian arrangements, it appears that such protection would entail a layered protection system with responsibilities for the prospective nuclear power plant operator within the nuclear power plant protected area, the Austrian Federal Police (Bundespolizei, under the command of the Interior Ministry) within a zone outside the protected area, and the Austrian military (Bundesheer[9]) for protection against

[9] The Bundesheer includes the Land Forces Command (Kommando Landstreitkräfte), the Air command (Kommando Luftstreitkräfte), and Special Forces Command (Kommando Spezialeinsatzkräfte, which has explicit counter-terrorism tasking). The Austrian military is equipped with the Mistral short range air defence missile system, an infrared homing surface-to-air missile with an effective range of more than five kilometers. The Austrian Air Force has a squadron of fifteen Eurofighter Typhoon aircraft and two 14-aircraft squadrons of 14 Saab 105Ö aircraft, all based at Hinterstoisser Air Base (formerly Zeltweg Air Base) near Knittelfeld and Zeltweg. The Saab 105Ö aircraft are twin-engine attack/surveillance aircraft with six hardpoints that can carry air-to-air missiles, air-to-surface missiles, gun pods, bombs, and rockets. The Eurofighter Typhoons are twin-engine multi-role fighters, in Austria equipped with AIM-2000 IRIS-T (short range) and AIM-120 AMRAAM (beyond visual range) air-to-air missiles and 27 mm Mauser (now Rheinmetall) BK-27 Revolver cannon with 150 rounds. The aircraft has 8 under-wing hardpoints and 5 under-fuselage pylon stations.

paramilitary or military attack, or terrorist attack using aircraft. Stand-off (or set-back) distances adequate to protect against vehicle bombs (including ship-borne bombs) should be established for nuclear power plants (it is considered highly unlikely that radioactive waste storage & disposal sites would be located near water)[10]. Protection of the switchyard for the nuclear power plant might also be necessary (and difficult), especially if the switchyard is located at some distance from the nuclear reactors. Similarly, protection of a dry spent fuel storage facility might also be required; such a facility might be integrated with the nuclear power plant site to facilitate protection.

[10] An analysis for the U.S. Nuclear Regulatory Commission prepared by the U.S. Army Corps of Engineers recommends a standoff distance of 110 meters (360 feet) for vehicle bomb defense (NRC, 1994).

2. IAEA SAFETY REQUIREMENTS FOR NUCLEAR SAFETY INFRASTRUCTURE

With only a minimal existing nuclear power infrastructure as of 2013[11] (compared with what would be required for a small nuclear power program), it will be assumed that Austria would follow consensus IAEA Safety Standards in establishing the infrastructure necessary to support a nuclear power program. The IAEA Safety Standards are arranged in three levels. At the top is the Fundamental Safety Principles. The next level is a series of mandatory ("shall" statements)[12] requirements documents that implement the Fundamental Safety Principles. The third and last level consists of safety guides that indicate how the requirements can be met, but are not mandatory ("should" statements).

The following are the IAEA Safety Requirements applicable to nuclear power plants:

Safety Fundamentals

- IAEA SF-1, Fundamental Safety Principles, November 2006, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf.

Specific Safety Requirements for Nuclear Power Plants

- IAEA SSR-2/1, Safety of Nuclear Power Plants: Design, January 2012, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1534_web.pdf.

- IAEA SSR-2/2, Safety of Nuclear Power Plants: Commissioning and Operation, July 2011, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1513_web.pdf.

- IAEA NS-R-3, Site Evaluation for Nuclear Installations, November 2003, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1177_web.pdf.

General Safety Requirements

- IAEA GSR Part 1, Governmental, Legal and Regulatory Framework for Safety, September 2010, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1465_web.pdf.

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[11] Nuclear power related courses are taught at the University of Natural Resources and Life Sciences Vienna (Boku), the University of Vienna, the Erich-Schmid Institute for Materials Science in Leoben, the Technical University of Vienna (including the Atominstitut), the Technical University of Graz, and the University of Innsbruck. University courses in radiation protection and radiological technology are taught at the Upper Austria University of Applied Sciences and the University of Applied Sciences Wiener Neustadt.

Nuclear consulting services are provided in Austria by ENCO (formerly Enconet) and BBM e.U., both in Vienna. Nuclear Engineering Seibersdorf (NES) provides for collection, conditioning, and temporary storage of radioactive wastes until final disposal. Seibersdorf Laboratories has programs on application of ionizing radiation (including dosimetry, analytical procedures, radiation protection, calibration of radiation protection measuring instruments, and operation of a hot cell laboratory). See the EC's Joint Research Centre EHRO-N description for Austria for more details, http://ehron.jrc.ec.europa.eu/austria.

[12] The IAEA does not have enforcement authority for its Safety Standards however the Safety Standards are used as the basis for all IAEA missions to nuclear power plants, radioactive waste management & disposal facilities, and nuclear regulatory authorities (IAEA, 2009).

- IAEA GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Interim Edition, November 2011, http://www-pub.iaea.org/MTCD/publications/PDF/p1531interim_web.pdf.

- IAEA GSR Part 4, Safety Assessment for Facilities and Activities, May 2009, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1375_web.pdf.

- IAEA GSR Part 5, Predisposal Management of Radioactive Waste, May 2009, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1368_web.pdf.

- IAEA GS-R-2, Preparedness and Response for a Nuclear or Radiological Emergency, November 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1133_scr.pdf.

- IAEA GS-R-3, The Management System for Facilities and Activities, July 2006, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1252_web.pdf.

- IAEA WS-R-5, Decommissioning of Facilities Using Radioactive Material, October 2006, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1274_web.pdf.

Specific Safety Requirements for Radioactive Waste Management

To date, there are no international or multi-national radioactive waste disposal facilities. The EHNUR project considers that none are likely to be created in the near future, notwithstanding the European Commission's SAPIERR 6th Framework Project[13] (EC, 2006), the ARIUS[14] organization, the ERDO[15] working group, the MoDeRn 7th Framework Project[16], and IAEA's similar project (IAEA, 2004).
Consequently, we consider that in the event that Austria implemented a small nuclear power program, the operating utility would have to plan to have its own radioactive waste management and disposal facilities, while continuing to pursue multilateral approaches in a two-track approach. At a minimum, the operating utility would need to plan for repositories for low and intermediate level radioactive waste (LILW) and high level radioactive waste (HLW) which is presumed here to consist of spent fuel (i.e., no reprocessing of spent fuel and return of vitrified waste to Austria for disposal)[17]. It may be that the volumes of LILW and HLW would be such that both waste streams could be disposed of in one repository. (This is what is planned in Canada, for example.)
The IAEA Safety Requirements applicable to such facilities are:

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13 Austria participated in the SAPIERR project.

14 The Association for Regional and International Underground Storage (ARIUS), formed to promote concepts for shared underground radioactive waste storage facilities on behalf of its members. The members of ARIUS are ONDRAF-NIRAS Waste Agency (Belgium), Kozloduy Nuclear Power Plant (Bulgaria), PURAM Waste Agency (Hungary), ENEA National Agency (Italy), Obayashi Corporation (Japan), Colenco Power Corporation (Switzerland), COVRA Waste Agency (the Netherlands), ARAO Waste Agency (Slovenia), and the Radiation Safety Centre Government Authority (Latvia). Austria is not part of the ARIUS effort.

15 ERDO is the European Repository Development Organization, which is investigating the feasibility of a shared solution for radioactive waste disposal. Austria is a member of ERDO, along with Bulgaria, Ireland, Lithuania, the Netherlands, Poland, Romania, Slovakia, and Slovenia. The IAEA and the European Commission are observers (http://www.erdo-wg.eu/Documents_files/ERDO-WG%20En.pdf).

16 Monitoring Developments for Safe Repository Operation and Staged Closure, http://www.modern-fp7.eu/; Austria did not participate in this project.

17 It should be noted, however, that the original plans for spent fuel from the Zwentendorf nuclear power plant apparently envisioned reprocessing, since after the shelving of the Zwentendorf plant there was a contract with COGEMA for reprocessing spent fuel that had to be cancelled (Weish, 1988).

- SF-1, GSR Part 1, GSR Part 3, GSR Part 4, GSR Part 5, GS-R-2, GS-R-3, and WS-R-5, identified in detail above; plus
- IAEA SSR Part 5, Disposal of Radioactive Waste, April 2011, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1449_web.pdf.

It is assumed herein that nuclear power plants in Austria would rely on medium-term, above ground dry spent fuel storage until a high level waste repository could be sited, licensed, constructed, and placed in operation. Austria (and the operating utility) would (sooner or later) have to comply with IAEA Safety Requirements related to transport of radioactive material (see below).

Safety Requirements for Transportation of Radioactive Material

Transport of LILW and spent fuel from the sites where it is produced to the eventual LILW and HLW repositories in Austria (as well as transport of fresh fuel elements to the nuclear power plants) will involve transportation of radioactive materials within Austria. The IAEA Safety Requirements for such transport are:

- SF-1, GSR Part 1, GSR Part 3, GSR Part 5, GS-R-2, and GS-R-3, already identified in detail above.
- IAEA SSR Part 6, Regulations for the Safe Transport of Radioactive Material: 2012 Edition, October 2012, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1570_web.pdf.

Safety Requirements for Nuclear Fuel Cycle Facilities

Lacking uranium resources of its own, it is assumed that utilities operating nuclear power plants in Austria would purchase nuclear fuel assemblies from a supplier (after supplying the uranium purchased on the open market to the supplier), and that nuclear fuel cycle facilities (mining, milling, conversion, enrichment, and fuel fabrication) would not have to be constructed in Austria. Thus, we do not further consider IAEA Safety Requirements for such facilities.

Draft Safety Requirements Documents Under Development

The following IAEA Draft Safety Requirements will also impact on a hypothetical Austrian nuclear power program:

- DS462, revision through addenda of GSR Part 1, NS-R-3, SSR-2/1, SSR-2.2, and GSR Part 4.
- DS457, Preparedness and Response for a Nuclear or Radiological Emergency, Revision of GS-R-2.
- DS456, Leadership and Management for Safety, Revision of GS-R-3.
- DS450, Decommissioning and termination of Activities, Revision of WS-R-5.

IAEA Safety Guides

There are many dozens of IAEA Safety Guides that provide additional guidance about how to meet the Safety Requirements (see the IAEA Safety Standards website for details, http://www-ns.iaea.org/standards/default.asp?s=11&l=90), but the Safety Guides are not requirements and will generally not be considered here. An exception to this is the following:

- IAEA SSG-16, Establishing the Safety Infrastructure for a Nuclear Power Programme, December 2011, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1507_Web.pdf.

SSG-16 provides for a staged implementation of nuclear power infrastructure for a state not already having a nuclear power program. Although SSG-16 is a Safety Guide and not a Safety Requirement, it is assumed that Austria would follow SSG-16 in most respects since SSG-16 considers the Requirements Documents identified above in three stages leading to the deployment of the first nuclear power plant. It would be expected that both the Nuclear Regulatory Authority and the prospective utility would use the other IAEA Safety Guides as points of reference in complying with the IAEA Safety Requirements documents.

3. SPECIFIC TOPICS TO BE CONSIDERED FOR A HYPOTHETICAL AUSTRIAN NUCLEAR POWER PROGRAM

The following aspects of constitutional, legal, and regulatory matters have been identified that Austria would have to address in order to embark on a nuclear power program:

- Passage of a Constitutional Amendment Allowing Nuclear Power in Austria. This would be a necessary first step considering the current constitutional prohibition against nuclear power in Austria. (It is to be noted in this regard that on 13 August 1999 the Austrian Parliament adopted the Federal Constitutional Act for a Nuclear-Free Austria.) Overturning the current constitutional prohibition is taken as a starting point for the current thought experiment. A national referendum would not be required.

- Legislation Establishing an Independent Nuclear Regulatory Authority. A truly independent Nuclear Regulatory Authority (i.e., one in which a politician cannot remove the head of the Authority for political reasons; one in which the Administrator of the Authority is appointed by the Bundeskanzler (Federal Chancellor) or the Bundesregierung (Federal Government) with the approval of the Austrian Parliament for a fixed term of office, perhaps five years, with the possibility of being appointed for an additional term) would probably be insisted on by the nuclear skeptical Austrian population and Parliament. Note that European Council Directive 2009/71/Euratom of 25 June 2009 and Council Directive 2011/70/Euratom both call for the nuclear regulatory authority to be both *de jure* and *de facto* independent (Atiyas and Sanin, undated).

- Legislation Establishing a Nuclear Power Plant Operating Organization – This would be necessary only if Austria were to decide to charter a nuclear operating organization to construct and operate nuclear power plants, and then sell the electricity to entities for distribution. Such an arrangement is not recommended here due to the inherent difficulty of the regulation of one government entity (the nuclear operating authority) by another (the Nuclear Regulatory Authority), but it must be acknowledged that such an arrangement is actually quite common among countries with nuclear power plants[18].

- Legislation Concerning Requirements for Utilities Proposing to Construct and Operate a Nuclear Power Plant. Austria could elect to enact laws regarding utilities operating nuclear power plants other than those provisions that are strictly applicable to nuclear safety and radiation protection. These requirements could include:

  - Financial stability: The ability of a utility to fund construction on its own or to go to the financial markets for loans to cover the costs of siting, design, construction, and startup testing could be an important consideration.

  - Controlling ownership of the utility: Would Austria decide that only Austrian (or EU) companies should own and operate nuclear power plants, or would Austria permit majority

[18] The National Nuclear Regulatory Authority being placed in the position of regulating the nuclear power plants of another government entity is currently the practice in more than half of the countries currently operating nuclear power plants: Argentina, Bulgaria, the Czech Republic, France, Hungary, India, Iran, Mexico, Pakistan, the People's Republic of China, the Republic of Korea, Romania, the Russian Federation, Slovenia, in part in Sweden (in the case of Vattenfall), Ukraine, and in part in the United States (in the case of the Tennessee Valley Authority). This is also the planned arrangement in three countries with near-term nuclear power plant construction programs (Lithuania, Turkey, and Vietnam).

ownership of Austrian nuclear power plants by non-EU foreign companies? Austria could conceivably also contemplate a Build-Own-Operate arrangement in which a foreign company builds the reactors, owns the reactors, and operates the reactors, selling the electricity to the Austrian market.

Given the lack of nuclear power plant construction and operating experience among Austrian utilities, it is possible that not only would Austria allow foreign ownership, but indeed might *encourage* it in order to attract an experienced utility to invest in and operate an Austrian nuclear power project. EnBW (Germany) might be an option since two remaining operating nuclear power plants in Germany will close in 2019 (Phillipsburg Unit 2) and 2022 (Neckarwestheim Unit 2), EnBW might in theory welcome a chance to construct and operate nuclear power plants in Austria[19] EnBW has experience operating both PWRs and BWRs. EnBW is publicly traded, but 93.5% of the shares are held by NECKARPRI-Betiligungsgesellschaft mbH (which is owned by a subsidiary that is 100% controlled by the German Federal State of Badem-Wüttemberg; also controls 46.55% of the shares of EVN) and OEW Energie-Beteiligungs GmbH (which is controlled by OEW Zweckverband, which is a union of nine German administrative districts or *Landkreis* – Ravensberg, Alb-Donau, Bodensee, Biberach, Zollnerhalb, Rottweil, Sigmaringen, Freudenstadt, and Reutlingen).

AXPO (Switzerland) is similarly situated since its operating nuclear power plants are scheduled for closure between 2020 and 2034, and Axpo has experience with both PWRs and BWRs. Axpo is part of Axpo Holding AG, which is wholly owned by the Cantons of North Eastern Switzerland (Aargau, Glarus, Schaffhausen, Thurgau, Zug, and Zurich) and their Cantonal utility companies (Utilities of Canton of Zurich, AEW ENERGIE AG, St. Gallisch-Appenzellische Kraftwerke AG, and Elektrizitätswek des Kantons Thurgau AG).

Electricité de France (EdF)[20] would represent another possibility to operate nuclear power plants in Austria. (Note that the French government owns 85% of EdF well as 88% of Areva.) EdF has a long-standing relationship with Areva, and the two might act together in a bid to construct nuclear power plants in Austria. Within the size range of 700-1500 MWe, Areva has (in a joint venture with Mitsubishi) the ATMEA1 PWR (1150 MWe) and the KERENA BWR (1250 MWe)[21]. Areva might insist on supplying fuel as well as reprocessing the spent fuel by its Areva NC subsidiary. EdF has experience operating PWRs and AGRs (a U.K. only gas-cooled reactor design).

A third possibility would be GDF Suez, operator of the Doel and Tihange PWR nuclear power plants in Belgium. GDF Suez has expressed interest in or submitted bids for construction of nuclear power plants in Brazil (EPR design), Chile, France (EPR design at Penly; since withdrawn), the Netherlands, Turkey (with the ATMEA1 design) and in the United Arab Emirates (with the EPR design), and has also considered constructing new nuclear power units at the Sellafield site (together with Iberdrola; since withdrawn). The company has a

[19] Note that EnBW owned 32.5% of EVN as of 7 May 2012. Since EVN is part of a syndicate (with Wiener Stadtwerke) that owns 25% of Verbund, EVN owns 12.5% of Verbund.

[20] Electricité de France owns 25% of Energie Steiermark. EdF also owns and operates 15 nuclear units in the United Kingdom.

[21] Areva has two advanced reactor designs, one of which (EPR at 1600 MWe net or higher) is too large for Austria's grid. Areva is also part of a joint venture with Mitsubishi in the ATMEA1 design, which at 1150 MWe net may fit into Austria's grid, but which design has only a single containment and a higher core damage frequency than other advanced designs in the same power class.

presence in Austria in the natural gas market, and GDF Suez Cofely also has a presence in Austria.

If an Austrian utility were to decide to construct the VVER-1200/491 design, it would make some sense to do so with the partnership of a European utility that has experience with VVER-1000 reactors. Such a situation might mean a partnership with ČEZ a.s,, Bulgaria's NEK, Ukraine's Energoatom, or the Russian Federation's Rosenergoatom (which has VVER-1200/491 units under construction at the Baltic and Leningrad II sites). All of these utilities are majority or wholly owned by their respective governments.

More distant possibilities include Nuclear Power Corporation of India, Ltd. (NPCIL, owner of the soon to operate Kudankulam AES-92/VVER-1000 reactors) and China Guangdong Nuclear Power Company[22] (CGNPC, operator of the Tianwan AES-91/VVER-1000 units). Both NPCIL and CGNPC are owned by their respective governments.

On the other hand, since 72% of Austrians do not trust companies operating nuclear power plants (EC, 2010), Austria might opt to charter a not-for-profit government company to build, own, and operate nuclear power plants, selling the electricity that is produced at cost to conventional utilities. Such a choice, however, places liability for nuclear accidents squarely on the Austrian government (and therefore on the Austrian population), and (as noted above) introduces the unfortunate result that one government agency (the Nuclear Regulatory Authority) would be placed in the position of having to regulate the activities of another government agency (the Nuclear Operating Authority). This approach is not recommended here.

– Ratemaking: Would Austria establish a ratemaking structure for a utility operating a nuclear power plant, or would Austria require that nuclear power plants be owned and operated as merchant plants? Electricity ratemaking in Austria is currently handled E-Control under the authority of the Federal Ministry of Economy, Family and Youth (Bundesministerium für Wirtschaft, Familie und Jugend, BMWFJ).

– Decommissioning funding: Austria would very likely establish legislation requiring the establishment of decommissioning funding for nuclear power plant projects. Austria might consider requiring decommissioning funds be deposited in a protected fund of the full amount required for decommissioning as part of the construction permitting process. Austria might also consider a more traditional mechanism such as a surcharge on electricity sales with the proceeds required to be placed in a protected decommissioning fund (protected in the sense that the money could not be used for any other purpose). Unless the full amount required for decommissioning is required to be established in a fund prior to commencement of commercial operation, there would have to be some arrangement made for providing decommissioning funding in the event that an accident were to occur that would result in early decommissioning of the plant (prior to accumulating sufficient funds for decommissioning), or in the event that the owner/operator utility would decide at some point that continued operation had become uneconomical (prior to accumulating sufficient funds for decommissioning).

[22] CGNPC was renamed in mid-May 2013 as the China General Nuclear Power Group, with the acronym CGN.

- Accession of Austria to International Treaties, Conventions, and Agreements:

  Austria has already acceded to a number of international treaties, conventions, and agreements related to nuclear power:

  – Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (ratified 22 December 1989);

  – Convention on Nuclear Safety (ratified 24 November 1997);

  – Convention on the Physical Protection of Nuclear Material (ratified 21 January 1989) and the Amendment (ratified 18 September 2006), but the Amendment is not yet in force;

  – Treaty on the Non-Proliferation of Nuclear Weapons and the Additional Protocol (INFCIRC/193/Add.8, 12 January 2005);

  – Convention on Early Notification of a Nuclear Accident (ratified 18 February 1988); and

  – Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (ratified 13 June 2001);

  Austria is not a signatory to the following:

  – Vienna Convention on Civil Liability for Nuclear Damage, and the Protocol to Amend the Convention;

  – Convention on Supplementary Compensation for Nuclear Damage;

  – Optional Protocol to the Vienna Convention on Diplomatic Relations, Concerning the Compulsory Settlement of Disputes; and

  – Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention.

  Austria has also acceded to a number of agreements that have a bearing on obligations related to nuclear power:

  – Aarhus Convention – Austria ratified the Aarhus Convention (*Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters*, Aarhus, Denmark, 25 June 1988) on 17 January 2005. The European Commission approved the Aarhus Convention on 17 February 2005.

  – Aarhus Convention PRTR Protocol – Austria ratified the PRTR protocol (*Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters*, Kiev, Ukraine, 21 May 2003) on 23 March 2010. The European Commission approved the PRTR Protocol on 21 February 2006.

  – Espoo Convention – Austria became a Party to the Espoo Convention (*Convention on Environmental Impact Assessment in a Transboundary Context*, Espoo, Finland, 25 February 1991) on 23 March 2010. Austria became a party to the 1st Amendment and the 2nd Amendment of the Espoo Convention on 14 September 2006.

  – SEA Protocol – Austria ratified the SEA Protocol (*Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary*

Context, Kiev, Ukraine, 21 May 2003) on 23 May 2010. The EC also approved the SEA Protocol on 12 November 2008.

- EC Directives on public participation and access to justice (Directives 85/337/EEC, 96/61/EC, and 2003/35/EC).

- Austrian Representation on IAEA, International, and EU Committees:

  Austria might consider upgrading its representation on IAEA Safety Committees (NUSSC, RASSC, TRANSSC, and WASSC) and also nominate the Administrator of the eventual Nuclear Regulatory Authority as a member of the Commission on Safety Standards (CSS).

  Austria also might upgrade its participation in WENRA from Observer to Member status, with the eventual Nuclear Regulatory Authority Administrator as Austria's member in WENRA.

  Austria would probably change its membership in ENSREG from the Lebensministerium to the Administrator of the eventual Nuclear Regulatory Authority.

  Austria might also consider membership in the International Framework for Nuclear Energy Cooperation (IFNEC) in which a number of EU Member States also belong (Bulgaria, Estonia, France, Germany, Hungary, Italy, Lithuania, the Netherlands, Poland, Romania, Slovenia, and the United Kingdom).

  Finally, Austria might consider joining the Network of Regulators of Countries With Small Nuclear Programmes (NERS). Other EU Member States belonging to NERS are Belgium, the Czech Republic, Finland, Hungary, the Netherlands, Slovakia, and Slovenia. Switzerland also belongs to NERS.

- Plausible essential attributes of an Austrian nuclear power program, considering the nuclear skeptical Austrian population and Austrian Parliament, include:

  - Consistent and extensive transparency by both the Nuclear Regulatory Authority and any utility constructing and operating a nuclear power plant. This should also apply to the TSOs for the Authority and utility.

  - Significant stakeholder involvement in Nuclear Regulatory Authority decision-making.

  - Consistent and extensive public availability of information by both the Nuclear Regulatory Authority and any utility constructing and operating a nuclear power plant (subject, of course, to limitations related to security provisions of the nuclear power plant, and to limitations related to proprietary information). This should also apply to the TSOs for the Authority and utility.

  - Public comment and required Nuclear Regulatory Authority response concerning rulemaking proposals, and Nuclear Regulatory Authority and prospective utility response concerning comments on environmental impact assessments.

  - A very high standard of safety and severe accident risk reduction. Considering the Austrian public's views on nuclear safety, even if the population and Austrian Parliament were to change position and allow construction and operation of nuclear power plants within Austria, it is considered very likely that such plants would be held to an exemplary and very high standard of safety and severe accident risk reduction. It would not be expected that the INSAG standards of a core damage frequency of less than 1×10^{-5} per year and a large release frequency of less than 1×10^{-6} per year would be accepted. Rather, it seems more likely that Austria would elect to have more stringent safety goals, probably more of the order of a core damage frequency of less than 1×10^{-6} per year and a large release frequency of less than 1×10^{-7} per year. While such seemingly aggressive safety targets are very difficult for current Generation II nuclear power plants to meet, it seems possible (given assessments to date) that such targets could be met by Generation III and Generation III+ designs.

It is considered unlikely that the nuclear skeptical Austrian population and Austrian Parliament would accept any safety target other than the most stringent regarding large release (probably 10^{-7} or less per year) (Bengtsson et al., 2010), and would be unlikely to accept a core damage frequency target above 10^{-6} per year from all causes (internal and external events at power operation and shutdown/refueling). The use of mean values is recommended herein, along with the display of the range of uncertainty (typically the range from the 5th to 95th percentile of the uncertainty distribution is provided), for comparison to safety targets. It is also recommended that the comparison to safety targets be made considering all causes (internal and external events at power operation and shutdown/refueling).

- Memberships in International, Regional, and Industry Organizations:

  – A utility applying to construct and operate a nuclear power plant in Austria should probably be expected to belong to the World Association of Nuclear Operators (WANO), and to the technology-appropriate owners group (BWR Owners Group, CANDU Owners Group, Framatome Owners Group, Westinghouse Owners Group, VVER Owners Group, etc.).

  – The Nuclear Regulatory Authority should probably belong to the Multinational Design Evaluation Program (MDEP), the IAEA Global Nuclear Safety and Security Network (GNSSN), the IAEA International Regulatory Network (RegNet), and the International Framework for Nuclear Energy Cooperation (IFNEC). The Nuclear Regulatory Authority should probably also join EMUG (European MELCOR Users Group) and whatever users group exists for the ASTEC code (developed by IRSN and GRS). [Use by the regulatory authority of the MAAP code is not recommended as it is seldom used in Europe (mostly in Japan, the Republic of Korea, and the U.S. as a result of its sponsorship by EPRI).] MELCOR is broadly in use in Europe[23] and use of ASTEC is increasing due to EC Framework Program ERMSAR, EVITA, SARnet, and SARnet2 activities[24].

- Austrian Grid Capacity: Austria has a somewhat limited grid capacity. The largest single unit currently on the Austrian grid is the Theiss unit at 775 MWe (oil/natural gas).

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[23] EMUG participants includes CIEMAT (Spain), European Commission JRC, DIMNP University of Pisa (Italy), ENEA (Italy), IBRAE (Russia), Karlsruhe Institute of Technology (Germany), KTH (Sweden), NUBIKI, and Paul Scherrer Institute (Switzerland) among research organizations; GRS (Germany), Nuclear Research Institute Rez (Czech Republic), TUV Nord, and VUJE (Slovakia) among research institutes among TSOs; AREVA (France), SNPTC (People's Republic of China), and Westinghouse Germany among vendors; GDF Suez (France), NRG (Belgium),Risk Engineering Ltd. (Bulgaria); Vattenfall among utilities; and Serco (UK) among engineering organizations; and UJD (Slovakia) among regulators.

[24] Users of ASTEC include BARC (India), EdF (France), ENEA (Italy), Empresarios Agrupados (Spain), European Commission Joint Research Centre (Netherlands), GRS (Germany), IRSN (France), Karlsruhe Institute of Technology (Germany), Kurchatov Institute (Russia, Nuclear Research Institute Rez (Czech Republic), Ruhr University Bochum (Germany), UJD (Slovakia), and VUJE (Slovakia).

The Austrian grid experiences peak load in the winter months (November to January). Peak loads are around 10,800 megawatts according to ENTSOE. According to the U.S. Central Intelligence Agency (CIA) World Factbook, Austria is the 11th largest electricity exporter in the world and at the same time the 8th largest electricity importer in the world. According to the Austrian Energy Agency, electricity consumption in Austria is increasing by 2% per year[25] (a doubling time of about 35 years). (This would imply a doubling of electricity consumption, for example, between 2013 and 2048.) Inadequate reserve margin is forecast by 2020 in four neighboring countries (Germany, Hungary, Slovakia, and Slovenia). Note that there is no direct interconnection between Austria and Slovakia. These conditions suggest that continued imports of electricity may slowly become more problematic by 2020 and thereafter.

- Public Hearing and Public Comment Processes: There should be mandatory provisions for public hearings and public comments on licensing proposals (these provisions would likely be demanded by the nuclear skeptical Austrian population and the Austrian Parliament). These provisions should apply to nuclear power plant and radioactive waste management/disposal siting, safety, and decommissioning, and to operation of a research reactor. Funding of third party stakeholders could also be considered in nuclear legislation, specifically related to public comment preparation and public hearing participation (for counsel and expert testimony)[26].

[25] Austrian Energy Agency, *Stop the increase of electricity consumption*, http://www.klimaaktiv.at/english/savingenergy/SavingEnergy.html.

[26] Participant funding is common across a variety of agencies and ministries in Canada (including the Canadian Nuclear Safety Commission), and is also common in state utility regulatory agencies in the United States. The U.S. Environmental Protection Agency (EPA) also has participant funding provisions. Provisions for participant funding also exist in France and Sweden.

4. ESTABLISHING THE NUCLEAR SAFETY INRASTRUCTURE FOR A NUCLEAR POWER PROGRAM (IAEA SSG-16)

IAEA Specific Safety Guide SSG-16 (IAEA, 2011) provides considerable and international consensus guidance on progressive implementation of IAEA Safety Standards in establishing a nuclear safety infrastructure. The guidance covers Phase 1 (safety infrastructure before deciding to launch a nuclear power program), Phase 2 (safety infrastructure preparatory work for construction of a nuclear power program), and Phase 3 (safety infrastructure during implementation of the first nuclear power plant).

SSG-16 indicates that years 1 through 3 are required for Phase 1, years 3 through 7 are required for Phase 2, and years 7 through 10 are required for Phase 3. Phases 1-3 take the process from a decision to launch a nuclear power program to the end of startup testing for the first plant.

In Phase 1, years 1 through 3, SSG-16 foresees the performance of the initial site survey and preparation of an environmental impact assessment (EIA). At the end of this phase, the National Nuclear Law is foreseen to be passed, following which the Nuclear Regulatory Authority issues safety requirements which are needed for preparation of bid specifications by the prospective utility. At the end of year 7, SSG-16 indicates that the prospective utility should be prepared to invite bids. (Some shortening of the process could be accomplished by the prospective utility requiring that a reactor supplier should comply with the European Utility Requirements (EUR).)

In Phase 3, SSG-16 has the evaluation of construction bids occurring with contract award, followed by the submittal of the construction license documentation and its evaluation by the Nuclear Regulatory Authority, issuance of the construction license, site preparation, and completion of construction.

Accomplishing all of this in <u>4 years</u> (i.e., years 7 through 10, 48 months) represents an optimistic appraisal of the situation by IAEA. In EHNUR Work Package 4, the durations for these activities are 111 months (<u>9 years</u> and 3 months, with nominal durations of 15 months for receipt & evaluation of bids, contract negotiations, and contract signing; 30 months for preparation of construction license application, its review by the Nuclear Regulatory Authority, and issuance of the construction license; 18 months for site preparation; and 48 months for construction and readiness for fuel load and startup tests). Even in the most optimistic case, these durations total 95 months, or <u>8 years</u> rather than the four years assumed by SSG-16.

The SSG-16 period of 4 years is thus too optimistic. The combined duration for SSG-16 Phases 1-3 should be seen as 15-16 years, and not 10 years. (Strangely enough, the introduction to SSG-16 actually acknowledges a 15-year period under optimum conditions, rather than the 10 years discussed above. In addition the INSAG-22 estimated duration for these activities included a range for Phases 1-3 of 11 to 20 years.) This would put the first unit of Austria's hypothetical nuclear power program coming online at the earliest in about 2028, almost at the boundary of EHNUR’s principal 2030 horizon.

5. FUNCTIONAL AREAS ADDRESSED BY THE ACTIONS RELEVANT TO THE GOVERNMENT AND NUCLEAR REGULATORY AUTHORITY

A national nuclear power program is a major undertaking requiring careful planning and preparation by the Austrian Government, by the Nuclear Regulatory Authority, and any prospective utilities proposing to construct and operate nuclear power plants. Such a program represents a long-term commitment:

- 3 years for passage of relevant constitutional amendment and national nuclear legislation (range of 1-3 years);
- 2 years for the Nuclear Regulatory Authority to be established and issue regulatory requirements for nuclear power plants and radioactive waste management and disposal facilities (range of 1-2 years);
- 15 years for the construction of the first unit from feasibility study to the start of commercial operation (range from 13-17 years);
- 2 year intervals between the first unit and each succeeding unit (range from 1-3 years);
- 60 year service life (typical of Generation III and Generation III+ designs);
- 5 years for decontamination and immediate dismantlement for decommissioning, and transport of low and intermediate level waste to a repository;
- 5 years cooling (minimum) of spent fuel in wet storage before packaging in dual-purpose casks for dry storage awaiting transport to the high level waste repository;
- 10 years for dual purpose cask transport to the high level waste repository, and emplacement of casks in the repository; and
- 5 years for repository closure.

Such a program amounts to a total commitment of more than 100 years from the decision to permit establishment of a nuclear power program until the closure of the high level waste repository.

In the subsections of Chapter 6 that follow, we have mostly followed the topical outline of SSG-16. Inasmuch as we have considered that Austria would probably encourage an experienced utility to construct and operate nuclear power plants in its limited nuclear power program, we have expended only modest effort in the SSG-16 Actions that apply to the utility. Thus, we have eliminated discussion in most cases regarding Actions 18, 54, 57-58, 83, 96, 110, 112-114, 119, 127-128, 130, 139, 141, 149-159, 162-163, 165-169, 173, 176-181, 183, 186-187, and 198 because these Actions are uniquely utility Actions in SSG-16. These Actions are, of course, of potential relevance to the Nuclear Regulatory Authority in its oversight of nuclear power plant activities.

5.1. NATIONAL POLICY AND STRATEGY FOR SAFETY

The SSG-16 nuclear safety infrastructure functional area for National Policy and Strategy for Safety consists of Actions 1-16 (see Annex 1). These Actions are addressed in the following paragraphs.

The Austrian Government should ground any nuclear power program policy in the IAEA Fundamental Safety Principles (IAEA, 2006)[27]. The Fundamental Safety Principles identify a Safety Objective:

[27] SF-1 has been endorsed by, among others, EURATOM, the OECD Nuclear Energy Agency (NEA, http://www.oecd-nea.org/), and the United Nations Environment Program (UNEP, http://www.unep.org/). In addition to being an IAEA Member State (since 1957), Austria is also a Member Country of NEA (since

- *The fundamental safety objective is to protect people and the environment from harmful effect of ionizing radiation.*

The Fundamental Safety Principles then identify ten principles that support the Safety Objective:

- *The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.*
- *An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.*
- *Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.*
- *Facilities and activities that give rise to radiation risks must yield an overall benefit.*
- *Protection must be optimized to provide the highest level of safety that can reasonably be achieved.*
- *Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.*
- *People and the environment, present and future, must be protected against radiation risks.*
- *All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.*
- *Arrangements must be made for emergency preparedness and response for nuclear and radiation incidents.*
- *Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.*

There is additional discussion under each of the ten Fundamental Safety Principles further elaborating on them. Note that the ten safety principles "*form a set that is applicable in its entirety; although in practice different principles may be more or less important in relation to the particular circumstances, the appropriate application of all relevant principles is required*" (IAEA, 2006).

It is assumed that the Austrian National Nuclear Policy would consist of at least the following elements.

Actions 1-4 are government actions which are assumed to be addressed by the Austrian Parliament in the enabling legislation for the nuclear power program, the Austrian Nuclear Regulatory Authority, and the Technical Support Organization for the Authority.

Consistent with the IAEA Fundamental Safety Principles, the Austrian Government should establish by law (in the enabling legislation) that the primary responsibility for nuclear safety lies with the prospective facility operating organizations (SF-1 and GSR Part 1, Requirement 6). Although other groups (designers, manufacturers, constructors, employers, contractors, consigners, and carriers) may have legal, professional or functional responsibilities with regard to safety, the primary responsibility for safety rests with and remains with the prospective operating organization at all

1958), has been a Member State of the United Nations since 1955, and joined the European Union (and EURATOM) in 1995.

times. This primary responsibility for safety cannot be delegated or outsourced. In all cases, the operating organization retains legal responsibility for the actions of its contractors and its consultants. If consequences result from the action of an organization or employee acting for the licensee, the licensee will be held responsible by the Austrian Nuclear Regulatory Authority. The licensee may have legal recompense in regard to the organizations or employees acting on its behalf, but the licensee is fully responsible for safety.

The primary responsibility for safety applies to the lifetime of facilities and the duration of licensed activities – including site evaluation, design, construction, commissioning, operation, shutdown, decommissioning, and transport of low and intermediate level radioactive waste (LILW) and high level radioactive waste (HLW) to repositories for final disposal, as well as similar activities for research reactors.

In the event of adoption of a small nuclear power program, the Austrian Government would be expected to establish an independent Austrian Nuclear Regulatory Authority to regulate the siting, construction, operation, and decommissioning of nuclear power plants; the siting, construction, operation, and final closure of low and intermediate radioactive waste (LILW) and high level waste (HLW) repositories; and the regulation of research reactors. The Nuclear Regulatory Authority should be led by a single Administrator[28] appointed by the Bundeskanzler (or Bundesregierung) with the advice and consent of the Austrian Parliament.

The Administrator of the Nuclear Regulatory Authority would serve a fixed 5-year term, with the possibility of reappointment for an additional 5-year term[29], and could be removed from office only for cause (medical incapacitation, criminal activity, etc.). The Administrator would report directly to the Bundeskanzler (or Bundesregeirung), and not to an Austrian Government Ministry. This is necessary in order to ensure the de facto independence of the Nuclear Regulatory Authority.

The Austrian Nuclear Regulatory Authority would require the legal authority to (IAEA GSR Part 1, §2.13):

- Issue, amend, suspend, and revoke licenses as necessary (both facility licenses and licensed personnel).
- Require the provision of all necessary safety related information, including information from suppliers, even if this information is confidential or proprietary.
- Access, solely or together with the applicant or licensee, for the purpose of making inspections on the premises of any designer, supplier, manufacturer, constructor, contractor, or operating organization associated with the licensee.

It is anticipated that the Nuclear Regulatory Authority would have a staff of about 245 persons[30], and an annual budget of the order of €35-50 million (covering staff, benefits, taxes, training, and

[28] Some nuclear regulatory authorities are led by commission forms of administration (e.g., Canada, Japan, France, and the United States) however these tend to be authorities in countries with relatively large nuclear programs. In countries with small nuclear programs, it is much more typical to have a regulatory authority with a single administrator (e.g., Czech Republic, Finland, Hungary, Slovakia, Slovenia, Sweden, Switzerland, and the United Kingdom).

[29] Five-year terms are common, however the head of SSM (Sweden) serves for six years, and the head of STUK (Finland) serves for seven years.

[30] This staff size is based on the following considerations (totaling 245 people):

research). The goal of regulation would be to support a high level of safety (safety as high as reasonably achievable, in the words of the IAEA Fundamental Safety Principles) for the Austrian people and the environment.

The Austrian Government should not charter a company to construct and operate nuclear power plants. Rather, the Government should require that nuclear power plants and the necessary radioactive waste management and disposal facilities be constructed and operated based on licenses issued by the Nuclear Regulatory Authority.

The Austrian Government should require by law that radioactive waste management and disposal related to nuclear power plant operation and decommissioning is the responsibility of the operating utility or utilities. The Finnish and Swedish models are recommended herein, whereby the utility or utilities establish a Radioactive Waste Management and Disposal Company which conducts necessary research and proposes a design for the low and intermediate level waste (LILW) and high level waste (HLW) repositories, and proposes sites for these repositories. The Austrian Nuclear Regulatory Authority would review the proposed designs and sites for the repositories, and would license the repositories once the reviews and stakeholder interactions on the proposals are completed.

The Austrian Government should establish an Austrian National Nuclear Safety Laboratory as a Technical Service Organization for the Nuclear Regulatory Authority[31]. The Laboratory could (and perhaps should) operate a nuclear research reactor (but not for medical isotope production, which is undertaken by MedAustron, or the provision of services to industry)[32]. The Laboratory would be a TSO solely for the Austrian Nuclear Regulatory Authority, and perform no work for nuclear industry organizations (this should be an absolute prohibition to avoid conflicts of interest). The Laboratory should however be free to participate in EC Framework projects with other TSO and research organizations. The Laboratory could also, in cooperation with Universities, offer opportunities for

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- Resident inspectors, two in the day time, one each on evening and night shifts, with capacity to cover illnesses and vacations (assuming eight inspectors per site and four sites, 32 persons in total).
- Nuclear power plant licensing and safety analysis group (assume 50 persons in total, covering the relevant disciplines), including nuclear power plants and research reactors.
- A nuclear power plant operator licensing group (licensing of reactor operators, senior reactor operators, shift engineers, and plant managers is anticipated), including operation of a training center for Nuclear Regulatory Authority personnel (assume 30 persons in total).
- Decommissioning, radioactive waste management, and radioactive waste disposal group (assume 20 persons in the relevant disciplines).
- Headquarters inspection staff (assume 15 persons in total).
- Emergency planning and emergency response group (assume 10 persons in total).
- Nonproliferation staff (assume 5 persons in total).
- Regulatory research staff (assume 20 persons in total).
- Enforcement and general counsel (assume 20 persons in total).
- Public information and public document library group (assume 15 persons in total).
- Administration (assume 15 persons in total).
- Senior management (assume 13 persons, one for each group above plus two deputy administrators).

[31] Although Austria has an Academy of Sciences (http://www.oeaw.ac.at/), there is no research institute within the Academy structure concerning the safety of nuclear power plants, the safety of radioactive waste management and disposal, and the safety of spent fuel management. The same is true of the Austrian Institute of Technology (http://www.ait.ac.at/departments/energy/) and the Atominstitut at the Technical University of Vienna (http://ati.tuwien.ac.at/).

[32] If the Austrian Parliament wishes Austria to enter the medical isotope production business or to provide radiation-related services to industry, the Parliament should establish a charter for a separate organization to do so, subject to regulation by the Austrian Nuclear Regulatory Authority.

graduate and post-graduate research oriented on the work of the Austrian Nuclear Regulatory Authority.

It is anticipated that the total staff of the Austrian National Nuclear Safety Laboratory would total about 50 persons (including management and support staff). At such a size, it is doubtful that the full range of technical specialties relevant to a small nuclear power program (and the related waste management and disposal activities) could be covered. In such cases, the Nuclear Regulatory Authority should be authorized to contract with independent experts (such as seismic specialists at ZAMG, for example) and with TSOs (such as GRS, for example) and nuclear research centers (such as the EC's Joint Research Centre) in other European Countries[33]. Careful attention should be paid in these cases to whether the nuclear industry controls the center (as an extreme example, Nuclear Research Institute Řež in the Czech Republic is owned by ČEZ a.s., owner and operator of the Dukovany and Temelín nuclear power plants).

The enabling legislation should identify the separation of responsibilities for nuclear site protection between the licensee and Austrian authorities (civil defense[34], fire and rescue, police[35], military[36], etc.). The Austrian military should have responsibility for protecting nuclear sites from acts of war and from terrorist use of aircraft, and the Austrian police should have responsibility for protecting nuclear sites from acts of sabotage and terrorism (in conjunction with the site security force). An alternative might be the establishment of a Nuclear Constabulary (as has been done in the United Kingdom) for the protection of nuclear power plants, the radioactive waste repository, and nuclear materials shipments (fresh nuclear fuel and spent nuclear fuel) to and from the nuclear power plants and to the repository.

The preparation of environmental impact assessments (EIAs) should be the responsibility of the project proponent (the prospective licensee), subject to review by the Austrian Nuclear Regulatory Authority. EIAs (European Union Directive 85/337/EEC as amended, and the Aarhus Convention and Espoo Convention) are required for both licensing and decommissioning, and may also be required for siting if siting is approved separately from plant licensing. A strategic environmental assessment (SEA) (European Union Directive 2001/42/EC, and the Kiev Protocol) is required for the entire nuclear power program.

5.2. GLOBAL NUCLEAR SAFETY REGIME

The so-called "global nuclear safety regime" is covered by Actions 11-19 in SSG-16. The IAEA defines the global nuclear safety regime (in SSG-16) as the combination of international conventions (such as the Convention on Nuclear Safety and the Joint Convention on the Safety of Radioactive Waste Management and the Safety of Spent Fuel Management), codes of conduct (such as the Code of

[33] For example, the nuclear regulatory authority of the Netherlands (KFD) uses GRS (Germany) and Bel V (Belgium) as TSOs (Philippe, 2012:28).

[34] The Austrian Civil Protection Association (ÖZSV, http://www.zivilschutzverband.at/) is a collective of ten associations, one federal and nine regional offices, which informs the population on civil defense in Austria, particularly on behavior in emergency situations. The federal organization is the Bundesministerium für Innneres (Interior Ministry).

[35] Bundeskriminalamt, Bundesministerium für Innneres (Interior Ministry), is the Austrian police force.

[36] The ABC-Abwehr des Bundesheeres (CBRN Defence of the Austrian Army) would share responsibility for response to a nuclear accident. Defense against military attack on Austrian nuclear facilities would be the response of the Austrian military.

Conduct on Research Reactors), IAEA safety standards (SF-1 and the Requirement documents), international peer reviews (including IAEA and WANO missions), knowledge networks and expert networks, and multinational and bilateral cooperation agreements.

It is to be noted that none of the mechanisms cited by the IAEA as comprising the global nuclear safety regime is mandatory, or is enforceable by the IAEA. Even the Convention on Nuclear Safety – which is widely cited as an example of a legally binding instrument – is in fact unenforceable[37] since there are no consequences (except perhaps bad publicity) for violating the terms of the Convention. The IAEA cannot perform a safety mission in a Member State on its own initiative – IAEA must be *invited* by the Member State. The global nuclear safety regime in essence relies on peer and public pressure for its effectiveness; even this degree of pressure is watered down by diplomatic niceties. (Indeed, perhaps the use of the word "regime" in this context is out of place.)

As indicated above, it is expected that Austria would follow the IAEA Fundamental Safety Principles and the IAEA Safety Requirements. It is also expected that with the implementation of a nuclear power program, Austria would increase its participation in IAEA standards development activities. In addition, it is expected that Austria would take full advantage of IAEA missions by requesting relevant missions[38] in a timely fashion. (It is not immediately evident whether such missions would be requested by the Austrian Nuclear Regulatory Authority or perhaps by the Federal Ministry for European and International Affairs based on consultation with the Authority. In German, this Ministry is known as *Bundesministerium für europäische und internationale Angelegenheiten* (BMeiA).

The Austrian Nuclear Regulatory Authority should be expected to seek contacts with peer organizations both within and outside the European Union. In particular, the Authority would be expected to seek contacts with nuclear regulatory organizations which are regulating the same type of plants as those chosen by the prospective Austrian nuclear utility. (For example, if the prospective utility were to choose the AP1000 design, then the Austrian Nuclear Regulatory Authority would be expected to seek close contacts with the National Nuclear Safety Administration of the People's Republic of China – regulator for the Sanmen and Haiyang plants – and with the U.S. Nuclear Regulatory Commission – regulator for the Vogtle 3 & 4 and Virgil Summer 2 & 3 plants.)

[37] As an example of how unenforceable the Convention on Nuclear Safety is, the King of Belgium, the Prime Ministers of Bulgaria, the Czech Republic, Slovakia, and Ukraine (Cabinet of Ministries of Ukraine, 2006), and the Presidents of France, Russia and Slovenia, can dismiss the heads of their nuclear regulatory authority at will. This is also true of the Federal Natural Resources Minister of Canada (indeed, the head of CNSC – a former head of INRA and Chair of the Third Review Meeting of the Contracting Parties to the Convention on Nuclear Safety – was dismissed by the Minister in 2008). This is not "*independent*" in any sense since the political leaders of these countries can dismiss the head of their regulatory at any time for any reason.

[38] As of 2013, these missions included DSA (Decommissioning Safety Appraisal), DSARS (Design and Safety Assessment Review Service), EIA (Environmental Impact Assessment Peer Review), EPREV (Emergency Preparedness Review Service), INSARR (Integrated Safety Assessment for Research Reactors), INSServ (International Nuclear Security Advisory Service), IPPAS (International Physical Protection Advisory Service), IPSART (International Probabilistic Safety Assessment Review Team), IRRS (Integrated Regulatory Review Service), ISCA (Independent Safety Culture Assessment), ORPAS (Occupational Radiation Protection Appraisal), PROSPER (Peer Review of Operational Safety Performance Experience), PSR (Periodic Safety Review Team), OSART (Operational Safety Review Team), RAMP (Review of Accident Management Program and Emergency Operating Procedures), SEED (Site & External Events Design Review Service), TranSAS (Transport Safety Appraisal Service), and WSA (Waste Safety Appraisal).

Due to Austria's position within the European Commission, Austria should not only prepare for participation in the global nuclear safety regime, but should also participate extensively in the European nuclear safety regime (ENSREG, EURATOM, and WENRA) as well as other international nuclear safety organizations (INRA, NERS, and OECD/NEA).

In implementing a nuclear power program, Austria would need (consistent with its international obligations) to establish a dialogue with neighboring countries: Czech Republic, Germany, Hungary, Italy, Liechtenstein, Slovenia, Slovakia, and Switzerland (based on shared borders); and also potentially with Bosnia & Herzegovina, Croatia, Kosovo, Montenegro, Poland, Romania, and Serbia (since some or all of these countries are within the same distance as parts of some of the countries bordering on Austria). Compliance with the Aarhus Convention, the Espoo Convention, and the Strategic Environmental Assessment Protocol would involve extensive contacts between Austria and neighboring trans-boundary countries (as well as with stakeholders in these countries), and between the prospective nuclear utility and these countries (and stakeholders in these countries).

5.3. LEGAL FRAMEWORK

The legal framework within SSG-16 consists of Actions 20-23. These matters are addressed above in Sections 3 and 4, and in Section 5.1.

5.4. REGULATORY FRAMEWORK

The Regulatory Framework aspects of SSG-16 are addressed by Actions 24-38. These matters are partly addressed above in Section 5.1.

It must be recognized vis-à-vis Action 24 concerning the independence of the Austrian Nuclear Regulatory Authority hat, compared with a utility that has the resources to construct and operate a nuclear power plant, the Nuclear Regulatory Authority will always be at a considerable disadvantage. The utility will have far larger resources (legal, technical, public relations, etc.), and typically can afford higher salaries than the Nuclear Regulatory Authority, which cannot get into what amounts to a bidding contest for regulatory and technical talent. Nevertheless, Article 8 of the Convention on Nuclear Safety (to which Austria is a contracting party) requires that the Nuclear Regulatory Authority be provided with financial and human resources to fulfill its assigned responsibilities. Action 24, therefore, would require substantial financial and human resources for the Nuclear Regulatory Authority.

We have considered the budget necessary for the Austrian Nuclear Regulatory Authority in part by looking at what several such authorities in other countries spend, and the size of their regulatory authorities' staffs. The nuclear regulatory authorities of Belgium, Canada, the Czech Republic, Finland, France, Hungary, Slovakia, Spain, the United Kingdom, and the United States were considered, and there was remarkable agreement on the amount of spending by the regulatory authority per nuclear power unit regulated. The range was from about €1.25 million to €4 million per regulated reactor (with one outlier value of €7.3 million per unit). The size of the regulatory authority staff per nuclear power unit regulated was also relatively consistent, ranging from 20 to 29 (with outlier values of 42 and 59 per unit).

There are two possible arrangements regarding licensing nuclear power plants. One is a somewhat traditional two-step process in which a construction license and an operating license are authorized in separate processes. The construction license process would resolve the issue of siting of the nuclear power plant and its preliminary design, and the operating license would resolve the issue of the final plant design. Such an arrangement could require extensive environmental impact assessments (EIAs) at both the construction license and operating license stages.

Another possibility is something similar to what the United States has adopted – early site permits and design certification. The U.S. Nuclear Regulatory Commission can approve early site permits for 15 years, and design certification also for 15 years. Such a system is highly recommended for a limited nuclear power program such as that envisioned here. Site permits and design certification would limit the number of reviews that the Nuclear Regulatory Authority would have to conduct, allowing the Authority to be more comprehensive in the reviews that it does conduct. In the context of a country such as Austria with limited nuclear power program prospects given its grid size, it is suggested here that site permits and design certification be limited to 10 years, with the possibility for renewal upon timely application and the opportunity for stakeholder comment (allowing for the possibility of changed conditions which might prompt comments from stakeholders). It is recommended, however, that the Austrian government not entirely adopt the NRC approach to design certification, which is a "*notice and comment*" approach, with hearings conducted solely at the NRC's discretion (and even then only considering the comments, not on the Design Certification as a whole) (Philippe, 2012:38). Government-authorized funding to encourage public participation in the review and licensing processes conducted by the Nuclear Regulatory Authority would facilitate those reviews by making public participation more focused (and presumably more technical) in nature[39].

Concerning design certification, Austria could participate on the OECD Nuclear Energy Agency's Multi-National Design Evaluation Program (MDEP). MDEP already includes Canada, Finland, France, India, Japan, the People's Republic of China, the Republic of Korea, the Russian Federation, South Africa, the United Kingdom, and the United States, along with associate member the United Arab Emirates. MDEP includes design specific working groups on the AP1000, the APR1400, and the EPR advanced reactor designs. If a prospective Austrian utility were to choose another standard design, Austria could propose creation of another MDEP working group.

Action 26 would have the government *per se* identify the prospective senior managers of the Nuclear Regulatory Authority. This proposal involves the government too deeply in the staffing of the Nuclear Regulatory Authority, which is supposed to be an independent regulatory authority. The government of course would nominate the Administrator of the Authority, but since no other Authority manager is identified as going through this nomination and Parliamentary approval process, the government should leave the staffing of the Authority to the NRA Administrator.

It is suggested here that a fixed term of office should be established[40] in order to avoid the situation in which the Administrator of the Nuclear Regulatory Authority is terminated every time a government comes to power. A fixed term of office provides for more continuity in regulation. The Administrator should only be able to be removed from office for cause (such as criminal activity, bribery or other corruption, financial malfeasance, etc.) through what could essentially be an

[39] Funding of participants is also recommended by the European Nuclear Energy Forum (ENEF).

[40] The members of the ENSI supervisory Board in Switzerland are appointed for four-year terms. The commissioners of the U.S. Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission are appointed for a five-year term of office. The commissioners of the French authority ASN and the counsellors of the Spanish CSN are appointed for a six-year term of office.

impeachment-type process, or what could be an official process by the Bundeskanzler or Bundesregierung[41].

Action 27 would be accomplished by the Austrian Parliament in the enabling legislation. More than "*effectively independent*", a key lesson of the Fukushima accident is that the Nuclear Regulatory Authority must be clearly independent of any government entity with responsibility for either promoting or carrying out a nuclear power program and radioactive waste management and disposal. Moreover, the Nuclear Regulatory Authority must be insulated, with the exception of the process for appointment of the Chairman (and Commissioners, if a Commission form is selected), from politics by establishment of a fixed term. Removal from office during this fixed term would be possible only for "*cause*", not at the whim of the President or Bundeskanzler or Bundesregierung of Austria. Politics will also, necessarily, intrude in the determination of the annual budget of the Nuclear Regulatory Authority, which would be approved by the Austrian Parliament.

In terms of appointments, the government should appoint only the Administrator of the Nuclear Regulatory Authority (and Commissioners, if a Commission form is selected). The responsibility for development of the Authority's organization should rest with the Administrator (and Commissioners). The Authority must have a budget sufficient to allow it to attract exemplary talent (but not entirely in competition with the utility, which will always have a far larger budget)[42].

The Authority should follow the IAEA Fundamental Safety Principles and Safety Requirements, and should require that the prospective utility also follow these documents. However, in connection with Action 29, the regulatory approach of the Authority should in the first instance be determined by the enabling legislation passed by the Austrian Parliament, with only the details left to the Authority to develop. (For example, if an early site permit and design certification process is to be used, this should be provided for in the enabling legislation.)

Action 30 should clearly be carried out by the Nuclear Regulatory Authority as part of its rulemaking authority, as well as by the issuance of regulatory guidance documents. The scope of the Authority's inspection powers should be defined in the enabling legislation passed by the Austrian Parliament (e.g., the ability of the authority to have inspectors enter the nuclear power plant at any time for inspection purposes, a resident inspector program, etc.), but the details of the inspection program (in terms of the types and frequency of inspections) should be developed by the Nuclear Regulatory Authority. The enforcement powers of the Authority should also be spelled out in the enabling legislation; civil penalties should be commensurate with the risk posed by the violations[43].

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[41] For example, Commissioners of the U.S. Nuclear Regulatory Commission can be removed from office by the President for "*inefficiency, neglect of duty, or malfeasance in office*".

[42] Any organization (such as a utility) that has or has access to sufficient resources to construct and operate a nuclear power plant (construction of which would be expected to cost several billion Euro) will necessarily have more resources than a Nuclear Regulatory Authority. The point here is that the Authority should have sufficient resources that it can offer competitive salaries, especially for senior and mid-level management positions.

[43] The enabling legislation should not place the Nuclear Regulatory Authority in the position of having extremely limited civil penalty authority. Otherwise the prospective utility may consider modest or even large civil penalties for regulatory violations to simply be a cost of doing business (if, indeed, the regulatory authority were empowered to issue civil penalties in the case of a government utility. When the EC can fine companies like Microsoft billions of Euro for violations of non-competition requirements, one cannot have the Nuclear Regulatory Authority be limited to civil penalties in the manner of the U.S. Nuclear Regulatory Commission (for example). The civil penalties should be sufficiently severe (as warranted by the nature of

Concerning Action 31, it is clear that the Nuclear Regulatory Authority must issue its regulations before the prospective utility begins the bidding process for the first nuclear power plant. The requirements which the bid must meet should be known in advance in order that regulatory "*ratcheting*" not occur, resulting in unforeseen cost increases during the construction phase. The process of issuing regulations should be expected to take a year or more before the basic safety requirements of the nuclear power plants to be constructed are identified by the Nuclear Regulatory Authority's regulations.

Regarding Action 32, working relationships between the Nuclear Regulatory Authority and its prospective or actual licensees must of course be established. However, such relationships should be formal (not overly friendly), and should be conducted in public to the maximum extent possible (recognizing the need to protect sensitive security and commercial details from public disclosure).

5.5. TRANSPARENCY AND OPENNESS

Transparency and openness issues are addressed in SSG-16 by Actions 39-47. As indicated in Section 4.0, it is expected that the nuclear skeptical Austrian public and Austrian Parliament would require exemplary standards of transparency and openness, subject only to limitations in case of matters touching on security and clearly proprietary information. Even in the case of the latter, the Austrian nuclear Regulatory Authority should review and determine which passages of a document are actually proprietary, and which can be released to the public.

The exemplary standards of transparency and openness would be expected to apply to the Nuclear Regulatory Authority and its TSO & consultants, as well as to the prospective utility and its TSOs, consultants, and contractors. Any effort by the Nuclear Regulatory Authority or the prospective utility to limit public access to documents would have to be well and publicly justified as involving sensitive security or commercial (proprietary) issues, or the effort could backfire and damage relations with stakeholders. The requirements of the Aarhus Convention with regard to public access to information would have to be scrupulously observed.

Actions 39 and 40 would place responsibility on the government *per se* for establishing guidance and a policy to inform the public and interested parties on the benefits and risks of nuclear power, and to facilitate their involvement in the decision making on a prospective nuclear power program. In reality, there are split responsibilities here, not responsibilities exclusive to the government.

It is not the government's responsibility to inform the public about the risks and benefits of nuclear power. Discussions within government on these matters would already have taken place in the context of the constitutional amendment allowing nuclear power, and in the context of approval of enabling legislation by the Austrian Parliament. Of course, the Nuclear Regulatory Authority has a role in explaining nuclear power plant risk from the standpoint of its regulations and safety targets. Apart from taking the decision to permit the establishment of a nuclear power program in Austria the government *per* se should maintain neutrality on the benefits of nuclear power. It would be expected that the utility, its chosen reactor vendor, and the Austrian Nuclear Society (Österreiche

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the offense) to unmistakably get the prospective utility's attention – that is, the size of the civil penalty should affect its revenues, and the attention drawn to its violation by the Nuclear Regulatory Authority should also be painful. The extremely limited civil penalty authority of the U.S. Nuclear Regulatory Commission is not recommended as an example; the NRC was able to fine a utility only somewhat more than a million dollars for having nuclear power plant control room operators sleeping on duty (a minor amount when operation of the plant was providing the utility with over one million dollars per day in revenue).

Kerntechnische Gesellschaft, ÖKG) would be active in describing the benefits of nuclear power. Internationally, the International Atomic Energy Agency (IAEA), the World Nuclear Association (WNA), the World Association of Nuclear Operators (WANO), and the European Atomic Forum (Foratom) also undertake such roles.

The discussion on the risks of nuclear power is an appropriate matter to be placed before the regulatory body, to the extent that the question is not completely addressed in the national nuclear legislation. The government *per* se should maintain neutrality, and the Nuclear Regulatory Authority should consider the issue in the context of environmental impact assessment (EIA) on specific licensing actions on nuclear facilities (e.g., if the benefits of the proposed facility do not outweigh its risks, then a license would not be issued), and in the context of its regulations and safety targets.

Facilitation of stakeholder involvement in decision making on a nuclear power program a matter that government would have addressed in the context of its decision to allow a nuclear power program and in the passage of the enabling legislation for that purpose. (It is also expected that stakeholders on all sides of the issue would be heavily involved in the electoral campaign in which the constitutional amendment to reverse Austria's anti-nuclear stance is considered.) Of course, the Nuclear Regulatory Authority should encourage involvement of stakeholders in its decision making processes. One would expect that the utility would also do so in its own self-interest, but this is not often the case.

Concerning Action 41, it is assumed that the safety implications of a nuclear power program would be fully aired during the political process of passing enabling legislation. Subsequent to this, the Nuclear Regulatory Authority should inform all interested parties of the safety requirements and safety targets/safety goals applicable to nuclear power plant operation.

In regard to Action 42, the health and environmental impacts of the nuclear power program would be identified, subject to public comment, and resolved by the Nuclear Regulatory Authority in the context of an Environmental Impact Assessment for specific nuclear facilities. The applicant for a license to construct and operate a nuclear power plant bears responsibility for providing health and safety information for its own facility and for having the Environmental Impact Assessment prepared.

Actions 43-46 are obvious and require no further comment. Action 47 should be emphasized as transparency can reasonably be expected to be a cornerstone of Austrian nuclear regulation. These actions concern: (a) establishment and maintenance of trust in the Nuclear Regulatory Authority; (b) communication with stakeholders by the Nuclear Regulatory Authority about its licensing process, safety requirements, and regulatory oversight; and (c) maintaining a transparent approach on safety issues.

5.6. FUNDING AND FINANCING

Financing and funding aspects of a nuclear power program are addressed by SSG-16 Actions 48-60. Funding of the Nuclear Regulatory Authority and its TSO would be expected to come from authority granted by the Austrian Parliament in the enabling legislation and in general government funding legislation.

It is plausible that the Parliament would require some form of fees from prospective licensees in order to cover all or part of the budget of the Nuclear Regulatory Authority. It is also plausible that the Parliament would provide the Nuclear Regulatory Authority with the funds both for its own operations and that of its TSO, thus giving the Authority more direct control over the research and investigations performed on its behalf by the TSO.

Funding for nuclear power plant siting, licensing, construction, operation, decommissioning, spent fuel and radioactive waste storage & disposal would be the responsibility of the prospective utility, subject to such standards of adequacy as the Nuclear Regulatory Authority may determine necessary to assure safety, and subject to economic regulatory control (currently by E-Control, as noted above).

It is presumed here that the Austrian Parliament has already dealt with Actions 48 and 50 in its decision-making to decide to permit a nuclear power program in Austria. As part of Action 48, it is assumed that Austria would want to establish a moderate size national laboratory, funded through the Austrian Parliament (either directly or as part of the Nuclear Regulatory Authority's budget). In the past, this role was filled by Austrian Research Centre Seibersdorf, now Seibersdorf Laboratories. It is not recommended here to continue in this fashion since Seibersdorf Laboratories does work for the IAEA and the CTBTO as well as producing its own radioactive waste (the management and disposal of which would have to be regulated by the Nuclear Regulatory Authority). Instead it is recommended that a separate national nuclear laboratory be formed, focused on the safety of nuclear power plants and radioactive waste management and disposal. The Austrian government might decide (as have other governments) to create a national laboratory with other technical interests as well.

Action 49 concerns long term economics of nuclear power and ensuring that the units can operate to the end of their design service life. This is a matter for utility economic regulation (rate-making), and assurance of equipment service life for the service life of the unit is the responsibility of the prospective utility under the Nuclear Regulatory Authority's supervision. This is not a government responsibility in the first instance.

Action 51 concerns the funding mechanisms for radioactive waste management, spent fuel storage, decommissioning, and ultimate disposal of radioactive waste. These again are a matter of economic regulation (rate-making), subject to the proviso that the Nuclear Regulatory Authority must be assured that sufficient funds are available to assure public safety and environmental protection.

It is assumed here that the utility would use dry spent fuel storage until a high level waste repository is licensed in Austria. EC opinion surveys have revealed that 69% of Austrians are not confident that the disposal of radioactive waste can be done in a safe manner (EC, 2010), but believe that a solution should be developed now and not left to future generations (EC, 2008).

Considering these factors, it is not inconceivable that Austria would require licensing (but not construction) of radioactive waste disposal facilities (including one for high level radioactive waste and spent nuclear fuel) <u>before</u> it would license a nuclear power plant. On the other hand, this may not change much if safe disposal were to be demonstrated, since 63% of Austrians are opposed to nuclear power (EC, 2008). It is considered doubtful that Austria would opt to have its spent nuclear fuel reprocessed (owing to concerns about proliferation of nuclear weapons), relying instead on direct disposal of spent fuel as waste. (However, the original plan for spent fuel from the cancelled Zwentendorf nuclear power plant in Austria involved reprocessing by COGEMA in France.)

Concerning Action 52, it is <u>not</u> the government's responsibility to provide long term funding for education and training for a nuclear power program. This should be done by the utility license applicants in their own self interests. The Nuclear Regulatory Authority is responsible for the educational background of employees that it selects, and for providing training opportunities for its staff. The government's responsibility is for Technical Support Organization (TSO) infrastructure to support the Nuclear Regulatory Authority.

It is assumed that Action 53 is dealt with by the Austrian Parliament in the enabling legislation for the Nuclear Regulatory Authority. Likewise, it is assumed that the Austrian Parliament would deal with the waste management, spent fuel management, and decommissioning funding issues in the nuclear power program enabling legislation. The ideal infrastructure would be for the nuclear power plant licensee(s) to charter a radioactive waste management and disposal organization (as has been done in Finland, Sweden and Switzerland) for which the Nuclear Regulatory Authority has oversight (including adequacy of funding). The Nuclear Regulatory Authority would also be responsible for establishing regulations governing radioactive waste and spent fuel management, regulations for the disposal of radioactive waste, and regulations for decommissioning. The government's role in financial provisions for waste management & disposal and decommissioning depends on the structure decided in the enabling legislation (e.g., whether the nuclear power plants are to be run as merchant plants by the operating utilities, or whether the government establishes a ratemaking authority and bases funding for waste management & disposal and decommissioning based on rate of return).

5.7. EXTERNAL SUPPORT ORGANIZATIONS (TSOs) AND CONTRACTORS

Measures related to external support organizations and contractors are addressed by SSG-16 Actions 61-71. These matters are partially addressed above. Since the prospective utility or other licensee has the primary responsibility for safety, the prospective utility or other licensee has the primary responsibility for the adequacy and quality of the work performed by its TSOs, consultants, and contractors. The utility or other licensee may not delegate this responsibility, even though it requires its TSOs, consultants, and contractors to have quality assurance programs in compliance with IAEA standards, and requires the work of these entities to meet high scientific standards. Regardless of what measures the prospective utility undertakes in this regard, the utility retains primary responsibility for safety.

Action 61 states that the government should consider the availability of expertise, industrial capability, and technical services that could support the safety infrastructure in the long term. Action 62 states that the government should assess the need to create or enhance national organizations to provide technical support to the regulatory body and the operating organization for the safe operation of nuclear power plants. Strict separation should be maintained between TSOs for the Nuclear Regulatory Authority and the prospective utility. TSOs can work for one or the other organization, but not both, in order to avoid conflicts of interest. A situation of the Regulatory Authority's TSO doing work for the utility, or the utility seeking to have the Regulatory Authority's TSO perform work on its behalf, should both be prohibited by law.

If this leaves the Nuclear Regulatory Authority without a TSO, then the government should fund the creation of a TSO directly reporting to the Nuclear Regulatory Authority (as in the example of Belgium, where Bel V serves as a TSO to FANC, and is within FANC's organizational structure), or the government could expand the staff of the Nuclear Regulatory Authority to fully cover all necessary competencies.

The nature of construction and operation is the responsibility of the prospective operating utility (Action 63). Whether the utility involves Austrian companies is up to the utility; many utilities and reactor vendors focus extensive efforts on establishing a supply chain that involves companies within the country in which the nuclear power plant is being constructed. However, this is the choice of the utility and its vendor, and is not a governmental responsibility.

It is assumed that the Austrian Parliament would address the question of Nuclear Regulatory Authority TSOs and financial provisions for external expertise in the enabling legislation and in annual budgets for the Nuclear Regulatory Authority. This would address Actions 64 and 65.

Action 66 is the responsibility of the Nuclear Regulatory Authority in terms of its TSOs. In terms of the utility's TSOs, that is the utility's responsibility, subject to inspection of the TSOs by the Nuclear Regulatory Authority.

Action 67 (concerning establishment by the Regulatory Authority of a framework for qualification of technical services related to nuclear safety) should be accomplished by the Nuclear Regulatory Authority sooner than Phase 3 (which is what is recommended in SSG-16). Action 68 (concerning the continued recruitment of staff and the building of competence within organizations) is obvious and requires no further comment. Action 69 requires clarity from the Nuclear Regulatory Authority in terms of what external support activities it will regulate and inspect. This should be done in Phase 1 and not deferred until Phase 3. Likewise, Action 70 (establishment of arrangements to avoid conflicts of interest) should be implemented in Phase 1. Action 71 is obvious, except to note that the Nuclear Regulatory Authority may need to regulate/inspect the organizations and contractors providing services to the prospective utility and its selected vendor.

5.8. LEADERSHIP AND MANAGEMENT FOR SAFETY

Leadership and management for safety are addressed by SSG-16 Actions 72-84. Action 72 concerns the government role in fostering a safety culture within organizations. Achieving and maintaining a proper safety culture is a responsibility of both the Nuclear Regulatory Authority and the prospective operator. The Nuclear Regulatory Authority can issue regulations empowering it to monitor the safety culture of operating organizations. If the government has concerns, it can (as an IAEA Member State) request the IAEA to conduct an IRRS mission (to review the NRA's safety culture) or a SCART mission (to review the operating organization's safety culture).
Action 73 would be met by the Nuclear Regulatory Authority's management system. It is recommended that the Authority also have its own quality assurance (QA) program (and as well for its TSO), and that it seek international certification as appropriate.

Action 74 should be limited to the government's appointment of the Nuclear Regulatory Authority Administrator. The Authority itself would be responsible to ensure that its senior managers have the requisite leadership capabilities and safety culture attitudes.

Actions 75-77 (concerning development of management systems and strong safety cultures, management of change, and development of self-assessment competence) should be part of the normal activities of both the Nuclear Regulatory Authority (and its TSOs) and of the prospective utility (and its TSOs).

Actions 78-80 (effective leadership for a strong safety) are obvious and require no further comment. Action 81 represents knowledge preservation and should be required by the Nuclear Regulatory Authority and be part of its regulatory inspection program for the utility and its selected reactor vendor. Actions 82 and 84 (development of leadership programs with a strong emphasis on safety, and review by the Regulatory Authority of the utility's safety management program) are obvious and require no further comment.

5.9. HUMAN RESOURCES DEVELOPMENT

Human resources development for the nuclear safety infrastructure is addressed by Actions 85-98 in SSG-16.

Actions 85 & 86 as set forth by IAEA would place responsibility on the government for attracting, training, and retaining an adequate number of experts to meet the needs of all organizations involved in a nuclear power program, and to identify the competences required and the approximate number of experts required. These Actions are misplaced to some extent. These responsibilities are best met by the Nuclear Regulatory Authority and the prospective utility organization. If the Nuclear Regulatory Authority concludes that it needs more personnel or more resources, it can go to the government for an increase in its budget.

Regarding Action 87 & 88, with the exception of the Nuclear Regulatory Authority and its TSOs (to the extent that they are government funded), it is not the responsibility of the government to provide for training of personnel of the operating organization. The concept that this is the government's responsibility has over the years acquired almost mythical status, but it is incorrect.

If a utility wants to construct and operate a nuclear power plant, it is its own responsibility to ensure that its personnel are properly trained. The government's responsibility in this regard is to ensure that the utility's personnel are properly trained and qualified – not to provide the training and qualifications for the utility. If the utility perceives that there are not enough training possibilities, it is the utility's responsibility to ensure that these are created, either directly through its own efforts (by offering employment-linked scholarships) or by endowing chairs in the relevant disciplines at universities and other training institutions.

It should be noted that the nuclear industry has established the World Nuclear University for training purposes. In addition, four European nuclear regulatory authority Technical Service Organizations (TSOs) (Bel V, IRSN, GRS and LEI) have created the European Nuclear Safety Training & Tutoring Institute (ENSTTI), which could provide training for regulatory agency and TSO personnel. Finally, the European Nuclear Education Network (ENEN) was formed to provide higher education and training in nuclear-relevant disciplines.

Action 89 – concerning the assurance that senior regulators gain an understanding of the principles and criteria of nuclear safety – is not the national government's responsibility. Once created, this responsibility belongs squarely with the Nuclear Regulatory Authority. What is necessary is that the national government should ensure that the NRA has adequate resources to hire qualified staff and to train them in the principles and criteria of nuclear safety.

Actions 90 through 92 are a normal part of the business of any organization, and are expected to be accomplished by both the Nuclear Regulatory Authority (and its TSOs) and the prospective utility (and its TSOs). Action 91 would be expected to be an important means of training Nuclear Regulatory Authority staff.

Regarding Actions 93 and 94, it is not the government's responsibility to establish new curricula relevant to nuclear safety. It is expected that the Nuclear Regulatory Authority will in the first instance hire experienced personnel. Later, it may be sensible for the Authority to be able to offer summer positions (internships) to advanced undergraduates and graduate students in order to provide training. It may also be sensible for the Authority to be able to offer tuition support to students in return for their working at the Authority for a minimum fixed period after graduation. It is the utility's responsibility to ensure that enough capable personnel are available as needed, and to support educational institutions to the extent required to achieve this.

Actions 95 and 97 are oriented toward human resource development and management. These are also fundamental aspects of any business and would be the responsibility of both the Nuclear Regulatory Authority and the prospective nuclear power plant owner & operator.

Action 98 states that the government should promote the development of education in the nuclear field; we do not regard this as a government responsibility, but rather the responsibility of the regulated industry seeing clearly its own self-interest in doing so. The concept that this is government's responsibility has acquired an almost mystical character; this responsibility should be placed squarely on the regulated utility where it belongs. The government is not expected to develop education in other fields, and it should not be expected to do so in the nuclear field.

5.10. RESEARCH FOR SAFETY AND REGULATORY PURPOSES

Nuclear safety research and for regulatory purposes specifically, are addressed by Actions 99-104 in SSG-16.

Regarding Actions 99 & 100, the Nuclear Regulatory Authority must have the necessary resources to have regulatory safety research performed as needed. If sufficient expertise is not available in Austria, the Nuclear Regulatory Authority should be empowered to contract with external experts within the EU as a first preference, and then more broadly if need be. A small country cannot be expected to have TSOs with expertise in all conceivable disciplines related to nuclear safety at the outset of a nuclear power program. There are a variety of nuclear research organizations within Europe upon which Austria could rely on a contract basis to perform research and provide independent expertise[44].

Action 101 should be a normal part of doing business for both the Nuclear Regulatory Authority and the prospective utility. Concerning Action 102, it is expected that the government would promptly establish nuclear research institutions due to the limited existing nuclear infrastructure in Austria. And that this would not wait until Phase 2. Similarly for Action 103, it is expected that newly established nuclear research institutions would immediately begin work on safety research. Action 104 is the responsibility of both the Nuclear Regulatory Authority and the prospective utility.

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[44] The European research organizations that could conceivably perform research or provide expertise on a contract basis potentially include:

- GRS in Germany, http://www.grs.de/;
- The VTT Technical Research Centre in Finland, http://www.vtt.fi/, however it must be noted that VTT also does work for industry, and may have a conflict of interest;
- The Center for Nuclear Technology in Riso, Denmark, http://www.nutech.dtu.dk/;
- The European Commission's Joint Research Centre in Ispra or Petten, http://ec.europa.eu/dgs/jrc/index.cfm;
- The Helmholtz-Gemeinschaft Deutscher Forschungszentren in Germany, http://www.helmholtz.de/, including affiliated institutes in Berlin, Karlsruhe, Jülich, and Rossendorf; and
- The Demokritos National Center for Scientific Research in Greece, http://www.demokritos.gr/default.aspx?lang=en.

Specifically excluded from this list, due to the fact that they perform nuclear research for utilities and/or are owned by utilities, are:

- Nuclear Research Institute Rez in the Czech Republic, http://www.nri.cz/web/ujv/hlavni-strana (owned by ČEZ, operator of Dukovany & Temelín, and includes Energoprojekt Praha, NPP designer);
- Jožef Stefan Institute in Slovenia, http://www.ijs.si/ijsw/JSI (provides training for Krško NPP personnel & performs R&D for the plant);
- NRG in the Netherlands, http://www.nrg.eu/ (performed safety analyses for AREVA, Westinghouse, and EPZ, operator of the Borssele NPP);
- Vinçotte Nuclear Safety in Belgium, http://www.vnsafety.eu/doc.php?nd=o2&tid=2&lg=1&docid=29&site=1 (provides safety advice to nuclear installation operators and constructors).

5.11. RADIATION PROTECTION

Actions 105-116 address Radiation Protection matters. Action 105 attempts to place on the government the responsibility for the additional radiation risks and radiation protection needs associated with the operation of nuclear power plants. In terms of radiation dose standards, these should be established either by legislation or in regulations issued by the Nuclear Regulatory Authority. The national government's role in this regard is in environmental radiation monitoring and emergency planning & response.

Concerning environmental impact analysis (EIA) in Action 106, there is a division of views internationally regarding whether the government should prepare the EIA (as in Canada and the United States) or whether it should be prepared by the project proponent. The latter option is recommended here, with the Nuclear Regulatory Authority being in the role of promulgating regulations concerning EIA and reviewing the proponent's EIA to determine its adequacy.

Concerning Action 107, it is assumed here that this would be dealt with by the government in the legislation establishing the Nuclear Regulatory Authority. Concerning Actions 108 and 109, it is assumed here that these regulations would be among the first issued by the Nuclear Regulatory Authority. For Action 111, the evaluation of the environmental impact analysis by the Authority would await its submittal by the prospective utility under the regulatory regime recommended herein.

Action 115 indications Regulatory Authority review of the utility's radiation protection and environmental protection chapters of the safety analysis report. This is obviously necessary and should be accomplished in accordance with the Authority's regulatory requirements and related standards.

Action 116 states that the Regulatory Authority should ensure that arrangements are in place for monitoring of all releases from the nuclear power plant to the environment. Again, this is obviously necessary. In order to maintain transparency, both the Nuclear Regulatory Authority and the utility should periodically report on radioactive releases and environmental dose rates.

5.12. SAFETY ASSESSMENT

Safety assessment is addressed in SSG-16 in Actions 117-121. Although these actions are few in number, they are extremely important in ensuring a high level of safety for nuclear power plant operation, decommissioning, and for management and ultimate disposal of radioactive waste from plant operation and decommissioning.

Safety assessment is one of the key areas of nuclear safety infrastructure. This is because both the Nuclear Regulatory Authority's design certification and licensing decisions, as well as the utility's operation of its nuclear units, are based on the safety assessments, both deterministic and probabilistic.

Safety assessments, consistent with IAEA safety standards, must consider both deterministic and probabilistic aspects of safety. Whether the deterministic aspects of safety are to be addressed by traditional conservative analysis, or by the more recent Best Estimate Plus Uncertainty (BEPU) methods is a matter left to the Nuclear Regulatory Authority's judgment and regulations.

It is important that both deterministic and probabilistic analyses do not rely excessively on screening methods. This is particularly true of probabilistic safety assessments for advanced nuclear power plant designs in Generation III and Generation III+ which have rather low estimated core damage frequencies and large release frequencies. It would not be acceptable to evaluate seismic risks using only seismic margin analysis (SMA); a full probabilistic seismic safety analysis should be performed for both power operation and shut down/refueling conditions.

Acton 117 indicates that the government should familiarize itself with the IAEA safety standards and the safety practices in other countries to gain an understanding of the resources necessary for safety assessment. It is assumed that that this would be done by the government during the passage of enabling legislation, and by the Nuclear Regulatory Authority as part of its regulations and budget requests.

Concerning Action 118, it is assumed here that the TSO(s) for the Nuclear Regulatory Authority would have been created by the Austrian Parliament as part of the enabling legislation, and that the Authority and the TSO(s) would have already been interacting on a regular basis in Phase 1. The Austrian government could request an IAEA Safety Assessment Capacity and Competency Review (SAC) mission.

Action 120 cannot be performed until the prospective utility submits its Safety Analysis Report (SAR) for review. It is assumed here that the safety requirements are issued by the Nuclear Regulatory Authority as one of its first priorities, and that the SAR submitted by the utility would be responsive to the requirements. Assuming that the submittal occurs early within the life of the Authority, the Authority would probably need the assistance of its TSO(s) as well as external experts in certain areas (e.g. seismicity, probabilistic safety assessment, and structural engineering).

Action 121 states that the Nuclear Regulatory Authority should obtain expert support for independent verification of the safety analysis report in order to verify compliance with regulatory requirements. This is an important aspect of regulation, and as noted earlier the Nuclear Regulatory Authority requires the legal authority and financial means to obtain independent expertise when required.

5.13. SAFETY OF RADIOACTIVE WASTE MANAGEMENT, SPENT FUEL MANAGEMENT, AND DECOMMISSIONING

SSG-16 Actions 122-132 address the safety of radioactive waste management, spent fuel management, and decommissioning. Austria has specific international obligations for radioactive waste management and spent fuel management owing to its Contracting Party status to the Joint Convention on the Safety of Radioactive Waste Management and on the Safety of Spent Fuel Management (Joint Convention).

Action 122 states that the government should recognize the long term nature of safety requirements for and the cost implications of radioactive waste management and spent fuel management, including decommissioning and the disposal of radioactive waste. It is assumed that this would be done as part of the government's enabling legislation and financial regulation (rate-making) of the prospective utilities.

Regarding Actions 123 and 125, there is a diversity of views internationally over whether disposal of high level radioactive waste is a national government responsibility (as in Australia, France, Germany, Japan, the Netherlands, Spain, the United Kingdom, and the United States), or is the responsibility of the operating utilities, overseen by the Nuclear Regulatory Authority (as in Belgium, Canada, Finland, Sweden, and Switzerland). The latter point of view is recommended to be adopted for Austria, especially based on the Finnish and Swedish models.

Concerning Action 124, it is assumed that the national radioactive waste management strategy would be defined by the Austrian Parliament in the enabling legislation, and that the Nuclear Regulatory Authority would subsequently issue regulations to implement the enabling legislation. As noted previously, it is recommended here that the operating utility would be charged with creating the necessary repositories (probably at least one for LILW and another for HLW/spent fuel), and that the utility's proposals would be reviewed and modified/approved (as appropriate) by the Nuclear Regulatory Authority.

Regarding Action 126, it is expected that the Nuclear Regulatory Authority would address the regulatory requirements on radioactive waste management, spent fuel management, and decommissioning within a year of its establishment.

The reviews and oversight foreseen in Actions 129 (assessment of the prospective operating organization's programs for waste management, spent fuel management, and decommissioning) and 131 (regulatory oversight program for facilities and activities for radioactive waste management and spent fuel management) should not be deferred to Phase 3, but should be accomplished in Phase 1 or Phase 2. Action 132, concerning maintaining awareness of international efforts and progress with regard to radioactive waste disposal, is obvious and requires no further comment.

5.14. EMERGENCY PREPAREDNESS AND RESPONSE

Emergency preparedness and response are addressed in SSG-16 by Actions 133-145. As noted by IAEA, although a good design and safety culture, as well as safe operation, should make the likelihood of an accident with a large radioactive release as low as possible. In all events, however, the frequency of such an accident will never be zero, thus emergency planning and preparedness is a necessity for the utility, the Nuclear Regulatory Authority, and for national and local government. This is also an area for which cooperation between Austrian authorities and authorities in trans-boundary neighboring states is a necessity. Austria also has treaty obligations under the Convention on Early Notification of a Nuclear Accident (which Austria ratified in 1988).

Articles 36, 37, and 38 of the Austrian Radiation Protection Act set out the general principles of intervention, radiation monitoring, and countermeasures to be taken in the case of a radiological emergency (BMLFUW, 2012:5). Responsibilities for offsite emergency management are shared between BMLFUW (Lebensministerium), the Federal Ministry of Health, the National Crisis and Disaster Protection Management for the Federal Ministry of the Interior, the Federal Alarm Centre for the Federal Ministry of the Interior, the Federal Ministry of European and International Affairs, and the nine Austrian Provinces. BMLFUW is the competent authority for international information exchange (ECURIE[45], the Convention on Early Notification, and various bilateral agreements)[46]. Austria operates the RODOS decision support system as part of its response to radiological emergencies[47]. In addition, BMLFUW operates an automatic radiation monitoring system, Austrian Radiation Early Warning System (Strahlenfrühwarnsystem), consisting of three hundred measuring stations throughout the country and ten aerosol monitoring stations near Austrian borders. Implementation of countermeasures is the responsibility of the Austrian provincial governments.

Action 133 states that the government should develop awareness of the need for early establishment of emergency plans. Such plans exist in Austria, but would have to be supplemented as the time approaches for the operation of the first nuclear unit. The need for emergency plans is already clearly understood.

Action 134 states that the government should identify institutions and new arrangements for supporting emergency preparedness and response. This has been done for Austria, and would have to be supplemented by establishing appropriate contacts with the Nuclear Regulatory Authority and the operating utility.

Actions 135 (specification by the government of national institutions with responsibilities for emergency preparedness and response) is already in effect in Austria, but would require integration of the Austrian Nuclear Regulatory Authority into the existing structure. Action 136 (specifying the general approach for emergency preparedness and response on the basis of the likelihood and severity of accidents) is best done by the Austrian Nuclear Regulatory Authority and not by the government since the Authority will have more of the necessary expertise. It is expected that the Authority would accomplish this Action in its regulations issued within a year of its creation.

Action 137 is already accomplished. It is expected that Action 138 would, as indicated above, be addressed in the regulations to be issued within a year after the Regulatory Authority's creation.

Action 140 should be accomplished in Phase 1 and not deferred until Phase 3. Action 142 is obvious and requires no further comment. Action 143 is already accomplished in Austria with the exception of integrating the Nuclear Regulatory Authority into the existing structure. Action 144 is obvious. Action 145 should be implemented by at least two major exercises before the startup of the first

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[45] ECURIE Is the European Community Urgent Radiological Information Exchange. ECURIE is under the European Commission's Joint Research Centre (JRC). ECURIE signatories include all 27 European Union Member States as well as Croatia and Switzerland. ECURIE resulted from a 1987 Council Decision 87/600/Euratom on 14 December 1987.

[46] Austria has bilateral agreements concerning nuclear safety and radiation protection with Belarus, the Czech Republic, Germany, Hungary, Liechtenstein, Poland, Russia, Slovakia, Slovenia, Switzerland, Tajikistan, and Ukraine.

[47] The RODOS (Real-time On-line Decision Support) system was developed as part of numerous European Commission Framework Programme research projects in the 3rd, 4th, 5th, and 6th Framework Programmes.

Austrian nuclear power plant (to permit corrective actions to be implemented and demonstrated in the second exercise), and exercises should occur regularly thereafter.

The Austrian government or the Austrian Nuclear Regulatory Authority (depending on whether the issue is addressed in the enabling legislation or left to the NRA to decide) would have to determine the sizes of Emergency Planning Zones (EPZs) around nuclear power plants and the radioactive waste repository. The EPZ sizes vary from country to country, and there is also the experience of the accidents at Chornobyl and Fukushima to consider.

Considering the preponderance of homes without cellars or basements, and the preponderance of blocks of apartments (flats) in Austria, it may be necessary to consider precautionary evacuation in the case of a severe accident at an Austrian nuclear power plant. This is because aboveground housing provides very little protection against radiation from the passing plume and from radioactivity deposited on the ground or on building surfaces. The radius of the plume exposure pathway EPZ should be determined with this Austrian characteristic in mind. (The 16 km distance of the plume exposure pathway EPZ in the United States was determined at least partly considering the presence of cellars or basements in many houses.)

The ingestion exposure pathway EPZ – in which there are controls placed on drinking water, milk, meat, and fresh foodstuffs – also has to be considered with Austrian conditions in mind, and considering the accident experiences at Chornobyl and Fukushima. There is a real question whether the 80 km ingestion EPZ established in the U.S. is adequate in light of these experiences. On the other hand, if the specific features of the nuclear power plant design approved for construction in Austria are considered (double containment, annulus filtration, spent fuel pool inside containment, and availability of containment filtered venting), an 80 km ingestion EPZ may be adequate as a basis for response. This is a matter that should be taken up by the Austrian government in enabling legislation, and reinforced by specific requirements to be issued by the Nuclear Regulatory Authority.

5.15. OPERATING ORGANIZATION

SSG-16 addresses Actions 146-159 to the operating organization.

Action 146 states that the operating organization should be involved together with the government in activities for the development of the safety infrastructure. Assuming here that an experienced utility would construct the nuclear power plants in Austria (the examples of EnBW, AXPO, EdF, and various utilities with VVER experience have been previously cited), the adequacy of the nuclear safety infrastructure is the responsibility of the national government insofar as the Nuclear Regulatory Authority and its TSO(s) is concerned, and otherwise is the responsibility of the utility.

It is assumed here that Actions 147 and 148 would be dealt with in the enabling legislation passed by the Austrian Parliament in providing for the regulation of nuclear power plants in Austria. Establishment of a government entity to operate nuclear power plants is not advised based on international experience, and because it would place the government in unconditional liability for nuclear accidents occurring at operating nuclear power plants (not only liability for damages within Austria, but trans-boundary damages as well.

5.16. SITE SURVEY, SITE SELECTION, AND EVALUATION

Actions 160-169 in SSG-16 address site survey and site evaluation activities for nuclear power plants. Siting opportunities for nuclear power plants in Austria would be expected to be limited under the best of circumstances. Austria is a land-locked country, and thus has no seacoast sites available.

Four Austrian provinces (Länder) comprise the bulk of the Austrian population. Vienna, Lower Austria, Upper Austria, and Styria together comprise just under 6 million out of the total population of 8.44 million, more than 70% of the total (Statistik Austria, 2012).

Austria has a total area of 83,879 km^2. Of this total, 62% is occupied by the Alps and thus unavailable for nuclear power plant siting purposes. Only 28% of Austria is moderately hilly or flat. Almost 42% of Austrian territory is protected by nature conservation laws. See Figure 1 on the next page. (The site of the Zwentendorf plant is at 180 meters above sea level[48].)

The only major waterway in Austria is the Danube River (the Donau in German). Other rivers are the Inn (Tyrol; a tributary of the Danube), the Salzach (Salzburg; a tributary of the Inn River, which is itself a tributary of the Danube), the Enns (Styria & Upper Austria; a tributary of the Danube), the Gail & Drau (Carinthia), Mürz & Mur (Styria; the Mürz flows into the Mur, which is a tributary of the Drau). The Drau is perhaps better known outside Austria as the Drava. The Drau is a tributary of the Danube.

The few large lakes (Attersee, Traunsee, Wörthersee, and Neusiedlersee) are not thought to be suitable for cooling water sources for nuclear power plants (particularly Neusiedlersee which is quite shallow). The Attersee is at a relatively high elevation (467 meters), and is surrounded by mountains and small towns & villages. The Traunsee is just to the east of Attersee, and is similarly situated (elevation 423 meters). Wörthersee (elevation 439 meters) is near Klagenfurt, and is nearly completely surrounded by the city of Klagenfurt as well as other towns & villages. Neusiedlersee straddles the Austrian and Hungarian borders, and although it has a large surface area of 315 km^2, it is no more than 1.8 meters deep. Neusiedlersee is an endorheic basin (a closed drainage basin with no outflow). The lake is a nature preserve and a World Heritage site. Neusiederlee is also protected under the Ramsar Convention on Wetlands, to which Austria and Hungary are both contracting parties.

From the standpoint of transboundary accidents, nearly all of Austria is within 100 km of an international border, including essentially all of the most populous four provinces in Austria (Vienna, Lower Austria, Upper Austria, and Styria). Transboundary risks can therefore reasonably be expected to be an important issue for any Austrian nuclear power program.

SSG-16 Action 160 provides that the government should ensure that potential sites are identified, and that candidate sites are selected on the basis of a set of defined criteria, at a regional scale, and with the use of available data. If nuclear power plant siting criteria are not specified in the nuclear legislation passed by the Austrian Parliament, the establishment of siting criteria would be left to the Nuclear Regulatory Authority in its rulemaking powers.

Among the criteria which might be considered are those relating to proximity to small population centers (an individual risk limitation), population density in the 80-km area around the plant (a societal risk limitation), proximity to airports (as well as a prohibition against the construction of airports within a fixed radius of a nuclear power plant) and flight paths, proximity to active faults, proximity to flood plains (this would be balancing act between the cost of condenser cooling/circulating water, the level of the flood plain, e.g., 10,000-year or 1,000-year, and the flood-proofing design of the facility), proximity to dams (both upstream and downstream), and proximity to potentially hazardous facilities (such as chemical plants, natural gas pipelines, refineries, hydrogen production facilities, etc.).

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[48] *AKW Zwentendorf*, http://www.wien-vienna.at/akw_zwentendorf.php. [15 Apr 2013]

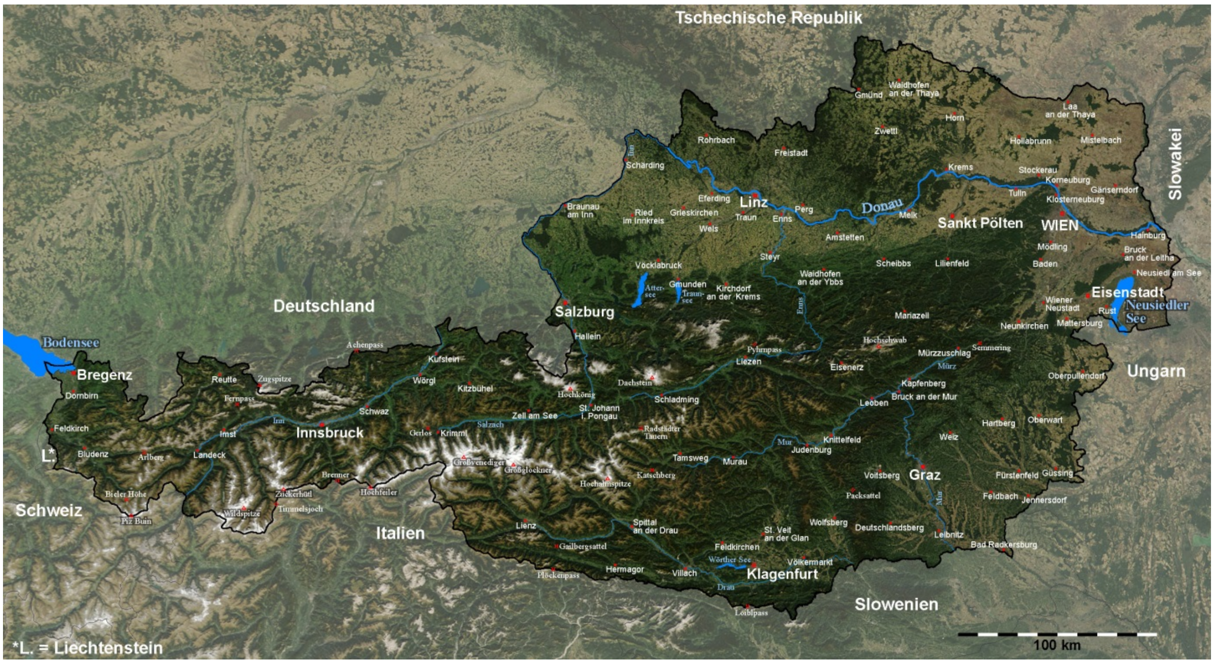

FIGURE 1: SATELLITE MAP OF AUSTRIA SHOWING GENERAL LANDFORMS AND CITY LOCATIONS.

Siting a nuclear power plant (or a geological repository for radioactive waste) requires a thorough understanding of natural phenomena hazards, anthropogenic (man-made) hazards, and interactions between and among such hazards.

It is the prospective utility's responsibility to conduct siting surveys and site selection, using the Nuclear Regulatory Authority's siting regulations. The government might consider, as a part of the Nuclear Regulatory Authority's enabling legislation, the establishment of a siting commission to clearly identify those areas in Austria that are not suitable for nuclear power plant construction (exclusionary criteria). Such a move might save a lot of time on the part of the prospective utility and the Nuclear Regulatory Authority, ***provided*** that the siting commission's deliberations be transparent, involving stakeholders, and to the extent possible, not political but technical in nature (recognizing, of course, that politics cannot be entirely avoided).

Action 161 states that the regulatory body should establish specific safety requirements for site evaluation, including requirements for the site authorization process, in compliance with IAEA safety standards. IAEA Safety Requirements document NS-R-3, *Site Evaluation for Nuclear Installations* (IAEA, 2003), is the governing document for site evaluation for both nuclear power plants and independent spent fuel storage facilities (such as a dry spent fuel storage site). IAEA Safety Requirements document SSR Part 5 contains requirements for site characterization for a disposal facility for radioactive wastes. The requirements for site evaluation in either case should not allow premature screening of external hazards (both man-made hazards and natural phenomena hazards). Hazards screening must consider the nature of the site region, the design of the facility, and the implications of safety targets for hazard occurrence intervals.

Action 164 states that the regulatory body should review and assess site evaluation reports, and should make a decision regarding the acceptability of the site selected and the site related design basis. It is obvious that the Nuclear Regulatory Authority would do so, since siting is a fundamental aspect of facility safety.

5.17. DESIGN SAFETY

Herein we have taken a pragmatic approach to design safety which considers both general design requirement considerations as well as considerations specific to Austria and its electricity grid (including the power plant size range that will fit into the grid). SSG-16 addresses design safety in Actions 170-184.

Actions 170 and 171 are both more properly in the province of the Nuclear Regulatory Authority (in a review capacity and in its rulemaking capacity) and the prospective utility (in the first instance). It is up to the prospective utility to propose a nuclear power plant design, and up to the Nuclear Regulatory Authority to review it against its regulations. If an obviously superior design (in terms of safety, for example) exists, pressuring the utility to adopt it is a matter of public opinion and political will.

Actions 172, 174, and 175 concern development of in-depth understanding of safety principles and safety requirements applicable to nuclear power plants, enacting nuclear safety requirements that are necessary for the utility to issue bid specifications, and identifying nuclear infrastructure gaps. In SSG-16, all three of these Actions are left to Phase 2. This is considered here to be too late, and all three Actions should be implemented in Phase 1.

Action 182 provides that the Nuclear Regulatory Authority should review and assess safety documentation to verify whether the design complies with regulatory requirements. This is obviously necessary, and it should be done before construction is allowed to begin. In accord with Action 184, the final "as-built" design should be verified by the Nuclear Regulatory Authority (considering any design changes and changes in the state-of-the-art) before fuel loading and commissioning are allowed to proceed. Design verification is very important activity for both the utility and the Nuclear Regulatory Authority, as illustrated by the experience in the United States with the Diablo Canyon nuclear power plant in which major seismic design errors were discovered very late in construction. The utility should be under a continuing obligation to notify the Nuclear Regulatory Authority of proposed design changes, and should seek Authority approval before their implementation. Both the utility and the Authority should maintain a "living" safety analysis and a "living" probabilistic safety assessment in order to properly account for design changes during the course of construction[49].

Action 185 simply states that the Nuclear Regulatory Authority should issue requirements on commissioning. These requirements should be issued within the first year after creation of the Authority. Issuance of commissioning requirements should not be left to Phase 3 as recommended in SSG-16 for the reason that the utility needs to know the commissioning requirements in order to issue bid specifications. It must be verified before construction begins that the design actually permits assessment of safety features by the commissioning requirements.

[49] The nuclear regulatory authorities of Finland, the Republic of Korea, and Switzerland require that a living PSA be maintained.

5.18. ADVANCED NUCLEAR POWER PLANT DESIGN AVAILABILITY FOR AN AUSTRIAN NUCLEAR POWER PROGRAM IN THE 2030 TIME FRAME AND THEREAFTER

There is a variety of advanced nuclear power plant designs that are either currently available for construction or that are expected to become available for construction in the near term (see EHNUR Work Package 4 for details). These advanced designs fall generally into two classes:

- Small Modular Reactors (SMRs); and
- Generation III and Generation III+ Advanced Reactors.

Generation IV nuclear power plant technologies are not expected to be commercially available until after 2040 (although some demonstration and prototype units may be constructed and operated before 2030). It is anticipated that the soonest a nuclear power plant could come online in Austria is 2028. Considering a two-year interval for plant completion, and considering a small program consisting either of four pairs of 700 MWe units or 4 units in the 1000-1500 MWe range, this would complete the small nuclear power program by about 2034. Thus, Generation IV technology is not further considered owing to its longer time frame for commercial availability.

SMRs have some advantages in the abstract, however for Austria constructing about 4500 MWe of such units could entail construction, operation, and regulation of a relatively large number of individual units[50]. SMRs are most suited to countries with small grids and/or a slow projected growth rate in electricity demand. It is therefore expected that nuclear power plant designs in Austria would be selected from the medium to large power class, specifically in the range of 700-1500 MWe net. It is further expected that nuclear power plant designs would be selected from among Generation III or Generation III+ designs.

In reality, there are only a half dozen available designs that would make sense for the Austrian grid conditions. The CANDU Energy EC-6 design is a 692 MWe pressurized heavy water reactor. A larger related design, with a net capacity of 1082 MWe, is the ACR-1000, which is cooled by pressurized light water but moderated by heavy water. There are three PWRs in the 700-1500 MWe class: (1) The Westinghouse AP1000 (1117 MWe net), (2) the ATMEA1 (1150 MWe net), and (3) the VVER-1200/491 (1082 MWe net). There are only two Generation III+ BWRs in this class: the KERENA design (1250 MWe net), and the ESBWR design (1520 MWe net).

None of these designs is yet in operation, but there are AP1000 projects under construction in the People's Republic of China and the United States; VVER-1200/491 construction projects in Belarus, Russia, and Turkey; and a recently approved ATMEA1 project in Turkey. The first AP1000 unit is expected to enter operation in the People's Republic of China in 2013 or 2014, and the first VVER-1200/491 unit is expected to enter operation at the Leningrad II nuclear plant in 2014. The first ATMEA1 unit is not expected to enter operation until 2019. No ACR-1000 units have yet been ordered. No EC-6 units have been ordered, however the relatively recent Qinshan units in the People's Republic of China and the Cernavoda 3 & 4 units are somewhat similar. No KERENA or ESBWR unit is under construction, but the ESBWR has been selected for possible construction by

[50] The largest SMR available for immediate deployment (SMART PWR) has a net capacity of 100 MWe, and this power level would entail building 40-50 individual units for a contemplated 4500 MWe of capacity. The largest SMR available for near-term deployment (2015-2020) is the IRIS PWR, with a net capacity of 335 MWe. For a contemplated 4500 MWe nuclear power program, such a net capacity would require construction of 13-14 individual units, and would run into serious problems siting so many units.

Detroit Edison and Dominion in the United States, and has been granted Final Design Approval by the US Nuclear Regulatory Commission.

We consider that the likely choice would be among the AP1000, the VVER-1200/491, the KERENA BWR, the ESBWR, and the CANDU Energy EC-6 designs. It appears to be unlikely that ACR-1000 units will eventually be ordered at all, and if they are ordered they may be restricted to Canada. The ATMEA1 has a higher estimated core damage frequency than the other PWR and BWR designs, and is comparable to the EC-6 estimated core damage frequency. The ATMEA1 has a single containment whereas the other designs have a double containment. The ATMEA1 design also has no passive systems (except for PARs and accumulators which the other three designs also have, and which are broadly present in European Generation II reactors as well), whereas the other four designs all incorporate passive safety systems. The ATMEA1 and EC-6 designs are Generation III (see EHNUR Work Package 4), whereas the other three designs are Generation III+.

Table 1 provides a comparison of the AP1000 PWR, the VVER-1200/491 PWR, the KERENA BWR, the ESBWR, and the CANDU Energy EC-6 designs. Assuming that Austria would not wish to add units greater than 10% of the current grid capacity[51], this would limit unit size to 1540 MWe.

The only advanced reactor with a capacity smaller than 1000 MWe net is the Generation III CANDU Energy Inc. EC-6 (690 MWe net). Four pairs of EC-6 units would provide a total of 5520 MWe net of base load generating capacity. At an availability factor of 90%, these eight units could be expected to produce about 43,500 GWh of electricity per year (this would represent 63% of Austria's current electricity generation). This would replace all of the current fossil fuel electrical generation (18,500 GWh) and all of the current electricity imports from the Czech Republic and Germany (19,500 GWh) – in total about 38,000 GWh – and leave 5,500 GWh for increased electricity demand as the nuclear power program is implemented. (Of course, some electricity produced by natural gas would remain due to peaking load production.)

[51] This is the figure identified as a maximum in IAEA, Electric Grid Reliability and Interface with Nuclear Power Plants, Nuclear Energy Series No. NG-T-3.8, March 2012, http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1542_web.pdf however this does not constitute a requirement. The World Nuclear Association also suggests 10%, but indicates that 15% would be acceptable if there is a high reserve capacity (World Nuclear Association, *Electricity Transmission Grids*, 25 April 2013, http://world-nuclear.org/info/Current-and-Future-Generation/Electricity-Transmission-Grids/#.UatdoEBkN8E).

TABLE 1: REACTOR DESIGN COMPARISON (PAGE 1 OF 3)

Parameter	AP1000	VVER-1200/ MIR-1200	KERENA	ESBWR	EC-6
Estimated Cost	€3.4 - €5.4 billion **(Note 11)**	€3.6 - €4.2 billion **(Note 11)**	unknown **(Note 8)**	unknown **(Note 19)**	€2.6 – €3.6 billion for twin units
Construction Duration Goal	36 months **(Note 10)**	54 months **(Note 14)**	48 months	45 months	57 months
Thermal Power	3400 MWt	3200 MWt	3370 MWt	4500 MWt	2084 MWt
Gross Electrical Power	1200 MWe	1158 MWe	1290 MWe	1600 MWe	740 MWe
Net Electrical Power	1117 MWe	1068 MWe	1250 MWe	1520 MWe	690 MWe
House Loads	83 MWe	90 MWe	40 MWe	80 MWe	50 MWe
Fuel Cycle Length	12-18 months	18-24 months	12-24 months	12-24 months	18 months
Net Design Efficiency	32.9%	33.4%	37.1%	33.8%	33.1%
Load Factor Design Target	93%	92%	92%	92%	92%
Design Service Life	60 years	60 years	60 years	**60 years**	60 years **(Note 15)**
Core Damage Frequency	5.1×10^{-7}/a	5.8×10^{-7}/a	$<1.0\times10^{-7}$/a	$<1.4\times10^{-7}$/a **(Note 24)**	$<1\times10^{-6}$/a (target)
Large Early Release Frequency	5.9×10^{-8}/a	2.0×10^{-8}/a	$<3.0\times10^{-8}$/a	2.5×10^{-8}/a	$<1\times10^{-7}$/a (target)
EUR Compliance	Yes **(Note 5)**	No **(Note 3)**	Yes **(Note 4)**	No	No
Operator Action Time	72 hours	6 hours	72 hours	72 hours	0.25 hours
Design Containment Leak Rate	0.1% Volume Per Day	0.2% Volume Per Day	0.5% Volume Per Day	0.5% Volume Per Day	0.2% Volume Per Day
Double Containment	Yes	Yes	Yes	Yes	No
Containment Free Volume	58,333 m^3	74,200 m^3	11,800 m^3 **(Note 7)**	**12,673** m^3 **(Note 21)**	65,500m^3 **(Note 18)**

Table 1: REACTOR DESIGN COMPARISON (page 2 of 3)

Parameter	AP1000	VVER-1200/ MIR-1200	KERENA	ESBWR	EC-6
Filtration of Double Containment Annulus	No	Yes	Yes	Yes	No
Spent Fuel Pool Inside Containment	No	Yes (Primary Containment)	No	No	No
Spent Fuel Pool Capacity	884 assemblies	10 years capacity plus full-core offload	1650 assemblies	10 years capacity plus full-core offload	10 years capacity
High Density Spent Fuel Storage Racks	Yes	Yes	unknown	Yes	No
Spent Fuel Pool Cooling Provided With Emergency AC Power	Yes **(Note 12)**	Yes **(Note 13)**	Yes **(Note 1)**	Yes **(Note 23)**	No **(Note 17)**
Core Catcher	No	Yes	No	Yes	No
Filtered Venting	No	No	No	No **(Note 22)**	No
Designed for 100% Metal-Water Reaction	Yes	unknown	Yes	Yes	unknown
Hydrogen Control	64 Igniters & 2 PARs	PARs	Primary Containment Inerted; recombiners	Primary Containment Inerted; PARs in Secondary Containment	PARs and Igniters
Load Following	Automatic between 50-100% power	Yes, between 50-100% daily	Automatic between 20-100% power	Automatic between 50-100% power	Automatic between 60-100% power
Passive Safety Systems	Yes **(Note 9)**	Yes **(Note 6)**	Yes **(Note 2)**	Yes **(Note 20)**	Yes **(Note 16)**
Turbine Speed	1800 rpm	3000 rpm	1500 rpm	1800 rpm	1800 rpm
Turbine Bypass Capacity	100% of Full Power	Unknown	60% of Full Power	100%	100% of Full Power
Remote Shutdown Station	Yes	Yes	Yes	Yes (2 emergency control rooms)	Yes

TABLE 1: REACTOR DESIGN COMPARISON (PAGE 3 OF 3)

Parameter	AP1000	VVER-1200/ MIR-1200	KERENA	ESBWR	EC-6
Passive Safety Systems	Yes **(Note 9)**	Yes **(Note 6)**	Yes **(Note 2)**	Yes **(Note 20)**	Yes **(Note 16)**
Turbine Speed	1800 rpm	3000 rpm	1500 rpm	1800 rpm	1800 rpm
Turbine Bypass Capacity	100% of Full Power	Unknown	60% of Full Power	100%	100% of Full Power
Remote Shutdown Station	Yes	Yes	Yes	Yes (2 emergency control rooms)	Yes
Design Industrial Partners	GDF Suez, Iberdrola, Endesa, RWE, Vattenfall, E.On	Inter RAO, Rosenergoatom, St. Petersburg AEP, Kurchatov Institute, AREVA Teleperm I&C, Alstom-Energomash, TVEL	EdF, E.On, TVO, VTT, PSI, NRG, Hochtief, FZJ	Fluor	Organization of CANDU Industries, GE-Hitachi Canada, AMEC, Cameco, B&W Canada, Westinghouse Canada, Rolls-Royce
Control Rod Material	Ag-In-Cd	B_4C-Dy_2O_3-TiO_2	B_4C	B_4C	Cd
SSE	0.3g PGA	0.2 PGA	0.3g PGA	0.3g PGA	0.3g PGA
Emergency Power	2 Diesel Generators + 2 ancillary diesels (80 kWe each)	4 Diesel Generators, and a Gas Turbine Generator; 72-hour batteries	Diesel Generators; 24 hour batteries	2 Non-Safety Diesel Generators; 72-hour batteries	Diesel Generators
Turbine Building Orientation	OK	OK	OK	OK	Adverse

TABLE 1: NOTES FOR TABLE 1

01. In the KERENA design, the spent fuel pool is cooled by natural convention in two trains with four tubular heat exchangers each, suspended from the spent fuel pool walls. The heat exchangers are cooled by the redundant closed cooling water system, which has emergency AC power provided as necessary. Makeup water can be supplied by the residual heat removal system, and from a connection with the fire suppression system.

02. There are three passive safety systems: (1) four Emergency Condensers (ECs; rated capacity of 66 MWt each) to remove decay heat from the reactor and from the four Core Flooding Pools without coolant loss from the reactor; (2) four trains of Containment cooling Condensers (rated capacity of 4.8 MWt each) to remove decay heat from the containment following accidents leading to the release of steam inside the drywell (diverse with respect to the Residual Heat Removal, RHR, system); and (3) the Core Flooding System which provides a low-pressure flooding system from four connected pools for controlling the effects of loss of coolant accidents (redundant and diverse with respect to the core flooding function of the RHR system). Passive Pressure Pulse Transmitters (PPPTs) are passive switching devices used to directly initiate reactor scram, containment isolation at the main steam line penetrations, and automatic depressurization of the reactor without the need for I&C equipment.

03. EUR compliance was completed for the VVER-1000 AES-92 design, which has similarities with the VVER-1200/491 design. In addition, the regulatory authorities in Belarus and Russia have approved the VVER-1200/491 for construction.

04. The KERENA design was assessed by STUK as licensable in Finland, but has not undergone a full regulatory review.

05. The AP1000 has been licensed in the People's Republic of China and the United States. In addition, the UK ONR granted the AP1000 design Preliminary Design Approval.

06. There are six passive safety systems for the VVER-1200/491: (1) emergency boron injection system; (2) 4×33% core flooding system; (3) 4×25% passive heat removal from secondary system to atmosphere; (4) core catcher; (5) passive system for annulus filtration and maintaining subatmospheric pressure in the annulus; and (6) 4×33% passive containment heat removal system.

07. The KERENA design uses a pressure suppression system to condense steam in the containment and thereby reduce pressure.

08. No cost estimate for KERENA was located during the EHNUR project. An early (2002 vintage) cost estimate for the smaller precursor design SWR-1000 (2778 MWt/977 MWe net) for Nth of a kind units estimated overnight costs of €1250/kWe installed, annual maintenance costs of €71/kWe installed, fixed operating costs of €37/kWe installed, variable operating costs of €0.76/kWh, decommissioning costs of €260-305/kWe installed, and electricity costs of 2.25 Euro-cents per kWh (Kolb & Martinsen, 2002:57-58 &120). Note that these costs do not include fuel costs.

09. AP1000 passive systems for emergency core cooling, containment isolation, containment cooling, main control room emergency habitability system.

10. This estimate is for the so-called Nth unit. The construction duration from first concrete to fuel load for the unspecified number of first units is 45 months, and the first two units in the People's Republic of China are on a 51-month duration.

11. Converted from dollars to Euro at the exchange rate of 0.77 as of 24 May 2013.

12. The spent fuel pool cooling system is backed up by the two-train active normal residual heat removal system. The spent fuel pool cooling system is supplied with backup power from two 80 kW ancillary diesel generators which can run for four days without offsite support. Additional water can be supplied from the ancillary storage tank after 72 hours, and is sufficient to provide spent fuel pool cooling for another four days.

13. The spent fuel pool can be refilled by using the active containment spray system.

14. The pilot units could have a 60-month construction duration, but series production aims at a 54-month construction duration.

15. Requires retubing of the calandria and other reburbishment after 30 years, which can result in an outage of 1-2 years.

TABLE 1: NOTES FOR TABLE 1 (CONTINUED)

16. Passive safety systems for EC-6 are a reserve water system (can provide secondary heat removal for three days; can provide water to emergency core cooling system heat exchangers; and can have makeup from a fire truck), severe accident recovery system (SARS).

17. The calculated time for boil off of spent fuel pool inventory (presumably to the top of the spent fuel assemblies) is calculated at 13 days.

18. This is the containment free volume for the CANDU 6 design (inside diameter 41.46 m, height above grade 46.02 m). The EC6 containment has an inside diameter of 41.45 m and a height of 51.21 m. An EC6-specific containment free volume could not be located in time for inclusion in this report, but the free volume should be similar to the CANDU 6. The containment walls for the EC6 are thicker and have more rebar, and the containment is steel lined (vs. epoxy liner for the existing CANDU 6 units).

19. GE-Hitachi estimates overnight costs of $1160-1250 per kWe installed. A more recent estimate was $1600 per kWe installed. This is considered to be unrealistically low, and is quite likely an overnight cost estimate in constant dollars in the year of estimation without including owner's costs and the time cost of money borrowed during construction. No project-specific cost estimates were identified during the preparation of this report. It is quite likely that the actual cost of construction (overnight costs plus owner's costs, financing charges, escalation, and inflation) would be larger than the other units listed in total cost, but may not be dramatically different in cost per kWe installed.

20. The passive systems in the ESBWR design include a Gravity Driven Cooling System (together with ADS & DPVs) and a Passive Containment Cooling System.

21. The ESBWR uses pressure suppression to reduce containment pressure. The free volume of the drywell is 7,206 m^3 and the free volume of the wetwell air space is 5,467 m^3. The suppression pool contains 4,383 m^3 of water.

22. There is a manually actuated wetwell airspace vent to the environment, but this is unfiltered (relying on the water I the suppression pool to retain aerosols). STUK reports that GE-Hitachi plans to add a filtered venting system for a unit in Finland.

23. The fire protection water system can be used to provide additional inventory to the spent fuel pool.

24. ESBWR PRA results, as summarized in NUREG-2105, Appendix I, January 2013.

According to the US Energy Information Administration, CO_2 production per kWh for coal is about 0.92 kg, for natural gas is about 0.51 kg, and for oil-fired generation is about 0.76 kg. Roughly speaking then, fossil-fired generation in Austria produces about 17.8 million tonnes of CO_2 annually:

- 4.44 million tonnes of CO_2 from coal-fired generation.
- 12.415 million tonnes of CO_2 from natural gas-fired generation.
- 0.94 million tonnes of CO_2 from oil-fired generation.

Austria produces about 67.7 million tonnes of CO_2 annually in total. Replacement of fossil-fired generation would reduce this to 49.9 millon tonnes, a reduction of 26%. For 2030, the European Commission's CO_2 emissions target is a 40% reduction compared with 1990. [See COM(2013)169, *Green Paper on a 2030 Framework for Climate and Energy Policies*.]

For Austria, this would mean reducing CO_2 emissions from 78.2 million tonnes to 46.9 million tonnes (CO_2 equivalent). Building and operating eight EC-6 units would take Austria down to nearly its 2030 target. Note that if we account for 66 grams of CO_2 emissions per kWh of nuclear generation[52] (as recommended by Sovacool (Sovacool, 2008); this would be a possible overestimate for PHWRs since they do not require enrichment), this results in a 14.9 million tonne CO_2 emissions reduction instead of 17.8 million tonnes. This would then put Austria at 52.8 million tonnes – still 6 million tonnes of CO_2 equivalent over its 2030 target. While nuclear power is not a panacea as regards CO_2 emissions, for Austria it would put Austria almost within reach of its 2030 greenhouse gas emission targets. Owing to limited long-term nuclear fuel supplies (without a massive switch from LWR and PHWR technologies to fast breeder reactors), nuclear power represent a bridging technology to the further development of renewables and (possibly) nuclear fusion in the longer term.

If Austria went with larger 1100-1500 MWe class nuclear units it would require four such units to obtain an output similar to the eight EC-6 units identified above. At the upper end of this class, four 1500 MWe reactors operating with a 92% availability factor would produce about 48,000 GWh per year. Table 1 compares the AP1000, the VVER-1200, the KERENA, the ESBWR, and EC-6 designs. There are three other advanced reactor designs in the 1100-1500 MWe class available for immediate deployment:

- APR-1400 (1400 MWe net) – Generation III; single containment (not further considered).
- ABWR (1350 MWe net) – Generation III; single containment (not further considered).
- AREVA EPR 1650 MWe net) – Generation III+; double containment (too large a capacity, and not further discussed).

The Mitsubishi APWR (1650 MWe net), the AREVA EPR (1650 MWe net), and the Toshiba EU-ABWR (1600 MWe net) are too large for the Austrian grid, and are therefore not further considered. (The large sizes of these units are understandable, coming as they do from two countries with large electricity grids as well as limited siting possibilities – namely Japan and France.)

Designs which are not yet available for deployment, but which may become available before 2020 or soon thereafter, include the KEPCO/Korea Hydro APR+ (which is planned to be a 1500 MWe net version of the APR-1400 but with a double containment and a core catcher, aimed at the European

[52] The European Commission's 2007 Energy Policy (EC, 2007) cites greenhouse gas emissions (in CO_2 equivalent) of 15 grams per kWh. Judging from Sovacool (Sovacool, 2008), this probably represents only the emissions during operation. Sovacool considered not only operation, but front end, construction, back end, and decommissioning emissions.

market), the Atomstroyexport VVER-1200A (with a double containment and core catcher), and the Atomstroyexport VVER-1500 (with a double containment and an air-cooled passive containment heat removal system). Later designs still on the drawing boards and not likely to become available for deployment until after 2020 (and perhaps well after this date) include the Hitachi-GE ABWR II, the APR-1000, and the VVER-1800. Only the APR-1000 is a fit for the Austrian grid size, and this design was still in the conceptual design stage in 2011.

It is perhaps interesting to note that the World Nuclear Association (WNA) "Nuclear Century Outlook" posits that Austria might have up to three GWe of nuclear power by 2030, up to five GWe by 2060, and up to seven GWe by 2100. These projections, of course, ignore the current constitutional prohibition against nuclear power. On the other hand, the projections are not markedly different from what is indicated herein in the EHNUR thought experiment.

5.19. PREPAREDNESS FOR COMMISSIONING

Actions 185-188 of SSG-16 address preparedness for the commissioning of nuclear power units. Action 185 is addressed above because it is considered to represent not only a commissioning Action but a design Action as well.

The Regulatory Authority would also need to be issued commissioning requirement for radioactive waste storage and disposal sites, and for spent fuel storage and disposal sites. Action 188 indicates that the regulatory body should require and assess the commissioning plan of the utility to verify compliance with regulatory requirements, and that the regulatory body should prepare a program to oversee the commissioning of systems important to safety during operation. Once again, the assessment of commissioning plans should be accomplished by the Nuclear Regulatory Authority during the safety assessment of the design in Phase 1 of the nuclear power program, and not left to Phase 2. The final details of actual regulatory oversight of the commissioning program can be accomplished in Phase 2.

5.20. TRANSPORT SAFETY

The safety of radioactive materials transportation is addressed by SSG-16 Actions 189-192. Action 189 is a government responsibility for establishment in enabling legislation for the Nuclear Regulatory Authority. The Authority would have to establish implementing regulations, and provide for effective interface with law enforcement and emergency response organizations.

Regarding Action 192, it is expected that the Regulatory Authority would issue regulatory requirements for transport of radioactive material within its first year of existence. As this is an area subject to frequent changes (e.g., the IAEA Safety Requirements document in this area is revised every two years), the Regulatory Authority would have to keep current in developments in the area of transport.

5.21. INTERFACES WITH NUCLEAR SECURITY

Interfaces between nuclear safety and nuclear security are addressed by SSG-16 Actions 193-200. Concerning Action 193 (fostering by the government of safety culture and security culture), the government can exercise a "bully pulpit" function regarding safety culture and security culture, but it is difficult to foresee how the government *per se* can do much more (you cannot legislate culture in this regard). The government should require that safety be the primary responsibility of the prospective operator (mirroring the IAEA Fundamental Safety Principles in this regard), and can require by legislation provisions to implement Austria's treaty obligations vis-à-vis nuclear security and non-proliferation. It will be the responsibility of the Nuclear Regulatory to pass regulations implementing these government provisions, and to carry out an effective review and inspection regime capable of detecting in a timely fashion any deviation from a proper safety culture and a proper security culture. It is also the Nuclear Regulatory Authority's responsibility to establish regulations governing the interface between safety and security.

Actions 194 and 195 (concerning security requirements and responsibilities for security) should be implemented in Phase 1. The utility will require the security requirements established in regulation in order to put its bid specifications, especially so in Austria since it is anticipated that Austria might require greater than average protection against some types of security threats (e.g. vehicle bombs, hijacking of commercial aircraft and their use similar to that in the 11 September 2001 terrorist attacks in the United States). A single perimeter is possibly not enough –Austria might specify an outer perimeter and an inner perimeter, with a zone in between the two to permit interdiction of any external threats.

Action 196 is a normal part of doing business for the Nuclear Regulatory Authority and would be addressed in the Authority's public communications program and interactions with stakeholders. Establishing the appropriate balance between the public's right to know and the need to protect security details from disclosure is a difficult activity which requires early attention by the Nuclear Regulatory Authority. This should be addressed in Phase 1 and not await Phase 2 for its implementation. The same is true of Action 197, which should be accomplished in Phase 1 and Phase 2 and not left to Phase 3 except to verify that the final "as-built" design continues to maintain a proper interface between nuclear safety and security.

5.22. OPERATIONAL SAFETY

Operational safety is not addressed in SSG-16 because SSG-16 only takes nuclear infrastructure from the start of the program through commissioning. The utility operating a nuclear power plant in Austria should have primary responsibility for its safety, irrespective of what other organizations (including the utility's contractors, consultants, etc.) may do. The Nuclear Regulatory Authority is expected to conduct periodic inspections and to use its resident inspectors in order to provide assurance that operations are being conducted safely and in compliance with regulatory requirements and the facility's operating license. Inspections should consider not only deterministic compliance matters, but also changes in the risk profile of the power plant as changes to its design and procedures are made. The Nuclear Regulatory Authority needs to maintain current awareness of the plant configuration and its risk implications, as does the operating utility.

An important aspect of regulation of nuclear power plant operation in Europe is the general requirement for a Periodic Safety Review (PSR) at least every ten years. The IAEA Specific Safety Guide SSG-25 provides guidance for PSR conduct and regulatory evaluation (IAEA, 2013). PSRs are performed in all of the EU Member States with a nuclear power plant, as well as in nearly every other country with a nuclear power plant (the exceptions being Armenia, Iran, and the United States).

It should be noted that France performs PSRs by plant class only, and not on a plant-specific basis. This is <u>not</u> recommended here due to the fact that even if the plant designs, procedures, staff training, and status of upgrades are identical, there are still site-related differences that must be accounted for in a PSR.

5.23. RADIOACTIVE WASTE & SPENT FUEL MANAGEMENT

As with operational safety, SSG-16 does not deal with radioactive waste and spent fuel management once commercial operation begins.

It is recommended here that the Nuclear Regulatory Authority not permit high density spent fuel storage racks to be used in the spent fuel pool in order to reduce the risk of a severe accident from the spent fuel in the pool. The Authority should also not permit two sets of spent fuel racks, one on top of the other, in the spent fuel pool because this practice results in the hottest fuel assemblies being placed higher in the pool which increases the likelihood (and perhaps the consequences as well) of severe spent fuel pool accidents .

The Authority should also ensure during the safety review stage that the spent fuel pool cooling system is redundant in all modes of operation (especially during outages when some equipment availability requirement are relaxed) and diverse, at least to the point where alternate equipment – available at the site – can be used to cool the spent fuel pool and to add water inventory to the spent fuel pool in case the pool level decreases.

Spent fuel should be removed from the spent fuel pool as soon as feasible (typically after five years), and placed in dry spent fuel storage at the reactor site. This limits the amount of spent fuel in wet pool storage. The spent fuel in dry storage would be there temporarily, awaiting transport to the eventual radioactive waste repository for disposal. The use of dual-purpose casks (allowing both dry storage and disposal) should be considered.

5.24. DECOMMISSIONING

SSG-16 does not address decommissioning. It is expected that following final shutdown of a nuclear power plant or research reactor that Austria would require prompt decontamination and dismantlement as the mode of decommissioning, and that the funding mechanism for decommissioning support this mode of decommissioning.

It is further expected that nuclear sites would ultimately be decommissioned to green field status, allowing further unrestricted use of the site, since it is likely that conventional nuclear power technology would be a bridging technology until improved renewable energy technologies and nuclear fusion technologies can be developed and deployed. Thus, it would not be expected that a nuclear power plant site in Austria would be reused by siting another nuclear (fission) power plant at the site after decommissioning an earlier unit.

6. THE COST OF A SMALL NUCLEAR POWER PROGRAM FOR AUSTRIA

The costs of a small nuclear power program for Austria consist of the following elements (assessment based on AP1000 as illustrative):

Governmental Costs – circa €7 billion over 110 years

- The cost of an NRA and its TSO for 110 years[53] - Average of €35 million for 55 years + average of €50 million for 55 years; total is €4.675 billion.
- The cost of additional offsite security measures occasioned by the presence of four nuclear power plant sites and at least one (if not two) radioactive waste disposal sites in Austria – €5.8 million/a per site[54], for a total of €1.624 billion for protecting four nuclear power plants for 70 years (assuming 60 years of operation, five years of construction, and five years of decommissioning), plus protection of a radioactive waste repository for 40 years (€232 million) – total cost of €1.856 billion. [Of course, the cost of protection would increase over time, but this is not accounted for here.]
- The extra costs of additional emergency planning and preparedness requirements (compared with the current situation without nuclear power plants on Austrian territory) – Not Estimated (perhaps €3 million/yr over 90 years, total €270 million; speculative).
- The costs to the government other than the nuclear regulatory authority for IAEA missions to the nuclear power plants and radioactive waste management and disposal sites – Not Estimated (perhaps of the order of €1 million/a, total €90 million, covering pre-operation, operation, decommissioning, and repository construction, operation & closure); speculative).
- The costs to government for passing the constitutional amendment allowing a nuclear power program (requiring a two-thirds majority in the National Council), and for Parliament to enact the enabling legislation allowing a nuclear power program and setting up the Nuclear Regulatory Authority (a so-called "Nuclear Law") – Not Estimated (perhaps €1 million; speculative).
- Additional costs to government for preparing and approving the annual budget for the Nuclear Regulatory Authority and its TSO - €120,000/a, times 110 years, total of €13.2 million[55].

Power Generation Costs for 60 Years of Operation of Four Units - €127 billion base case, €147 billion pessimistic case

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[53] This is derived as set forth earlier.

[54] The United Kingdom has a Civil Nuclear Constabulary that protects civil nuclear licensed sites (15 sites) and safeguards nuclear materials. The Constabulary operates under the strategic direction of the Department for Energy and Climate Change (DECC) via an eight-member Civil Nuclear Police Authority whose members are appointed by the Secretary of State. The income for the Constabulary comes from site license companies, and amounted to £73.3 million (about €86.5 million). On average, the Constabulary costs €5.8 million per site. The Constabulary has a total of about 1100 Constabulary officers and staff (961 and 128 for 2012).

[55] Estimate based on calculation for Polish conditions (Rozylow, 2013:Appendix 4); costs in Zloty were converted to Euro at the prevailing conversion rate of 0.24 on 24 May 2013.

- The complete cost of nuclear power plant construction for four large units or four pairs of smaller units (including site preparation, overnight costs, owner's costs, inflation, cost escalation of known scope, and interest charges on funds borrowed to support the construction program).

  The cost estimates in Table 1 above are from reactor vendors. More recent cost estimates of the all-in variety (accounting for overnight costs, owner's costs, financing costs, escalation, inflation, etc.) are in the range of €8-10 billion. Considering the increase in estimated costs for nuclear power plant projects in the past five years, it is not considered likely that even these higher cost estimates would hold for projects completed in about 2030 or later. Thus, we have considered two cases, a base case with a cost per unit of €10 billion, and a pessimistic case with a cost per unit of €15 billion. We have allowed 50% of construction cost as a crude estimate of financing costs. Thus, for the base case the capital cost is estimated at €60 billion, and for the pessimistic case the cost is estimated at €80 billion.

- The cost of nuclear fuel for 60 years is included in the OM& cost estimate below. We have examined the cost of dry spent fuel storage by itself. We have taken NRC and Westinghouse estimates for the AP1000 design as indicative of the quantity of spent fuel to be foreseen. The results for the VVER-1200 should not depart markedly from this calculation.

  The U.S. NRC estimates the initial core load of 157 fuel assemblies totaling 84.5 metric tonnes of heavy metal (NRC, 2008:Vol. 1, 3-2). Reloads consist of 64 fuel assemblies (Westinghouse, 2011:2), representing about 34.4 tonnes of heavy metal. Refueling occurs every 18 months, and there will be 38 reloads plus the discharge of the full core at the end of 60 years. A total of 2,589 spent fuel assemblies (157 + 38×64), or 703.7 tonnes of heavy metal (84.5 + 38×34.4), will be discharged. The Westinghouse plan for AP1000 units in the UK is to use the Holtec International Hi-Storm 100U vertical underground storage modules. These multi-purpose casks hold 32 fuel assemblies each. There will be two casks filled every 18 months plus a full core discharge for a total of 81 casks per unit (5 + 38×2) for eventual shipment to a geological repository. It was estimated in 2001 that dry spent fuel storage for a plant discharging 1000 metric tonnes of heavy metal is between $120-250 million (Bunn et al., 2001). We use the implicit GDP deflator for 2001-2013 (1.283), and the current (21 June 2013) exchange rate of 1.314 between dollars and Euro to arrive at a range of €200-400 million per unit. For 4 units, the range is €800 million (base case) to €1.6 billion (pessimistic).

- The cost of nuclear power plant operation for 60 years comes from primarily from fuel and operations & maintenance costs (O&M). Westinghouse claimed in 2003 that fuel and O&M costs for the AP1000 would be 1 cent/kWh (Belles, 2006:28). At the current (21 June 2013) exchange rate of 1.314, and accounting for the GDP deflator from 2003 to 2013, the current cost of fuel and O&M should be 1.6 Eurocents/kWh.

  To be conservative, we have considered to cases: a base case in which O&M & fuel are 3 Eurocents/kWh, and a pessimistic case in which O&M & fuel are 5 Eurocents/kWh. The base case assumes 93% availability factors (per design) and operation for 60 years, which yields 2116 trillion kWh; at 3 Eurocents/kWh, the cost of O&M for 60 years for four units would be €63 billion. The pessimistic case assumes 50% availability and operation for 60 years, which yields 1,137 trillion kWh; at a cost of 5 Eurocents/kWh, the cost would be €57 billion.

- The costs of repairs, safety modifications, refurbishment for four large units or four pairs of smaller units over 60 years.

  At a modest rate of €20 million per outage, and assuming 38 outages as above, this is €760 million per unit, or about €3 billion for the base case. For the pessimistic case, it would have to be expected that outage costs would be higher. We have taken €50 million per outage, with the result that the total cost is about €8 billion for four units.

Radioactive Waste Management & Disposal Costs – €10 billion base case, €15 billion pessimistic

- The cost of radioactive waste (LILW and HLW, including decommissioning wastes) storage, management, and ultimate disposal (including repository construction and closure).

  The cost of a deep geological repository for Finland (figured for the spent fuel only from five reactors) is currently estimated at €3 billion (according to Posiva Oy). We have conservatively estimated the repository cost €10 billion, allowing for the need for a larger repository for all wastes (LILW & spent fuel), allowing for cost escalation over time (from 2013 to a possible repository need late in the 21st century), and allowing for a high level of safety which would be expected to be demanded by the Austrian population and the Austrian Parliament. For the pessimistic case, we have estimated the repository cost at €15 billion.

- The cost of transport of LILW, HLW, and spent fuel to the repository or repositories (in case the LILW and HLW are disposed of separately) – Not estimated.

Decommissioning Costs - €1.5 billion per unit, €6 billion subtotal

- The cost of decommissioning (decontamination and immediate dismantlement) of four large nuclear power units.

  Westinghouse claimed in 2003 that the decommissioning charge for an AP1000 unit would be 0.1 cents/kWh (Belles, 2006:28). Assuming 60 years of operation at 1117 MWe net with a 93% load factor, this costing accumulates €420 million over 60 years (not accounting for interest accumulated). Experience with decommissioning indicates that this is optimistic. The Congressional Research Service reported actual PWR decommissioning costs in 2011 (Holt, 2011): (a) Trojan, 1130 MWe, $429 million; (b) Maine Yankee, 900 MWe, $500 million; (c) Connecticut Yankee (Haddam Neck), 582 MWe, $790 million; (d) Rancho Seco, 913 MWe, $500 million, not including future demolition of the cooling towers and other remaining plant structures. These actual decommissioning costs of $429-790 million far exceed the more typical estimates of $300-420 million that one sees in the literature. Decommissioning of the first theoretical Austrian nuclear unit would not take place until after 2100 (assuming 60 years of operation; allowing 20 years for nuclear legislation passage, regulations passage, and construction; and assuming a 5 year waiting period after operation and 10 years to decontaminate and decommission). Even at a 1% growth in costs over this period, the decommissioning cost would double, and at a growth rate of 1.5% per year, the decommissioning cost would increase four-fold to about €1.5 billion per unit.

GRAND TOTAL OF COSTS, BASE CASE: The grand total of all of the above costs ranges from €146 (base case) to €170 billion (pessimistic case). Note that this estimate does not account for utility profit

7. DISCUSSION & CONCLUSIONS

A thought experiment has been conducted concerning four questions for a theoretical small nuclear power program for Austria:

- What would be necessary in order to establish a nuclear power program in Austria?

  Austria would have to:

  - Pass a constitutional amendment rescinding the ban on nuclear power.
  - Pass a nuclear law (enabling legislation).
  - Pass legislation establishing liability for nuclear accidents.
  - Establish and staff an independent Nuclear Regulatory Authority (NRA) and its Technical Support Organization (TSO).
  - Establish regulation for nuclear powered electricity costs (either under the current E-Control or another regulatory body).
  - Establish a nuclear constabulary or equivalent organization to provide external security for four nuclear power plants and a geological repository, as well as spent fuel and radioactive waste shipments from power plant sites to the repository.
  - Upgrade emergency planning and response capabilities for responding to nuclear accidents inside Austria and for providing assistance to neighboring trans-boundary countries in such an event.

- Approximately how many nuclear units of what size would make sense for Austria, given a particular framework for reducing Austrian electricity imports, and for reducing generation of electricity from carbon intensive sources?

  Given the size of the Austrian grid and the likelihood of considerable resistance at siting nuclear power plants and radioactive waste repositories, a total of four nuclear power plants and a single geological repository for LILW and spent fuel are suggested. Only a limited number of advanced reactor designs fit the Austrian grid situation, and the choice of technology would likely be from among the AP1000 and the VVER-1200/491 PWRs, the KERENA BWR, and the EC-6 PHWR. Considering the large volume increase in spent fuel associated with the EC-6 (compared with the other three designs), this option is considered to be the least likely.

- How much time would be required for implementation of the assumed nuclear power program?

  Assuming an immediate start with passage of a constitutional amendment allowing a nuclear power program, the first reactor would be unlikely to begin operation before 2028. It is assumed that the next three units would follow at two-year intervals. Assuming 60 years of operation for each unit, the last unit would shut down for decommissioning in 2094. Assuming 10 years for decontamination, spent fuel shipment (after five years of cooling in the spent fuel pool), and dismantlement, and assuming all shipments to the geological repository are completed 10 years after the shutdown of the last unit, the closure of the geological repository could begin in 2104 and be completed 5-10 years later (i.e., not later than 2114).

- Approximately how much would the assumed nuclear power program cost, including regulation & government costs; plant construction, operation & decommissioning; and radioactive waste storage & final disposal?

  The grand total estimate for a 4-unit nuclear power program is €146-170 billion. This is a perhaps a somewhat low estimate that does not take into account cost increases over time (except very crudely for the regulatory authority cost), nor utility profits.

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ANNEX 1: DETAILS OF SSG-16 CONFORMANCE

A.1 IAEA SSG-16 PHASE 1

Implementing a nuclear power program is a major undertaking that requires careful planning and preparation, and a major investment in time and human & financial resources. While a nuclear power program is not unique in these aspects, it is different because of the safety issues associated with the program and due to the long term commitment to ensuring safety.

At a minimum (assuming 15 years to put the first plant online, assuming a two-year interval between succeeding plants (five units of 1100-1200 MWe class, or four two-unit blocks of 690 MWe class), assuming a 60-year service life, assuming immediate decontamination and dismantlement as the decommissioning mode, and finally assuming a relatively rapid implementation of final disposal for high level waste/spent nuclear fuel, a nuclear power program represents a minimum 100-year commitment on the part of the Austrian government.

The prime responsibility for safety rests with the prospective operating organization. The government is required to establish an effective governmental, legal, and regulatory framework to support a high level of safety. The prime responsibility for safety resting with the prospective operating organization cannot be delegated or outsourced – it must be discharged by the operating organization through leadership, adequate funding, sufficient expertise, and legal responsibility, as well as an exemplary safety culture.

SSG-16 Phase 1 (safety infrastructure before deciding to launch a nuclear power program) consists of the following Actions:

- 1-4, 11-13, 20-21, 24-26, 39-40, 48-51, 61-62, 72-74. 85-89, 99-100, 105-107, 117, 122-123, 133-134, 146, 147-148, 160, 170-171, 189, and 193.

We assume here that the operating organization is a utility with considerable experience in nuclear power. We also assume that the Austrian government has not opted to charter a government agency to build, own, and operate nuclear power plants, but has instead opted to have these activities performed by an experienced utility. Thus, those actions required of the utility are not considered in detail here, but would be something that the regulatory authority would address in its review of preliminary and final safety documentation and in its ongoing inspections. There are no unique utility Actions in Phase 1.

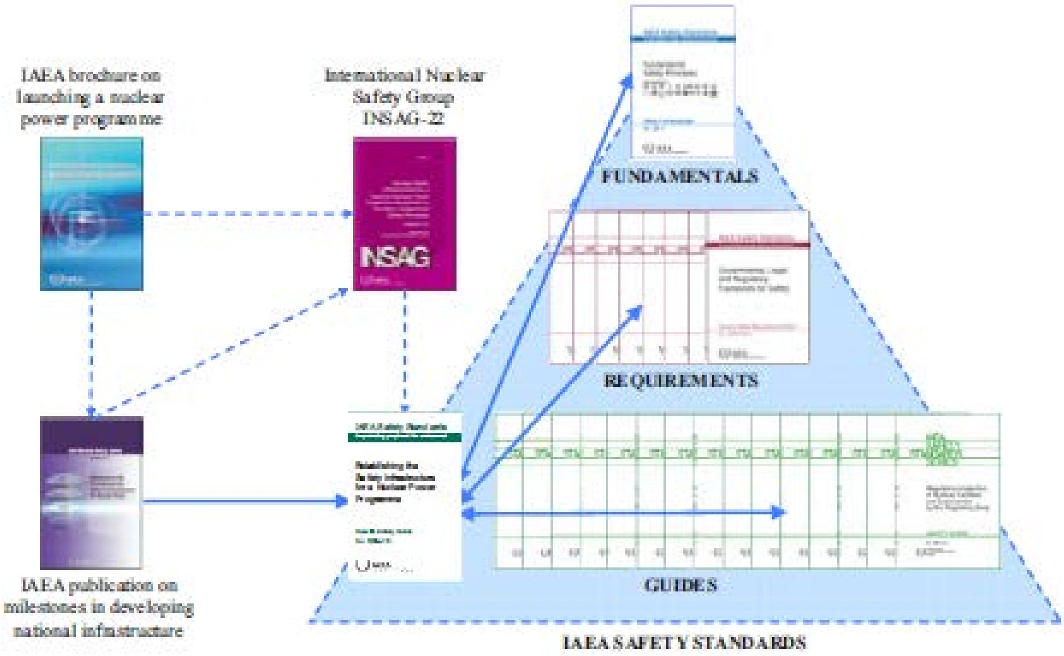

FIGURE 2: RELATIONSHIP BETWEEN SSG-16 AND OTHER IAEA DOCUMENTS.

Action 1: *The government should consider the necessary elements of a national policy and strategy for safety to meet the fundamental safety objective and the principles established in the IAEA Safety Fundamentals (SF-1).*

Action 2**:** *The government should provide for the coordination of all activities to establish the safety infrastructure.*

Action 3**:** *The government should ensure that the status of the safety infrastructure in relevant areas is assessed and that radiological considerations are adequately taken into account.*

Action 4**:** *The government should take due account of the assessment of the elements of the safety infrastructure and of the fundamental principle of justification when making a decision on whether or not to introduce a nuclear power programme.*

Action 11: *The government should prepare for participation in the global nuclear safety regime.*

Action 12: *The government should begin a dialogue with neighbouring States regarding its projects for establishing a nuclear power programme.*

Action 13: *The government and relevant organizations, if they already exist, should establish contact with organizations in other States and international organizations to seek advice on safety related matters.*

Action 20: *The government should identify all necessary elements of a legal framework for the safety infrastructure and should plan how to structure it and develop it.*

Action 21: *The government should consider the process that should be employed to license nuclear facilities in the later stages of the programme.*

Action 24: *The government should recognize the need for an Effectively independent and competent regulatory body, and should consider the appropriate position of the regulatory body in the State's governmental and legal framework for safety.*

Action 25: The government should seek advice from the regulatory body on radiation safety issues relating to a nuclear power programme.

Action 26: The government should identify the prospective senior managers of the regulatory body.

Action 39: *The government should establish a policy and guidance to inform the public and interested parties of the benefits and risks of nuclear power to facilitate their involvement in the decision making on a prospective nuclear power programme.*

Action 40: *The government should establish a process to ensure that the comments arising from consultation with relevant interested parties are considered, and it should communicate the results of these considerations to the interested parties.*

Action 48: *The government should plan funding for education and training, and for research centres and other national infrastructure, to support the safe operation of nuclear power plants.*

Action 49: *The government should consider the long term economic conditions of nuclear power plant operation, to ensure that the operating organization is able to ensure the safety of its nuclear power plants until the end of their planned operating lifetime.*

Action 50: *The government should consider the various possible sources for the funding of the regulatory body.*

Action 51: *The government should consider the various possible sources and mechanisms of funding for radioactive waste management and spent fuel management, the decommissioning of nuclear power plants and the disposal of radioactive waste.*

Action 61: *The government should consider the availability of expertise industrial capability and technical services that could support the safety infrastructure in the long term.*

Action 62: *The government should assess the need to create or to enhance national organizations to provide technical support to the regulatory body and the operating organization for the safe operation of nuclear power plants.*

Action 72: *The government should take into account the essential role of leadership and management for safety to achieve a high level of safety and to foster safety culture within organizations.*

Action 73: *The government should ensure that all the activities conducted are included within the framework of an effective management system.*

Action 74: *The government, when identifying senior managers for the prospective organizations to be established, should look for persons with leadership capabilities and an attitude emphasizing safety culture.*

Action 85: *The government should consider a strategy for attracting, training and retaining an adequate number of experts to meet the needs of all organizations involved in ensuring safety in a prospective nuclear power programme.*

Action 86: *The government should identify competences required in areas relating to nuclear safety and the approximate number of experts needed.*

Action 87: *The government should identify national institutions and institutions in other States that could provide education and training and could start training in key areas relating to nuclear safety.*

Action 88: *The government should identify gaps in safety related training at existing training institutions and should plan to strengthen existing training institutions or to establish new training institutions to fill these gaps.*

Action 89: *The government should ensure that prospective senior regulators identified by the government and prospective safety experts to be involved in the nuclear power programme gain an understanding of the principles and criteria of nuclear safety.*

Action 99: *The government should consider in which areas in-depth knowledge is necessary for assessing and analyzing safety related aspects of a nuclear power plant project, and should identify research centres that can start research programmes in safety related areas of knowledge.*

Action 100: *The government should identify gaps in the capabilities of domestic research centres to meet needs in core areas, and should plan to establish new research centres for core areas as necessary.*

Action 105: *The government should consider the additional radiation risks and special needs associated with the operation of nuclear power plants.*

Action 106: *The government should ensure that an initial radiological environmental impact analysis is conducted as appropriate on the basis of a defined set of criteria, at a regional scale and with the use of available data.*

Action 107: *The government should recognize the need for integrating radiation protection regulations and new safety regulations for nuclear power plants.*

Action 122: *The government should recognize the long term nature of the safety requirements for and the cost implications of radioactive waste management (including disposal of waste), spent fuel management and decommissioning.*

Action 123: *The government should consider the feasible options for radioactive waste management (including disposal of waste), spent fuel management and decommissioning, on the basis of a comprehensive long term strategy.*

Action 133: *The government should develop awareness of the need for the early establishment of emergency plans.*

Action 134: *The government should identify institutions and new arrangements for supporting emergency preparedness and response.*

Action 146: *If the operating organization has already been established or identified in Phase 1 (which is not the scenario developed in this Safety Guide, in which the operating organization is established at the beginning of Phase 2), it should be involved together with the government in activities for development of the safety infrastructure from the beginning.*

Action 147: *The government should consider the financial resources and the necessary competences and staffing that are expected from an organization operating a nuclear power plant so as to ensure long term safety.*

Action 148: *The government should consider the different ways of establishing an operating organization to ensure long term safety.*

Action 160: *The government should ensure that potential sites are identified and candidate sites are selected on the basis of a set of defined criteria, at a regional scale and with the use of available data.*

Acttion 170: *The government should learn the objectives for nuclear safety, and how they are taken into account in nuclear power plants of various designs.*

Action 171: *The government should consider the availability of the technical infrastructure as well as the reliability of the national power grid, and should consider the potential impacts of these on the design requirements for the safety of the plant.*

Action 189: *The government should consider the implications for the legal and regulatory framework of the transport of nuclear fuel and radioactive waste, over and above the existing transport of other radioactive material.*

Action 193: *The government should foster both safety culture and security culture, taking into account their commonalities and differences.*

A.2 IAEA SSG-16 PHASE 2

SSG-16 Phase 2 (safety infrastructure preparatory work for construction of a nuclear power program) consists of the following Actions:

- 5-8, 14-16, 22, 27-32, 41-42, 52-55, 63-66, 75-77, 90-94, 101-103, 108-113, 118, 124-127, 135-139, 149-154, 161-166, 172-176, 190-191, and 194-196.

We assume here that the operating organization is a utility with experience in nuclear power. Thus, those actions required of the utility are not considered in detail here, but would be something that the regulatory authority would address in its review of preliminary and final safety documentation and in its ongoing inspections. Thus, from the above list, Actions 54, 110, 112-113, 127, 139, 149-154, 162-163, 165-166, 173, and 176 can be deleted from the Actions requiring consideration. Instead, Austria should focus on the remaining Actions required of the government and the Nuclear Regulatory Authority.

The Austrian government could request that an IAEA Construction Readiness Review (CORR) mission be performed to assess the readiness of both the Nuclear Regulatory Authority and the prospective utility for the commencement of construction activities.

Action 14: *All the relevant organizations should participate in the global nuclear safety regime.*

Action 15: *The State should become a party to the relevant international conventions, as identified in Phase 1.*

Action 16: *All relevant organizations should strengthen their cooperation on safety related matters with states with advanced nuclear power programmes.*

Action 22: *The government should enact and implement the essential elements of the legal framework for the safety infrastructure.*

Action 27: *The government should establish an effectively independent regulatory body and should empower it with adequate legal authority, technical and managerial competence, and human and financial resources, to discharge its responsibilities in the nuclear power programme.*

Action 28: *The government should appoint senior managers and key experts to the regulatory body and should assign to them the responsibility for developing the organization.*

Action 29: *The regulatory body should consider the various regulatory approaches that are applied for nuclear power programmes of the same size, and should tentatively plan its approach, taking into account the State's legal and industrial practices and the guidance provided in the IAEA safety standards.*

Action 30: *The regulatory body should issue regulations and guides specifying the documentation and procedures necessary in the various steps of the licensing process and inspections to be conducted.*

Action 31: *The regulatory body should specify the safety requirements that should be known for the bidding process.*

Action 32: *The regulatory body should begin establishing a suitable working relationship with the operating organization and with international organizations.*

Action 41: *The government should inform all interested parties regarding the safety implications of the decision on the implementation of a nuclear power programme.*

Action 42: *All relevant organizations should continue to inform the public and interested parties on safety issues, including the expected health and environmental impacts of a nuclear power programme.*

Action 52: *The government should make provision for long term funding for education and training, and for research centres and other national infrastructure to support the safe operation of nuclear power plants.*

Action 53: *The government should decide on the mechanism for sustainable funding of the regulatory body.*

Action 55: *The government should enact legislation that requires financial provision for the funding of long term radioactive waste management, spent fuel management and decommissioning.*

Action 63: *The operating organization and the government should encourage industrial organizations in the State to develop their capabilities with the objective of participating in the construction of nuclear power plants and supporting their safe long term operation.*

Action 64: *The government, and the operating organization if applicable, should establish organizations to provide expertise and engineering support or other external support for regulatory oversight and for the safe operation of nuclear power plants, as identified in Phase 1.*

Action 65: *External support organizations and potential contractors should begin to build competence and quality management systems for ensuring safety.*

Action 66: *The regulatory body and the operating organization should plan arrangements for overseeing the activities performed by their respective external support organizations and contractors.*

Action 75: *The regulatory body and the operating organization should start developing and implementing effective management systems in their respective organizations and should promote a strong safety culture.*

Action 76: *The regulatory body and the operating organization should develop competences in managing the growth of and change in the organization.*

Action 77: *The regulatory body and the operating organization should make appropriate arrangements for measurement, assessment (both 'self-assessment' and independent assessment) and continuous improvement of their management systems.*

Action 90: *All relevant organizations should implement a strategy to attract and retain high quality trained personnel.*

Action 91: *All relevant organizations should support the safety related training of their prospective staff in nuclear organizations in other States.*

Action 92: *The regulatory body and the operating organization should actively recruit staff so as to ensure capability in areas relevant to safety in a timely manner.*

Action 93: *The government and relevant organizations should establish new institutes or new curricula relevant to safety, as identified in Phase 1.*

Action 94: *All relevant organizations should commence the education and training in academic and vocational institutions of the necessary number of persons for ensuring safety.*

Action 101: *The operating organization and the regulatory body should be involved in identifying areas for safety research.*

Action 102: *The government should implement plans to establish new institutions for research relating to safety, as identified in Phase 1.*

Action 103: *Research centres should begin conducting research relating to safety in areas in which in-depth knowledge is essential to support safe long term operation of nuclear power plants.*

Action 108: *The regulatory body and/or the government should amend the legislation and/or regulations as appropriate for the purposes of regulating radiation protection.*

Action 109: *The regulatory body should establish or approve, as appropriate, the limits and constraints regarding workers and the public both for normal and potential exposure situations in a nuclear power plant.*

Action 111: *The regulatory body should review and assess the radiological environmental impact analysis for the site selected, as appropriate.*

Action 117: *The government should familiarize itself with the IAEA safety standards and with other States' practices, as appropriate, to gain an understanding of the resources needed for capabilities for safety assessment.*

Action 118: *The operating organization, the regulatory body and external support organizations, as appropriate, should develop the expertise to prepare for the conduct or review of safety assessments.*

Action 120: *The regulatory body should carry out a comprehensive review and an independent verification of the safety analysis report submitted by the operating organization to verify compliance with the regulatory requirements.*

Action 121*: The operating organization and/or the regulatory body should obtain support from external support organizations or individual experts in performing or reviewing safety assessments, as necessary.*

Action 124: *The government and other interested parties as appropriate should establish the national strategy for radioactive waste management, spent fuel management and decommissioning, and should set the goals for its implementation to an appropriate schedule, including site investigations for the purposes of radioactive waste disposal.*

Action 125: *The government, together with the operating organization, should consider the need for establishing a national organization responsible for radioactive waste management, or for extending the organization for radioactive waste management if this already exists in the State.*

Action 126: *The regulatory body should establish the necessary regulatory requirements on radioactive waste management, spent fuel management and decommissioning, as necessary for bid specifications.*

Action 135: *The government should specify the national institutions with responsibilities for emergency preparedness and response.*

Action 136: *The government should specify the general approach for emergency preparedness and response on the basis of the probability and severity of the emergency.*

Action 137: *The government should start implementing new arrangements as identified in Phase 1 for strengthening the infrastructure for emergency preparedness and response.*

Action 138: *The regulatory body should develop basic regulations on emergency preparedness and response, as necessary for the development of infrastructure.*

Action 161: *The regulatory body should establish specific safety requirements for site evaluation, including requirements for the process for authorizing the site selected, in compliance with the relevant IAEA safety standards.*

Action 164: *The regulatory body should review and assess the site evaluation report, and should make a decision regarding the acceptability of the site selected and the site related design bases.*

Action 172: *All the relevant organizations should obtain an in-depth understanding of the safety principles and safety requirements applicable in the design of a nuclear power plant.*

Action 174: *The regulatory body should prepare and enact national safety regulations on design that are necessary for bid specification.*

Action 175: *The government and the operating organization as applicable should start to implement plans for improving the national technical infrastructure, as necessary, to fill in previously identified gaps in the capabilities necessary for ensuring safety.*

Action 190: *All relevant organizations should make a plan on how to meet the relevant international safety requirements and should start to fill the gaps identified in Phase 1.*

Action 191: *The regulatory body and the organizations in charge of the transport of radioactive material should participate in international activities and networks to provide mutual support.*

Action 194: *All the relevant organizations should coordinate safety and security aspects from the early stages of development, establishing maximum synergy and, where necessary, integration.*

Action 195: *The government should define the responsibilities of the operating organization and other competent authorities in relation to security.*

Action 196: *The government should develop mechanisms to communicate to the public appropriate information regarding safety and nuclear security.*

A.3 IAEA SSG-16 PHASE 2

SSG-16 Phase 3 (safety infrastructure during implementation of the first nuclear power plant) consists of the following Actions:

- 9-10, 17-19, 23, 33-38, 43-47, 56-60, 67-71, 78-84, 95-98, 104, 114-116, 119-121, 128-132, 140-145, 155-159, 167-169, 177-184, 186-188, and 197-200

We assume here that the operating organization is a utility with experience in nuclear power. Thus, those actions required of the utility are not considered in detail here, but would be something that the regulatory authority would address in its review of preliminary and final safety documentation and in its ongoing inspections. Thus, from the above list, Actions 18, 57-58, 83, 96, 114, 119, 128, 130, 141, 155-159, 167-169, 177-181, 183, 186-187, and 198 can be deleted from the Actions requiring consideration. Instead, Austria should focus on the remaining Actions required of the government and the Nuclear Regulatory Authority.

Action 17: All the relevant organizations should ensure continued participation in international activities and international networks for strengthening safety.

Action 19: The regulatory body should implement a cooperation programme with the vendor State and with other regulatory bodies that have experience of oversight of nuclear power plants of the same type as that selected.

Action 23: The government should ensure that the legal framework for the safety infrastructure is fully in place and that the legislation is complied with by the relevant organizations.

Action 33: The regulatory body should maintain suitable working relationships with the operating organization.

Action 34: The regulatory body should plan and conduct all the required licensing and oversight activities to be conducted during the licensing process, including siting, construction, commissioning and operation, consistent with the regulatory approach that was selected.

Action 35: The regulatory body should establish a consistent procedure for issuing, revising and revoking regulations and guides.

Action 36: The regulatory body should ensure that a full and comprehensive set of regulations and guides is in place for regulating construction, commissioning and operational activities at the appropriate time.

Action 37: The regulatory body should implement its programme for inspection and enforcement during construction including, as applicable, the design and manufacture of safety related components.

Action 38: The regulatory body should review and assess programmes to be implemented by the operating organization, as appropriate.

Action 43: All relevant organizations should seek to establish and maintain the confidence and trust of interested parties, including the public, on safety issues.

Action 44: All relevant organizations should continue to explain to interested parties the risks and benefits of the introduction of nuclear power and the measures taken to limit the risks.

Action 45: The regulatory body should communicate with interested parties about the licensing process, safety requirements and regulatory oversight.

Action 46: The operating organization and the regulatory body should communicate with interested parties about safety issues in construction and the commissioning programme.

Action 47: The operating organization and the regulatory body should maintain a transparent approach on safety issues with all interested parties involved in the construction programme, including suppliers, regarding the problems and difficulties encountered.

Action 56: The government should provide appropriate funding for the efficient and effective conduct of the regulatory body's activities.

Action 59: The regulatory body should verify, as part of the licensing process, that the operating organization has sufficient financial resources.

Action 60: The government or the regulatory body should verify that a system for the funding of decommissioning activities, radioactive waste management, and spent fuel management including disposal is in place.

Action 67: The regulatory body should establish a framework for the qualification of technical services that are significant for nuclear safety.

Action 68: External support organizations should continue the recruitment of staff and the building of competence in safety related matters.

Action 69: All the relevant organizations should ensure clarity in specifying the roles and responsibilities of external support organizations.

Action 70: All the relevant organizations should make appropriate arrangements to avoid conflicts of interest when obtaining external support.

Action 71: The regulatory body and the operating organization should oversee the activities performed by their respective external support organizations and contractors, and should assess the quality of the services provided, in accordance with their management systems.

Action 78: The senior management of all the relevant organizations should provide effective leadership and effective management for safety to ensure a sustainable high level of safety and a strong safety culture.

Action 79: All the relevant organizations should continue the implementation of a management system that promotes the concept that requirements for safety shall be paramount within the organization, overriding all other demands.

Action 80: The operating organization and the regulatory body should ensure that the effectiveness of their management systems is monitored and measured, and that self-assessments as well as independent assessments are conducted regularly for continuous improvement.

Action 81: All the relevant organizations should ensure that appropriate arrangements for management of safety related knowledge (including record management and report management) and knowledge transfer are in place.

Action 82: All the relevant organizations should ensure that leadership and succession development programmes are in place to develop future leaders with a strong emphasis on safety.

Action 84: The regulatory body should review and assess the operating organization's programme on safety management.

Action 95: The operating organization, the regulatory body and external support organizations should ensure the availability of sufficient competent human resources for the efficient and effective conduct of all activities at the appropriate time.

Action 97: The regulatory body should review and assess the operating organization's programme with regard to human resources management.

Action 98: The government should continue promoting the development of education in the nuclear field so as to continue providing a flow of qualified people in areas relevant to safety.

Action 104: Research centres and other relevant organizations should focus their research on the features and safety aspects of the nuclear power plant that will be constructed, including features and aspects specific to the actual plant site.

Action 129: The regulatory body should review and assess the operating organization's programmes for waste management and spent fuel management and for decommissioning, and should verify their compliance with the regulatory requirements.

Action 131: The regulatory body should implement its regulatory oversight programme for facilities and activities for radioactive waste management and spent fuel management.

Action 132: All the relevant organizations should be aware of international efforts and progress with regard to the disposal of radioactive waste.

Action 140: The regulatory body should establish detailed regulations on emergency preparedness and response.

Action 142: The government and the regulatory body should develop and implement emergency preparedness programmes at the local, national and international levels.

Action 143: The government and the regulatory body should establish arrangements for coordination between the emergency response plan of the nuclear power plant and the plans of the relevant national institutions that would be involved in emergency response.

Action 144: The regulatory body should review and assess the emergency programme and the emergency plans and procedures for nuclear power plants, and should verify compliance with the regulatory requirements.

Action 145: The government, the regulatory body and the operating organization should demonstrate emergency response capabilities by conducting appropriate exercises that include local authorities and local communities.

Action 182: The regulatory body should review and assess the safety documentation such as the safety analysis reports, and should verify the compliance of the design with regulatory requirements.

Action 184: The operating organization and the regulatory body should implement their respective processes to address modifications made to the design during construction and afterwards.

Action 185: The regulatory body should issue requirements on commissioning.

Action 188: The regulatory body should review and assess the commissioning programme, should verify compliance with requirements and should prepare a programme to oversee the commissioning of systems important to safety in the next phase.

Action 192: The regulatory body and the organizations in charge of the transport of radioactive material should fully implement the changes to the national requirements and arrangements for the transport of radioactive material in accordance with the plan in Phase 2.

Action 197: The regulatory body (possibly consisting of several authorities) should ensure that security regulations do not compromise safety and that safety regulations do not compromise security.

Action 199: All the relevant organizations should ensure that emergency preparedness and response plans in the fields of safety and nuclear security are complementary, coherent and well-coordinated among the entities involved.

Action 200: The operating organization and the regulatory body should continue to promote safety culture and nuclear security culture in their respective organizations.

ANNEX 2

ACRONYMS & INITIALISMS

ABC	atomic, biologische und chemische (nuclear, biological and chemical defense)
ABWR	Advanced Boiling Water Reactor (GE-Hitachi and Toshiba)
AEP	Atomenergoprojekt
AES	Atomic Electric Station (Russian acronym)
Ag	silver
AKW	atomkraftwerk (German word for nuclear power plant, NPP)
AMEC	AMEC plc, a British multinational consultancy, engineering & project management company
AMRAAM	Advanced Medium-Range Air-to-Air Missile (also known as AIM-120)
AP1000™	Advanced Passive 1000 MWe PWR (trademark of Westinghouse Electric Company, subsidiary of Toshiba)
APR+	Advanced Pressurized Reactor plus (Generation III+ PWR, KEPCO)
APR-1000	Advanced Pressurized Reactor 1000 (Generation III PWR, KEPCO)
APR-1400	Advanced Pressurized Reactor 1400 (Generation III PWR, KEPCO)
ARAO	Agencija za Radioaktivne odpadke (Agency for Radioactive Waste Management, Slovenia)
ARIUS	Association for Regional and International Underground Storage
ASN	Autorité de Sûreté Nucléaire (French acronym, nuclear regulatory authority)
ASTEC	Accident Source Term Evaluation Code (IRSN, France)
ATMEA1	Generation III pressurized water reactor design produced by a joint venture of Mitsubishi and AREVA
B_4C	boron carbide
BBM e.U.	Austrian nuclear safety and licensing consultancy
BEPU	best estimate plus uncertainty
BMLFUW	Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (Austria; also known as Lebensministerium)
BWR	boiling water reactor
CANDU™	Canadian Deuterium Uranium (trademark of CANDU Energy, Inc., subsidiary of SNC-Lavallin)
CBRN	chemical, biological, radiological & nuclear
CCGT	combined cycle gas turbine
Cd	cadmium
ČEZ	ČEZ a.s., Czech utility and holding company
CGN	China General Nuclear Power Group
CGNPC	China Guangdong Nuclear Power Company
CIA	Central Intelligence Agency (United States)
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Technológicas (Spanish research organization)
CNS	Convention on Nuclear Safety
CNSC	Canadian Nuclear Safety Commission
CO_2	carbon dioxide
COL	Combined Operating License
COVRA	Centrale Organisatie Voor Radioactief Afval (Central Organisation for Radioactive Waste, the Netherlands)
CSN	Consejo de Seguridad Nuclear (Spanish nuclear regulatory authority)
CSS	Commission on Safety Standards (IAEA)

CTBTO	Comprehensive Test Ban Treaty Organization
DECC	Department of Energy and Climate Change (United Kingdom)
DIMNP	Dipartimento di Ingegneria Meccanica, Nucleare e della Produzione (Department of Mechanical, Nuclear, and Production Engineering, University of Pisa, Italy)
DSA	Decommissioning Safety Appraisal (IAEA)
DSARS	Design and Safety Assessment Review Service (IAEA)
DTI	Department of Trade and Industry (United Kingdom)
Dy	dysprosium
EC	European Commisson; also Emergency Condenser
ECURIE	European Community Urgent Radiological Information Exchange
EDAM	Ekonomi ve Dış politika Araştırma Merkezi (Turkish acronym for the Centre for Economics and Foreign Policy Studies)
EdF	Electricité de France
EHRO-N	European Human Resources Observatory for the Nuclear Energy Sector (JRC)
EHNUR	Evaluation of a Hypothetical Nuclear Renaissance
EIA	Environmental Impact Assessment
EMUG	European MELCOR User Group
EnBW	Energie Baden-Württemberg AG (German energy company)
ENCO	Enconet
ENEA	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (Italian acronym for the National Agency for New Technologies, Energy and the Environment)
ENEN	European Nuclear Educatiion Network
ENS	European Nuclear Society
ENSREG	European Nuclear Safety Regulators Group
ENSTTI	European Nuclear Safety Training and Tutoring Institute
ENTSOE	European Network of Transmission System Operators for Electricity
E.On	International energy company headquartered in Dusseldorf, Germany
EPA	Environmental Protection Agency (United States)
EPR	Evolutionary Pressurized Reactor
EPREV	Emergency Preparedness Review (IAEA)
EPZ	Emergency Planning Zone; also a Dutch electric utility company, Elektriciteits Produktiemaatschappij Zuid-Nederland
ERDO	European Repository Development Organisation
ERMSAR	European Review Meeting on Severe Accident Research (established by SARNET)
ERS	Emergency Response Service (IAEA)
ESP	Early Site Permit
ESBWR	Economic Simplified Boiling Water Reactor
EU	European Union
EU-ABWR	Toshiba ABWR design for EU countries
EURATOM	European Atomic Energy Community
EVN	Energieversorgung Niederösterreich AG
FANC	Federaal Agentschap voor Nucleaire Controle
FORATOM	European Atomic Energy Forum
FZJ	Forschungszentrum Jülich (Germany)
GDF	Gaz de France
GDP	Gross Domestic Product
GE	General Electric
GNSSN	Global Nuclear Safety and Security Network (IAEA)
GSG	General Safety Guide (IAEA)
GSR	General Safety Requirement (IAEA)
HLW	High Level (Radioactive) Waste
Hz	Hertz (same as rpm)

IAEA	International Atomic Energy Agency
IBRAE	Nuclear Safety Institute of the Russian Academy of Sciences
IFNEC	International Framework for Nuclear Energy Cooperation
In	indium
INRA	International Nuclear Regulators Association
INSARR	Integrated Safety Assessment for Research Reactors (IAEA)
INSServ	International Nuclear Security Advisory Service (IAEA)
IPPAS	International Physical Protection Advisory Service (IAEA)
IPSAR	International Probabilistic Safety Assessment Review (IAEA)
IRIS	International Reactor Innovative and Secure
IRRS	International Regulatory Review Service (IAEA)
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (France)
ISCA	International Safety Culture Assessment (IAEA)
JRC	Joint Research Centre) (European Commission)
KEPCO	Korea Electric Power Company
KERENA	an advanced passive boiling water reactor (AREVA)
KfD	Kernphysiches Dienst (Netherlands nuclear regulatory authority)
kg	kilograms
KTA	Kerntechnischer Ausschuss (Germany)
KTH	Kungliga Tekniska högskolan (Sweden)
kWe	kilowatts electric
kWh	Kilowatt-Hour
KWU	Kraftwerk Union
LEI	Lithuanian Energy Institute
LILW	Low and Intermediate Level (Radioactive) Waste
MAAP	Modular Accident Analysis Program
MDEP	Multi-national Design Evaluation Program
MELCOR	severe accident progression code developed for the NRC by Sandia National Laboratories
MIT	Massachusetts Institute of Technology
MoDeRn	Monitoring Developments for Safe Repository Operation and Staged Closure (EC 7th Framework Research Programme)
MWe	Megawatts Electrical
MWt	Megawatts Thermal
NEA	Nuclear Energy Agency (OECD)
NEK	Nuclearna Elektrarna Krško; also NEK EAD, the National Electric Company of Bulgaria
NERS	Network of Regulators of Countries With Small Nuclear Programmes
NES	Nuclear Engineering Seibersdorf
NIRAS	Nationale Instelling voor Radioactief Aval en verijkte Splijtstoffen (Dutch acronym for the Belgian National Agency for Radioactive Waste and enriched Fissile Material)
NKS	Nordic Nuclear Safety Research
NPCIL	Nuclear Power Corporation of India, Limited
NPP	nuclear power plant
NRA	Nuclear Regulatory Agency
NRC	Nuclear Regulatory Commission (United States)
NRG	Nuclear Research and consultancy Group (Netherlands)
NUBIKI	Nukleáris Biztonsági Kutatóintézet (Hungarian Nuclear Safety Research Institute)
NUSSC	Nuclear Safety Standards Committee (IAEA)
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation & Development
ONR	Office for Nuclear Regulation (United Kingdom)
ORNL	Oak Ridge National Laboratory
OEW	Zweckverband Oberschwäbische Eklektrizitätswerke

ÖKG	Österreiche Kerntechnische Gesellschaft
ONDRAF	Organisme National des Déchets RAdioactifs et des matiéres Fissiles enrichies (French acronym for the Belgian National Agency for Radioactive Waste and enriched Fissile Material)
ORPAS	Occupational Radiation Protection Appraisal (IAEA)
OSART	Operational Safety Assessment Review Team (IAEA)
ÖZSV	Österreichischer Zivilschutz Verband (Austrian Civil Protection Association)
PGA	Peak Ground Acceleration
PHWR	Pressurized Heavy Water Reactor
PPPT	Passive Pressure Pulse Transmitter
PROSPER	Peer Review of Operational Safety Performance Experience (IAEA)
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
PURAM	Public Limited Company for Radioactive Waste Management (Hungary)
PWR	Pressurized Water Reactor
QA	quality assurance
RAMP	Review of Accident Management Program (IAEA)
RASSC	Radiation Safety Standards Committee (IAEA)
RBMK	Russian acronym for a boiling light water cooled, graphite moderated reactor (Reaktor Bolschoi Moschtschnosti Kanalny)
RegNet	International Nuclear Regulatory Network (IAEA)
rpm	revolutions per minute (same as Hertz)
SAC	Safety Assessment Capacity and Competency Review (IAEA)
SAPIERR	Support Action: Pilot Initiative on European Regional Repositories (EC 6th Framework Research Programme)
SAR	Safety Analysis Report
SCART	Safety Culture Assessment Review Team
SE/ENEL	Slovenské Elektrárne/ENEL
SEA	Strategic Environmental Assessment
SEED	Site & External Events Design Review Service (IAEA)
SF-1	Fundamental Safety Principles (IAEA safety standard)
SMA	Seismic Margin Analysis
SMART	System-Integrated Modular Advanced Reactor (Republic of Korea, Korea Atomic Energy Research Institute)
SMR	Small Modular Reactor
SSG	Specific Safety Guide (IAEA)
SSM	Strål säkerhets myndigheten (Swedish Radiation Safety Authority)
SSR	Specific Safety Requirement (IAEA)
STUK	Säteilyturvakeskus (Finnish Radiation and Nuclear Safety Authority)
TiO	titanium oxide
TRANSaS	Transportation Safety Assessment Service (IAEA)
TRANSSC	Transportation Safety Standards Committee (IAEA)
TSO	Technical Support Organization
TÜV	Technischer Überwachungs-Verein
TVEL	Russian nuclear fuel cycle company, subsidiary of Atomenergoprom
ÚJD	Úrad Jadrového Dozoru (Slovak nuclear regulatory authority)
UNEP	United Nations Environment Program
VLEEM	Very Long Term Energy Environment Model
VUJE	Slovak company (established in 1994 from the former Nuclear Power Plant Research Institute)
VVER	Russian acronym for PWR (Vodo-Vodyanoi Energetichesky Reactor)
WANO	World Association of Nuclear Operators
WASSC	Waste Safety Standards Committee (IAEA)

WENRA	Western European Nuclear Regulators Association
WNA	World Nuclear Association
WSA	Waste Safety Appraisal (IAEA)
yr	year
ZAMG	Zentral Anstalt für Meteorologie und Geodynamik (Central Institution for Meteorology and Geodynamics, Austria)