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# NPP Lithuania

## Expert Statement to the EIA Report

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**University of Natural Resources**
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**Institute of Meteorology (BOKU-Met)**

ENERGIE
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# CONTENT

# 1 INTRODUCTION

The company Lietuvos Energija AB plans to construct a new nuclear power plant (NPP). The new NPP will be constructed next to the Ignalina NPP, which is presently in operation and located in the north-east of Lithuania on the south bank of Drūkšiai Lake, six kilometers from the town of Visaginas and close to the border of Latvia and Belarus.

Two RBMK units form the Ignalina NPP. Each reactor unit has a net electrical capacity of 1,300 MW. Operation of these reactors was started in 1977 and 1978, respectively. Unit 1 was closed at the end of 2004, unit 2 is scheduled to be shutdown at the end of 2009.

The new NPP shall replace Ignalina NPP unit 1 and 2. The electric capacity of the new NPP shall be 3,400 MWe. In the EIA Report several reactor options are presented and it is stated that depending on the selected option 2 to 5 reactor units will be built.

Finalization of the new NPP is planned for 2015, operation time will be approximately 60 years or more. Decommissioning will be done in 20 to 100 years.

With reference to the ESPOO-Convention, the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management has expressed its interest to take part in the transboundary EIA. The Austrian Institute of Ecology was assigned by the Austrian Ministry of Agriculture and Forestry, Environment and Water Management the job of composing an Expert Statement on the EIA Program for the new NPP. In the second stage of the EIA process, the Austrian Institute of Ecology in cooperation with Dr. Helmut Hirsch, BOKU-Met and E7 Energie Markt Analyse GmbH were engaged by the Austrian Federal Environmental Agency to assess the Environmental Impact Assessment Report.

This expert statement contains a discussion of the proposed project as described in the EIA Report with regard to

- the safety of the nuclear options,
- the accident analysis with a focus on airborne transboundary emissions and the potential impact to Austria.
- the justification of the project including an energy economic consideration.

# 2 EINLEITUNG

Das Unternehmen Lietuvos Energija AB plant den Bau eines neuen Kernklraftwerkes (KKW). Das neue KKW soll in unmittelbarer Nähe des KKW Ignalina errichtet werden, das derzeit in Betrieb ist und am Südufer des Druksiai See's, sechs Kilometer von der Stadt Visaginas nahe der Grenze zu Lettland und Weißrussland liegt.

Das KKW Ignalina besteht aus zwei RBMK-Reaktoren, mit einer elektrischen Leistung von 1.300 MW. Die beiden Reaktorblöcke gingen 1977 bzw. 1978 in Betrieb. Block 1 wurde Ende 2004 stillgelegt, Block 2 soll Ende 2009 folgen.

Das neue AKW soll die beiden Blöcke Ignalina 1 und 2 ersetzen und eine el. Leistung von 3.400 MW haben. Im UVP-Bericht werden verschiedene Reaktoroptionen vorgestellt und es wird festgehalten, dass je nach Auswahl 2 bis 5 Reaktorblöcke gebaut werden.

Die Fertigstellung des neuen KKW ist für 2015 geplant, die Betriebsdauer soll 60 Jahre oder mehr betragen. Die Dekommissionierung des KKW wird 20 bis 100 Jahre dauern.

Im Rahmen der Espoo-Convention hat des österreichische Ministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW) Interesse an der Teilnahme an der grenzüberschreitenden UVP bekundet. In der Scoping-Phase hat das Österreichische Ökologie-Institut im Auftrag des BMLFUW eine Fachstellungnahme erarbeitet. Im eigentlichen Verfahren erging der Auftrag des Ministeriums zur Ausarbeitung der Fachstellungnahme an eine Arbeitsgemeinschaft, bestehend aus dem Österreichischen Ökologie-Institut, Dr. Helmut Hirsch, BOKU-met und e7 Energie Markt Analyse GmbH.

Die Fachstellungnahme enthält eine Diskussion des vorgeschlagenen Projekts, wie es im UVP-Bericht beschrieben ist in Hinblick auf

- die Sicherheit der KKW-Optionen,
- die Unfallanalyse mit einem Fokus auf luftgetragene grenzüberschreitende Emissionen und deren mögliche Auswirkungen auf Österreich,
- die Begründung für das Projekt einschliesslich energiewirtschaftlicher Betrachtungen.

# 3 SUMMARY

## 3.1 Description of the project

This part of the EIA report contains the general information about the proposed project, which is presented in the introduction of this expert statement. Along with that a list of answers to the comments and questions of parties in the international EIA procedure is presented. Alternatives to the site for the new NPP and for the cooling water system are discussed.

Most of the questions that were raised by Austria in the scoping phase were answered in the EIA report; some of them lacked the details requested. But there is one relevant shortcoming: No concrete project is presented for the new NPP.

**Instead of one specific project the EIA report presents eleven very different options. According to the Austrian understanding of the EIA directive, an EIA Report should present one specific project, and discuss alternatives to this preferred project.**

### Management of nuclear waste

Amounts and types of radioactive and non-radioactive waste are listed in chapter 6 of the EIA Report. A new solid waste management facility will be commissioned in 2010, which will be used for solid radioactive waste from Ignalina NPP, but shall also accept operational waste from the new NPP. The site for a near-surface repository for LILW has already been chosen. For liquid radioactive waste a new treatment facility will be built.

Today there are no interim storage capacities available for future spent fuel, and no plans for the construction of new interim storage facilities are discussed in the EIA Report. Also, a concept for long-term storage of spent fuel is missing in the EIA Report. Thus the management of spent fuel and HLW is not described adequately and it is questionable whether the EIA Report is in this respect in accordance with the ESPOO-Convention and the EIA Directive of the EU (COUNCIL DIRECTIVE 85/337/EEC).

## 3.2 Need for new power production capacities

The EIA report justifies the need for new capacities in consequence of closing down Ignalina NPP by the lapidary statement that otherwise – i.e. in the case of the so-called zero option – the county's energy security would not be ensured. A simplistic top down forecast of the electricity demand by 2025 is presented to illustrate this statement.

A more comprehensive analysis (see chapter 5), however, shows that the need for the proposed NPP with a capacity of at least 1,600 $MW_{el}$ up to the year 2025 is questionable because of the following reasons:

- The yearly electricity energy consumption has fluctuated considerably between 1996 and 2006. The driving forces behind these fluctuations remain unclear and can be only forecasted on the basis of a comprehensive sectoral and technology-oriented bottom-up analysis.

- Due to the adoption of the EU Directive on Energy Efficiency and Energy Services Lithuania is obliged to increase its efforts in improving the energy efficiency of its economy. Therefore we have to expect a number of measures facilitating power savings in different sectors, which will at least contribute to a limitation of the increasing trends in electricity demand.
- Since the proposed NPP project for economic and technical reason delivers base load electricity, it is important to differentiate between base load, medium load and peak load demand. Due to the structural changes in the Lithuanian economy we may expect a more dynamic development of the medium and peak load demand as compared to the base load demand. It is therefore questionable whether the proposed NPP will be able to operate at full capacity if the base load demand lags behind a potential overall increase of electricity demand.
- The Baltic power system was designed as an integral part of the wider Soviet system. As a result, many key assets serve for the wider region leading to overdeveloped infrastructure from the perspective of the single markets. Even after the closure of Ignalina NPP there actually remains a comfortable surplus in the system on the capacity level (MW) as well as on the level of potential production (GWh). Given very intensively in-creasing demand patterns, we could expect a production gap in 2015 at the earliest; assuming a less dynamic demand development, the installed capacity will be sufficient until 2025. In any case the planned construction of transmission lines to Poland and Scandinavia will drastically reduce the risk of capacity shortcomings.

**In conclusion it can be said that the EIA report does not clearly demonstrate the need for new electricity production capacities in Lithuania. For this purpose the following questions would require a traceable answer:**

- **How will structural changes, energy efficiency policy and economic development impact on the development of the yearly electricity consumption in the different demand sectors and sub-segments by 2025?**
- **What are the main influence factors on base load demand and how are they assumed to develop by 2025?**
- **How will the increasing regional integration of the Lithuanian electricity system impact on the need for new constructed base load power plants?**

## 3.3 Cost effectiveness of the NPP project

The EIA report declines any consideration about the economic viability and cost effectiveness of the proposed NPP project by arguing that the NPP project company has been established exclusively for constructing and operating a new NPP in Lithuania and it has, therefore, no mandate to occupy itself with any other kind of power plants.

This argument cannot be accepted. The EIA also has to address the issue of economic meaningfulness and cost effectiveness of the proposed NPP project. Otherwise ecological damage would be hazarded even in the case of a misinvestment.

As described in the following a number of reasons exist as to why the proposed NPP project seems questionable from an energy economic point of view.

For more details see chapter 6.

### Cost risks inherent to generation III reactors

There exists practically no experience with new construction of generation III reactors. The little experience that is available (EPR in Olkiluoto and Flamanville) indicates considerable cost risks in the following areas:

- construction cost overrun;
- construction time overrun.

Furthermore there is no reliable data available about O&M costs (excluding fuel costs), operating performance and potential backfitting costs, simply because no generation III reactor is as of yet in operation.

### Comparison to competitive options

It was not the mandate of this assessment to catch up with the shortcomings of the EIA report by presenting a comprehensive Least Cost Analysis of power supply extension in Lithuania. But in any case conclusions by analogy may be driven from similar cases – e.g. in Switzerland or in Germany. Preliminary calculations on a full cost basis[1] support the assumption that a newly constructed NPP has a chance to be cost effective compared to other power plant options only under very specific framework conditions: Overnight construction cost of maximum 2.000 to 2.200 €/kWel; O&M cost (except possible cost for backfitting) in a range up to € 70/kW$_{el}$a; avoidance of construction time overrun; reliable operation with at least 7.500 h operation time per year; low interest rate of 4–5%.

As described above all these assumptions by themselves are risky; assuming these conditions as a package is highly risky, particular for generation III NPP where basically no practical construction and operation experience exists. The most relevant competitors are coal power plants and gas-fired CCGT resp. CHP integrated in heat delivery systems. Even when allowing for $CO_2$ emission certificate costs of 30–40 €/t and considerably increasing fuel prices, these options are frequently more cost efficient than the newly constructed NPP. In case of higher $CO_2$ emission costs one can expect that the CCS technology will gain additional attractiveness in the medium term.

When proceeding to an **electricity system level**, additional aspects show up that will further deteriorate the cost effectiveness of the proposed NPP by reducing its probable running time which is a crucial factor in this context.

Firstly it has to be emphasised that in Lithuania itself several “must-run” power plants will be implemented with high probability within the next five to ten years. Due to technical reasons “must-run” power plants are always first in the merit-order irrespective of their actual variable cost – and thus reduce the runtime of the other capacities:

- An important source of “must-run” is the district heating sector, where the National Energy Strategy 2007 allows for a considerable extension of power produced from cogeneration in the district heating sector up to an amount of at least 35% of the total power balance by 2020. Several bigger CHP projects with a total

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[1] Full cost comparisons come up with more favourable results for a base load NPP than calculations on a system level that take into account the country-specific load profiles.

capacity of 400 $MW_{el}$ are explicitly mentioned in the Energy Strategy 2007. But with a total heat capacity of over 1,300 MWth the total potential for CHP can be assumed to be considerably higher than that. In addition some potential for CHP in the industrial sector may be assumed.

- Following the European Directive on electricity production from renewables, Lithuania has fixed a target of 7% share of renewable electricity by 2010, which represents a short-term increase of 4%. Furthermore it has to be expected that higher targets will be adopted for the period from 2010 to 2020. In the field of renewable electricity production Lithuania has considerable potential mainly with respect to biomass and wind.

Secondly it is important to state that the integration of the Baltic electricity system to the Nordic and the UCTE systems will be enforced by two new transmission lines to Poland and Scandinavia which are under preparation. Together with the already existing strong integration to the Russian system (including Kaliningrad), this will add to a much easier access to base load power from this market – and thus to more competition with imported base load power.

**Specific financing risks in a liberalised power market**

Nuclear power is amongst the most capital intensive power generation technologies with a share of at least 50% of capital cost in total power production cost. A competitive liberalised market is inevitably characterised by higher risk for the investor and therefore by higher interest rates than the regulated market model. Therefore, capital-intensive technologies face a significant disadvantage in the liberalised market.. In the case of NPP specific risk factors – such as the complex nature of the project, the prototype character and the long-term cost risks related to decommissioning waste management – add up to a risk uplift to the interest rate which is inherent only to NPP projects. This additional financing risk can be reduced only by an engagement of the state in the project – e.g. by means of a cap for decommissioning and waste management costs or by loan guarantees. It has to be underlined, however, that in a liberalised market, there exists strict regulation for government aid and therefore only limited potential for government support.

**In conclusion it has to be highlighted that the EIA report does not demonstrate the economic meaningfulness and cost effectiveness of the proposed NPP project. Therefore it is indispensible to present a cost comparison of the proposed NPP project to competitive options – at least on a full cost basis, but preferentially on a system least cost basis – reflecting the specific cost and financing risks inherent to generation III reactors.**

## 3.4 Reactor types considered for the new NPP

The new NPP shall replace Ignalina NPP unit 1 and 2. The electric capacity of the new NPP shall be up to 3,400 MWe. In the EIA Report eleven different reactors are presented, which are offered by Areva, General Electric-Hitachi, Westinghouse-Toshiba, Atomic Energy of Canada Ltd., Mitsubishi Heavy Industries and Atomstroyexport.

Nucleonics Week reports that a spokesman for the company Lietuvos Energija AB charged with organizing the investment stated in a recently published interview (NW 08/09/25) that four Western reactor vendors are being considered to supply the new Ignalina NPP: Areva, Westinghouse, General Electric Hitachi, and Atomic Energy of Canada Ltd. Even if this were confirmed by the responsible authorities of Lithuania, still there would be a considerable number of reactor options to be evaluated.

**Safety standards**

The EIA report provides a description of the basic principles of a NPP in general, and of three basic design types. A detailed specification of technical requirements is not presented in the EIA Report, since such specifications will be developed separately as the project proceeds. But the European Utility Requirements (EUR) are described as a principal source of technical requirements for the new NPP project.

It is made clear that in any case, the new NPP will have to meet the following requirements regarding core damage frequency (CDF) and large release frequency (LRF) by a significant margin: CDF <1E-5/yr, LRF <1E-6/yr. These probabilistic safety targets roughly correspond to those recommended by the IAEA (INSAG 1999). It is stated that new plants have to meet these requirements “by a significant” margin; however, it is not specified what would constitute such a margin. The plants must be designed to withstand external threats and terrorism, including the collision with a large passenger airplane.

Safety standards for new NPPs appear to be in a very early stage of development in Lithuania. The development of standards for new plants in parallel with the development of the project itself could potentially lead to problems due to time pressure for the compilation of new standards. There is also a risk that the standards under development will be tailored to suit the project.

**A more detailed description of the procedure to develop the safety standards for new NPPs would be of interest, including an explanation of how this procedure will be timed in relation to the new NPP project, and how it will interact with the development of the project.**

### 3.4.1 Reactor types

For each reactor type, development history and basic design features are briefly described in the EIA report. Core damage frequency (CDF) and large release frequency (LRF) are provided in most cases, as well as information on certification, efficiency, enrichment, burn-up, MOX capability and spent fuel arisings.

The description of the various reactor types in the EIA Report is fairly uniform; however, in some cases data are missing.

*Table 1: Overview of information*

| type | EPR | SWR-1000 | ABWR | ESBWR | AP | AP 1000 | CANDU 6 | ACR-1000 |
|---|---|---|---|---|---|---|---|---|
| manufacturer | AREVA | | GE – Hitachi | | Westinghouse | | AECL | |
| el. capacity | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| constr. time | ✓ | ✓ | ✓ | ✓ | X | ✓ | X | ✓ |
| efficiency | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| enrichment | ✓ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ |
| burnup | ✓ | ✓ | | ✓ | X | X | ✓ | X |
| fuel/yr | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| certification | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X | X |
| CDF | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| LRF | ✓ | ✓ | ?? | X | ✓ | ✓ | ✓ | X |

*(X = missing, ✓ = provided)*

No numbers are provided regarding the expected availabilities and costs of the various candidate reactor types. Cost overruns must be expected for new reactor types with little or no experience in cinstruction. Economic pressure and pressure of time could furthermore lead to problems at the beginning of the operating phase, lowering availability. Any estimate could only be highly speculative.

An evaluation and comparison of the numbers as provided in the EIA Report leads to the observations that CDF varies widely among reactor types – by a factor of almost 200. However, the relevance of the different CDF values for the assessment of different reactor types is not discussed in the EIA Report.

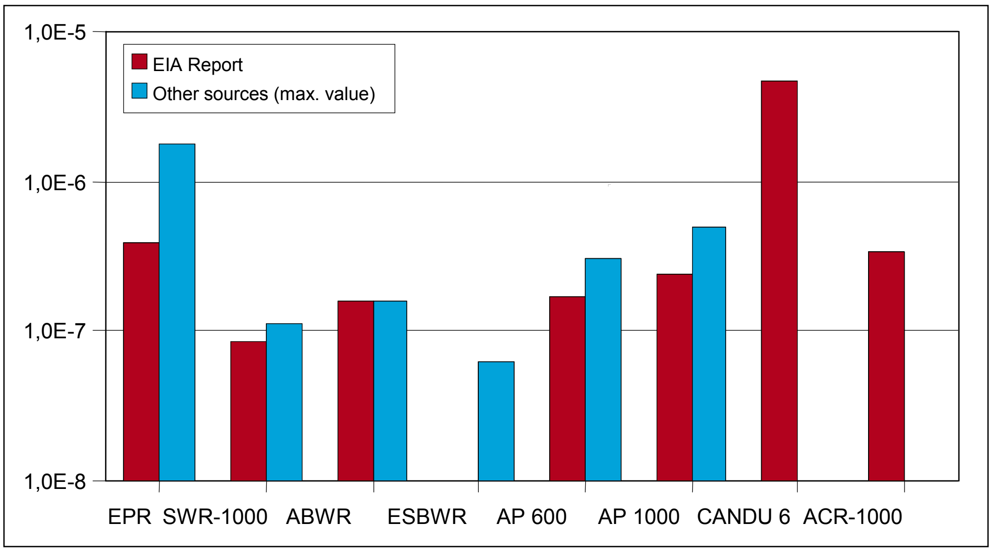

*Figure 1: Core damage frequency as reported in the EIA Report compared to other sources.*

**The synopsis of PSA results with their high variations and uncertainties (and possibly, inconsistencies) shows that it is not appropriate to rely too strongly on probabilistic criteria. The main criteria for the assessment of the reactor types should be deterministic.**

**A detailed presentation of the PSA results of the candidate reactors would be of interest (including the contributions of different events and plant states), as well as a discussion of their limitations and the bandwidths of their uncertainty. With this background, the differences in the results as indicated above should be discussed and assessed.**

**The overall importance of probabilistic and deterministic requirements for evaluating reactor designs and the relationship of the two approaches should also be explained.**

The candidate reactor types span a broad spectrum ranging from reactors with a basically tested design and only a few new features, to new, largely untried designs with many new features. However, there is no or very little practical experience for most reactor types.

Some reactor types rely mostly on active safety systems, some on passive systems; some on a combination of both.

It is generally regarded as advantageous if a reactor type depends more on passive rather than active safety systems since technical failures as well as human errors play a considerably smaller role in case of passive systems.

The concept of in-vessel cooling of molten core seems to be more promising and not beset with as many problems as ex-vessel cooling. In-vessel cooling has already been implemented as severe accident management measure at the Loviisa NPP in Finland. However, the chances of success of in-vessel cooling decrease the larger the capacity of a plant.

## 3.5 Accident analysis

In the chapter ”Risk Analysis and Assessment” of the EIA report presents a classification of events according to their probability of occurrence (PO) and their potential consequences. In this section the hazards of DBA and BDBA sequences are discussed shortly. The classification in table 10.2.3 does not distinguish between low frequencies of occurrence: all incidents with a frequency of occurrence below 1E-3/yr are rated as „improbable“. This is in contrast to the international practice. IAEA Guides, the EUR, the Finnish and also the Lithuanian nuclear regulations distinguish probabilistic safety targets of much less probability of occurrence as CDF and LRF.

It would be more instructive to present more detailed information from safety reports and PSAs which give an adequate illustration of the radiation hazard instead of a ranking which may be adequate for less hazardous industrial activities.

### Severe accident source term

The source term chosen as representative for a severe accident of 100 TBq Cs-137 and 1,000 TBq I-131 in a “Generation III” reactor by the EIA Report is not justified by any arguments. In Finnish regulation, the 100 TBq Caesium release is set as the limit for radiation protection. A large release (exceeding this limit) should have a probability of occurrence <5.0 E-7/yr.

PSA results for the EPR indicate that 9% of all core damage scenarios lead to late containment failure and 6% to early containment failure. These are the accidents relevant for the assessment of transboundary impacts. The release rates of such accidents are in the range of 2% to 20% for iodine and caesium. Even a release rate of only 1% would give more than 1,000 TBq Cs-137 and 10,000 TBq I-131, respectively, if the source term is based on the core inventory of the APWR given in the EIA report. This shows that the source term assumed for a severe accident in the EIA report is rather low for the investigation of severe accident consequences.

For the Austrian evaluation of transboundary impacts a release of 5% of the Cs-137 core inventory of 714 PBq given by the EIA report was assumed, which is a release of Cs-137 of 35.5 PBq. We consider the 5% release rate as a not too conservative, since a worst case release could be higher.

## Investigations of long-range consequences

The EIA Report contains maps of the 98th percentile of various radiological parameters, such as ground contamination and different doses, derived from dispersion model simulations of 730 cases with day-time and 730 cases with night-time releases. Thus, the upper 2% whose lower boundary is given on the maps are comprised of ca. 2 x 15 cases. These maps have been constructed for the LOCA DBA and a severe accident. The model simulations have been carried out with the SILAM system developed by the Finnish Meteorological Institute (http://silam.fmi.fi). The model was run with meteorological data from the ECMWF operational archive for the years 2001 and 2002.

It is appreciated that the authors of the EIA report present this impact analysis of accident emissions. This analysis is better than in most other comparable EIA reports, both with respect to the degree of realism of the model and to the fact that meteorological conditions are sampled that really occurred. Nevertheless we found that further details of the model setup are not provided.

The EIA authors argue that the 98th percentile and not the maximum (i.e. the 100th percentile) should be used because the latter is too sensitive to statistical variability, which is of course true. However, as is visible in the results, even the 98th percentile maps exhibit a good deal of statistical fluctuations. The results presented in the EIA report clearly show that inside these highest 2% there is still a big variability, or in other words, that the worst case – the maximum contamination – will be much higher than the 98th percentile.

## Austrian evaluations

The method used for the evaluation of potential impacts to Austria due to a severe accident at the proposed new Lithuanian NPP is based on dispersion calculations made with the Lagrangian particle dispersion model FLEXPARTin the RISKMAP project. In this project, 88 cases during the year 1995 were studied. Then the total (wet and dry) deposition of Cs-137 was evaluated over Europe. In Figure 2, we show the result for the worst case found among the 88 releases from the Ignalina NPP site, applying a source term of 5% from reactor inventory.

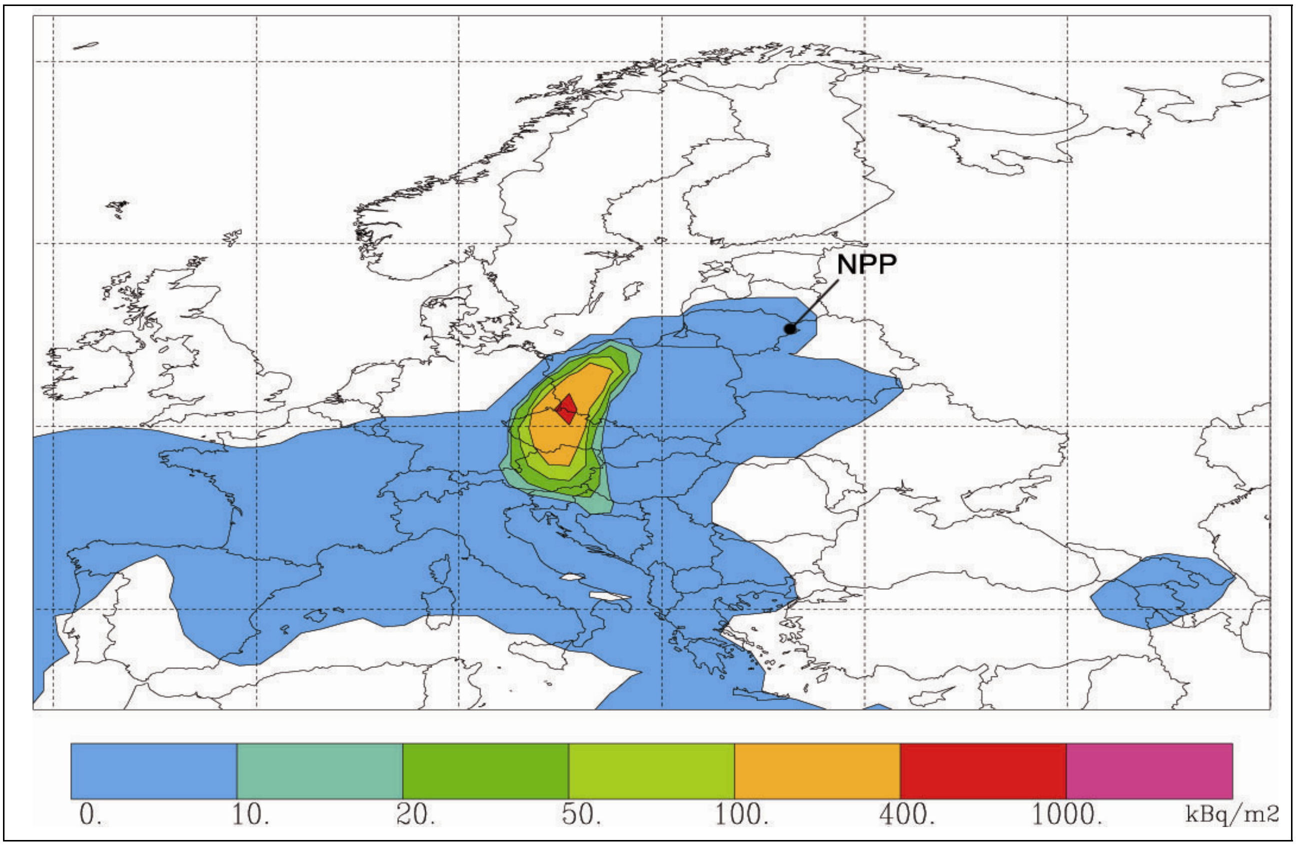

*Figure 2: Example of deposition of Cs-137over Europe resulting from a hypothetical severe accident in the new Ignalina NPP, assuming a release of 35.5 PBq in the hour after 1995-06-25 14:567. Output grid size is 1°. The outer border of the blue colour is at 0.1 kBq/m$^2$.*

The figure shows a detached region affected by the contamination extending through Poland, the Czech Republic, and Austria to the region of former Yugoslavia. In Austria, a deposition of 100 kBq/m$^2$ is exceeded in a large part of Upper Austria. At this contamination level, radiation protection measures for the population in Austria would be required. Sheltering or even stable Iodine prophylaxis could be ordered. During spring and summer food bans and restriction in stock farming could also be necessary if such a situation were to become reality.

From the Austrian point of view it is not justified to carry out the investigation of transboundary consequences of a severe accident by choosing an arbitrary emission limit as source term.

**First of all we recommend taking a deterministic approach in the safety analysis and finding out what emissions could occur. From published data on “Generation III” reactors, we have shown that containment failures cannot be excluded and even early containment failure could contribute to the large release frequency. The large releases – as far as published – indicate that releases of volatile aerosols could amount to between 2% and 20% of the core inventory, which is much more than the chosen limit of 100 TBq Cs-137.**

With respect to the climatological probability of contamination, possible accident related releases from the new NPP site are even more relevant for Austria than those from the Chernobyl site, and this given the background of the experience in the Chernobyl disaster which seriously affected Austria.

# 4 ZUSAMMENFASSUNG

## 4.1 Beschreibung des Vorhabens

Dieser Teil des UVP-Berichts enthält allgemeine Informationen zum vorgeschlagenen Projekt, welche in der Einleitung zu dieser Fachstellungnahme angeführt sind. Gleichzeitig enthält der Bericht eine Liste mit Antworten zu den Kommentaren und Fragen der Parteien im internationalen UVP-Verfahren. Die meisten der Fragen Österreichs aus der Scoping Phase werden im UVP-Bericht erörtert; manche allerdings ohne die gewünschten Details. Die meisten dieser Themen haben keine große Relevanz für die Bewertung grenzüberschreitender Auswirkungen und haben daher keine hohe Priorität für Österreich.

### Management des radioaktiven Abfalls

In Kapitel 6 des UVP-Berichts wird die Behandlung von nuklearen und nicht nuklearem Abfällen beschrieben. In 2010 soll eine neue Behandlungsanlage für feste radioaktive Abfälle aus dem KKW Ignalina in Betrieb genommen werden. Diese Anlage soll auch betriebliche Abfälle aus dem neuen KKW annehmen. Der Standort zur Errichtung eines oberflächennahen Endlagers für schwach- und mittelaktiven Abfall wurde bereits ausgewählt. Auch eine neue Behandlungsanlage für flüssigen radioaktiven Abfall wird geplant.

Derzeit gibt es keine Kapzitäten zur Zwischenlagerung zukünftiger abgebrannter Brennstäbe, und Pläne für deren Errichtung werden im UVP-Report nicht angeführt. Ebenso fehlt die Beschreibung des Konzepts für die langfristige Lagerung der abgebrannten Brennstäbe und der hochaktiven Abfälle. Da der Umgang mit hochaktivem Müll und abgebrannten Brennstäben im UVP-Bericht nicht ausreichend dargestellt ist, ist es fraglich ob der EIA-Bericht in dieser Hinsicht der ESPOO Konvention und der UVP-Richtlinie der EU entspricht.

## 4.2 Bedarf für neue Stromerzeugungskapazitäten

Der UVE-Bericht hält auf lapidare Weise fest, dass infolge der Schließung des KKW Ignalina im Fall einer Nichterrichtung neuer Kapazitäten (sog. Zero Option) die Versorgungssicherheit des Landes nicht mehr gewährleistet werden könnte. Als Beleg dafür wird lediglich eine vereinfachende Stromverbrauchsprognose bis 2025 vorgelegt.

Eine umfassendere Analyse zeigt, dass der Bedarf für das vorgeschlagene KKW mit einer Leistung von zumindest 1.600 $MW_{el}$ Projekt für den Zeitraum bis 2025 aus den folgenden Gründen als fraglich eingestuft werden kann:

- Der Jahresstromverbrauch hat zwischen 1996 und 2006 starke Schwankungen verzeichnet. Die Bestimmungsfaktoren hinter diesen Schwankungen bedürfen einer genaueren Analyse mittels eines nach Sektoren und Technologien differenzierten Bottom-up-Modells.
- Infolge der Umsetzung der EU-Richtlinie zu Energieeffizienz und Energiedienstleistungen wird Litauen seine Anstrengungen zur Verbesserung der Energieeffizienz quer über alle Sektoren hinweg merklich erhöhen müssen. Daher ist mit der Umsetzung einer Reihe Effizienz steigernder Instrumente zu rechnen, was ein allfälliges Wachstum des Stromverbrauchs zumindest merklich eindämmen wird.

- Da das vorgeschlagene KKW-Projekt aus ökonomischen und technischen Gründen ausschließlich Grundlast liefern kann, ist es wichtig zwischen der Nachfrage nach Grundlast, Mittellast und Spitzenlast zu unterscheiden. Aufgrund des Strukturwandels in der litauischen Wirtschaft ist davon auszugehen, dass sich die Mittel- und Spitzenlast dynamischer entwickeln wird als die Grundlast. Dies kann zu einer Einschränkung der KKW-Laufzeiten führen, wenn in Schwachlastzeiten die Grundlastnachfrage nicht ausreichend hoch ist.
- Das baltische Stromversorgungssystem wurde als Teil des sowjetischen Versorgungssystems errichtet. Dies hat aus Sicht der einzelnen Nachfolgestaaten zu einer überentwickelten Infrastruktur geführt. Daher ist davon auszugehen, dass auch nach einer Schließung des KKW Ignalina sowohl auf der Leistungs- als auch auf der Arbeitsebene eine ausreichende Reserve verbleibt. Bei äußerst stark steigender Nachfrage ist frühestens 2015 mit einer marginalen Erzeugungslücke zu rechnen, bei weniger Nachfragewachstum wäre das bestehende Erzeugungssystem bis 2025 ausreichend. In jedem Fall wären nach der Errichtung der geplanten Übertragungsleitungen nach Polen und Skandinavien Versorgungslücken praktisch auszuschließen.

**Zusammenfassend ist festzuhalten, dass der UVE-Bericht den Bedarf neuer Stromerzeugungseinheiten in Litauen nicht belegt. Für einen nachvollziehbaren Nachweis wären die folgenden Fragen zu beantworten:**

- **Wie werden sich die Strukturänderungen, die zu erwartenden energieeffizienzpolitischen Maßnahmen und die generelle wirtschaftliche und soziale Entwicklung auf die Jahresstromnachfrage bis 2025 differenziert nach Nachfragesektoren und Sub-Segmenten auswirken?**
- **Was sind die Haupteinflussfaktoren auf die Grundlastnachfrage und welche Annahmen werden hinsichtlich ihrer Entwicklung bis 2025 getroffen?**
- **In welcher Weise wird die zunehmende überregionale Verflechtung des litauischen Stromversorgungssystems Einfluss auf die Entwicklung der Nachfrage nach neu errichteten Grundlastkraftwerken haben?**

## 4.3 Wirtschaftlichkeit des vorgeschlagenen KKW Projekts

Der UVE-Bericht beschäftigt sich nicht mit der Wirtschaftlichkeit und Wettbewerbsfähigkeit des vorgeschlagenen KKW-Projekts mit der Begründung, dass die Projektgesellschaft ausschließlich zum Zweck der Errichtung und des Betriebs eines KKW gegründet wurde und sich daher gar nicht möglichen anderen Erzeugungsoptionen beschäftigen darf.

Diese Argumentation ist inakzeptabel. Eine UVP hat auch die Frage nach der Wirtschaftlichkeit und Kosteneffizienz des vorgeschlagenen Projekts zu stellen. Ansonsten würde man eine (unnötige) Umweltbelastung infolge einer Fehlinvestition in Kauf nehmen.

Im Folgenden wird eine Reihe von Gründen dargestellt, die die Wirtschaftlichkeit des dargestellten Projekts als fraglich erscheinen lassen.

### Kostenrisiken bei Generation III Reaktoren

Es bestehen praktisch keine Erfahrungen mit der Neuerrichtung von Generation III-Reaktoren. Die begrenzte Praxiserfahrung, die bereits vorliegt (EPR-Projekte in Olkiluoto und Flamanville) weist auf ein beträchtliches Kostenrisiko in den folgenden Bereichen hin:

- Überschreitung der budgetierten Fertigstellungskosten;
- Überschreitung bei der Fertigstellungzeit.

Darüber hinaus liegen keine verlässlichen Abschätzungen zur Zuverlässigkeit im Betrieb, zu den Betriebkosten – mit Ausnahme der Brennstoffkosten – sowie zu möglichen Nachrüstkosten vor, ganz einfach deshalb weil noch kein Generation III-Reaktor ans Netz gegangen ist.

### Wirtschaftlichkeitsvergleich mit anderen Erzeugungsoptionen

Es war nicht möglich, in dieser Stellungnahme die Mängel des vorlegten UVE-Berichts auszugleichen und eine umfassende Least Cost-Analyse von möglichen Kapazitätserweiterungen im litauischen Stromversorgungssystem vorzulegen. Es ist jedoch möglich Analogieschlüsse von ähnlich gelagerten Fragestellungen – z. B. für die Schweiz oder Deutschland – zu ziehen. Grobe Vergleichsrechnungen auf einer Vollkostenbasis – die üblicherweise Grundlastoptionen wie ein KKW bevorzugen, da das Lastprofil der Nachfrage nicht berücksichtigt wird – lassen darauf schließen, dass ein KKW nur unter ganz bestimmten Annahmen möglicherweise als wirtschaftliche Aufbringungsoption bezeichnet werden kann, und zwar: Baukosten (exkl. Bauzinsen) von max. 2.000 bis 2.200 €/kW$_{el}$; O&M-Kosten (ohne potentielle Nachrüstkosten) im Bereich von max. € 70/kW$_{el}$a; Vermeidung von Bauzeitverzögerungen; Betriebszeiten von mindestens 7.500 h/a; niedrige Zinssätze von 4–5 %.

Jede dieser Annahmen ist für sich genommen schon relativ riskant, im Paket erscheinen sie jedoch hochriskant, im Besonderen im Fall der geplanten Errichtung eines Generation III-Reaktors, für den nur äußerst begrenzte Praxiserfahrungen in der Errichtung und keinerlei Erfahrungen für den Betrieb vorliegen. Die relevantesten Mitbewerber sind Kohle- bzw. Gaskraftwerke – insbesondere wenn sie in Fernwärmenetze integriert sind. Auch unter der Annahme von Emissionszertifikatspreisen von 30 bis 40 €/t sowie weiter steigender Brennstoffkosten, sind diese Aufbringungsoptionen in der Regel kosteneffizienter als ein neu errichtetes KKW. Bei höheren Emissionszertifikatpreisen kann angenommen werden, dass sich mittel- und längerfristig die CCS-Technologie etablieren wird.

Wenn man in der Analyse weitergeht und das Versorgungssystem mit einbezieht kommen zusätzliche Aspekte hinzu, die beitragen, die Laufzeiten eines neu errichteten KKW zu beschneiden, was für die Wirtschaftlichkeit ein ausschlaggebender Faktor ist:

Zuerst ist zu betonen, dass in Litauen einige „Must-run“-Kraftwerke in Vorbereitung sind. „Must-run“-Kraftwerke werden aus technischen Gründen in der Kraftwerks-Merit-Order unabhängig von den aktuellen variablen Kosten immer vorgereiht – und reduzieren daher die Laufzeiten der anderen Kraftwerke:

- Am wichtigsten ist in diesem Zusammenhang der Fernwärmesektor, für den die Nationale Energiestrategie 2007 eine beträchtliche Ausweitung der Kraft-Wärme-Kopplung (KWK) auf ein Niveau von 35 % der gesamten Stromproduktion vorsieht. Einige größere KWK-Projekte mit einer Gesamtleistung von 400 MW sind in der Nationalen Energiestrategie explizit genannt. Es ist jedoch festzuhalten, dass man bei einem Fernwärmesektor mit einer Wärmeleistung von 1.300 $MW_{th}$ von einem beträchtlich größeren KWK-Potential ausgehen kann. Darüber hinaus ist anzunehmen, dass auch im Industriesektor Potentiale für die KWK-Nutzung gegeben sind.

- Im Rahmen der Umsetzung der gegenständlichen EU-Richtlinie hat Litauen bis 2010 einen Anteil von 7 % Stromproduktion aus erneuerbaren Energieträgern festgelegt, was eine kurzfristige Steigerung um 4 % bedeutet. Darüber hinaus ist davon auszugehen, dass für die Periode 2010 bis 2020 weitergehende Ziele festgelegt werden. In der Stromproduktion aus erneuerbaren Energieträgern weist Litauen beträchtliche Potentiale im Bereich der Biomasse sowie bei Wind auf.

Zum Zweiten ist festzuhalten, dass die weitere Integration des baltischen Elektrizitätssystems in das UCTE-Netz sowie mit Skandinavien durch zwei neue, in Planung befindliche Übertragungsleitungen – einerseits nach Polen und andererseits nach Skandinavien – deutlich verstärkt werden wird. Zusammen mit der bereits bestehenden starken Integration in das russische Elektrizitätssystem (einschließlich Kaliningrad), wird dies zu einem leichteren Zugang zu Grundlasterzeugungskapazitäten auf diesen Märkten führen – und damit auch zur Möglichkeit umfangreicherer Stromimporte.

### Besondere Finanzierungsrisiken in einem liberalisierten Strommarkt

KKW gehören zu den kapitalintensivsten Stromerzeugungstechnologien, mit einem Anteil von zumindest 50 % Kapitalkosten an den Gesamtgestehungskosten. In einem liberalisierten Wettbewerbsmarkt, der unausweichlich mit höheren Risiken für den Investor verbunden ist und damit zu höheren Zinssätzen führt, als dies in einem regulierten Markt der Fall wäre, sind kapitalintensive Erzeugungstechnologien benachteiligt. Im Fall eines KKW kommen noch besondere Risikofaktoren hinzu, die aus der Komplexität und dem überwiegenden Prototypcharakter des Projekts sowie aus langfristigen Risiken im Bereich des Rückbaus und Abfallmanagements resultieren. In Summe führt dies zu einem KKW-spezifischen Zuschlag bei den Zinssätzen, der nur durch ein staatliches Engagement im Projekt – z. B. durch eine Begrenzung der beim Investor verbleibenden Back-end-Kosten oder durch Kreditgarantien – reduziert werden kann. Es ist jedoch festzuhalten, dass in einem liberalisierten Markt staatliche Förderungen einer engen Regulierung unterliegen und daher die Möglichkeiten staatlichen Engagements zur Unterstützung von KKW-Projekten begrenzt sind.

**Zusammenfassend ist hervorzuheben, dass der UVE-Bericht die Wirtschaftlichkeit und Wettbewerbsfähigkeit des vorgeschlagenen KKW-Projekts in keiner Weise darlegt. Daher ist es unbedingt erforderlich, dass ein Kostenvergleich des vorgeschlagenen KKW-Projekts mit möglichen Alternativoptionen vorgelegt wird. Diese Beurteilung ist zumindest auf Vollkostenbasis, noch besser jedoch auf Ebene einer Least Cost-Analyse des Gesamtsystems durchzuführen und hat insbesondere die besonderen Kosten- und Finanzierungsrisiken von Generation III-Reaktoren zu berücksichtigen.**

## 4.4 Reaktortypen für das neue AKW

Das neue KKW soll die Blöcke 1 und 2 des KKW Ignalina ersetzen, seine elektrische Leistung soll bis zu 3.400 MWe betragen. Im UVP-Bericht werden 11 verschiedene Reaktoren vorgestellt, die von Areva, General Electric-Hitachi, Westinghouse-Toshiba, Atomic Energy of Canada Ltd., Mitsubishi Heavy Industries and Atomstroyexport angeboten werden.

Im September 2008 berichtet die Zeitschrift Nucleonics Week, der Sprecher des Unternehmens Lietuvos Energija AB, der mit der Organisation des Investments beauftragt ist, sagte in einem Interview vier westliche Reaktor-Firmen würden als Lieferanten für das neue KKW in Betracht gezogen: Areva, Westinghouse, General Electric Hitachi, and Atomic Energy of Canada Ltd. Auch wenn das von den Behörden in Litauen bestätigt wird, muss dennoch eine beträchtliche Zahl von Reaktoroptionen betrachtet werden.

### Sicherheitsstandards

Der UVP-Bericht enthält die Beschreibung allgemeiner Grundlagen der KKW-Technik im Allgemeinen und von drei prinzipiellen Reaktortypen. Eine detaillierte Darstellung der technischen Anforderungen ist im UVP-Bericht nicht enthalten, da diese Spezifizierungen erst mit dem Fortschritt des Projekts entwickelt werden. Die Anforderungen der europäischen Stromversorger (EUR/European Utility Requirements) werden im UVP-Bericht als wesentliche Quelle für technische Anforderungen an das neue KKW benannt.

Auf jeden Fall erklärt, dass das neue KKW die folgenden Bedingungen hinsichtlich Kernschmelzhäufigkeit (CDF/core melt frequency) und Häufigkeit großer Freisetzung (LRF/large release frequency) mit einem beträchtlichen Sicherheitsabstand erfüllen müsse: CDF <1E-5/a, LRF <1E-6/a. Diese probabilistischen Sicherheitsziele entsprechen in etwa den Empfehlungen der IAEO (INSAG 1999). Es wird festgehalten, dass das neue Kraftwerk diese Anforderungen mit einem „signifikanten" Abstand erfüllen müsse, was aber nicht genauer erläutert wird. Die neuen Reaktoren müssen so ausgelegt sein, dass sie externen Gefahren und Terroranschlägen standhalten, ebenso wie der Kollision mit einem großen Passagierflugzeug.

Die Entwicklung von Sicherheitsstandards für neue KKW scheint sich in Litauen noch in einem sehr frühen Stadium zu befinden. Die Entwicklung der Standards für das neue KKW parallel zur Entwicklung des Bauvorhabens könnte möglicherweise wegen des Zeitdrucks zu Problemen bei der Fertigstellung der Standards führen. Ausserdem besteht ein Risiko, dass die Standards auf das Projekt zugeschnitten werden.

**Eine detailliertere Beschreibung der Vorgangsweise zur Entwicklung dieser Standards wäre von Interesse, wobei auch das Verhältnis des zeitlichen Ablaufs der Entwicklung der Sicherheitsstandards zur Entwicklung des neuen KKW-Projekts, sowie deren Wechselwirkungen zu erklären wären.**

### Die Reaktortypen

Im UVP-Bericht wird für jede Reaktoroption, die Entwicklungsgeschichte sowie grundlegende konstruktive Maßnahmen kurz beschrieben. Kernschmelzhäufigkeit und Häufigkeit großer Freisetzung werden in den meisten Fällen angeführt, ebenso wie Infomationen zu Zertifizierung, Wirkungsgrad, Anreicherung, Abbrand, MOX-Tauglichkeit und jährlichem Anfall an abgebrannten Brennstäben. Die Beschreibung der verschiedenen Reaktortypen im UVP-Bericht ist ziemlich einheitlich, allerdings in einigen Fällen fehlen Daten.

*Table 2: Überblick über die Information im UVP Bericht (X = fehlend,□ = vorhanden)*

| Typ | EPR | SWR-1000 | ABWR | ESBWR | AP | AP 1000 | CANDU 6 | ACR-1000 |
|---|---|---|---|---|---|---|---|---|
| Hersteller | AREVA | | GE – Hitachi | | Westinghouse | | AECL | |
| el. Leistung | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Bauzeit | ✓ | ✓ | ✓ | ✓ | X | ✓ | X | ✓ |
| Wirkungsgrad | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Anreicherung | ✓ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ |
| Abbrand | ✓ | ✓ | | ✓ | X | X | ✓ | X |
| Brenstoff/a | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Zertifizierung | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X | X |
| CDF | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| LRF | ✓ | ✓ | ?? | X | ✓ | ✓ | ✓ | X |

*(X = fehlend, ✓ = vorhanden)*

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Zur erwarteten Verfügbarkeit und den Kosten der in Betracht kommenden Reaktoroptionen gibt es keine Angaben im UVP-Bericht. Kostenüberschreitungen sind beim Bau neuer Reaktoren zu erwarten, das es bisher wenig bis keine Erfahrungen damit gibt. Wirtschaftlicher und Zeitdruck könnten zusätzlich zu Problemen bei der Aufnahme des Betriebs und somit zu geringerer Verfügbarkeit führen. Jede Abschätzung wäre außerordentlich spekulativ.

Die Bewertung und der Vergleich der Angaben im UVP-Bericht führt zur Feststellung dass die Kernschmelzhäufigkeit (CDF) große Unterschiede zwischen den Reaktortypen aufweist – bis zu einem Faktor 200. Die Bedeutung der unterschiedlichen CDF-Werte für die Bewertung der Reaktortypen wird im UVP-Bericht nicht erläutert.

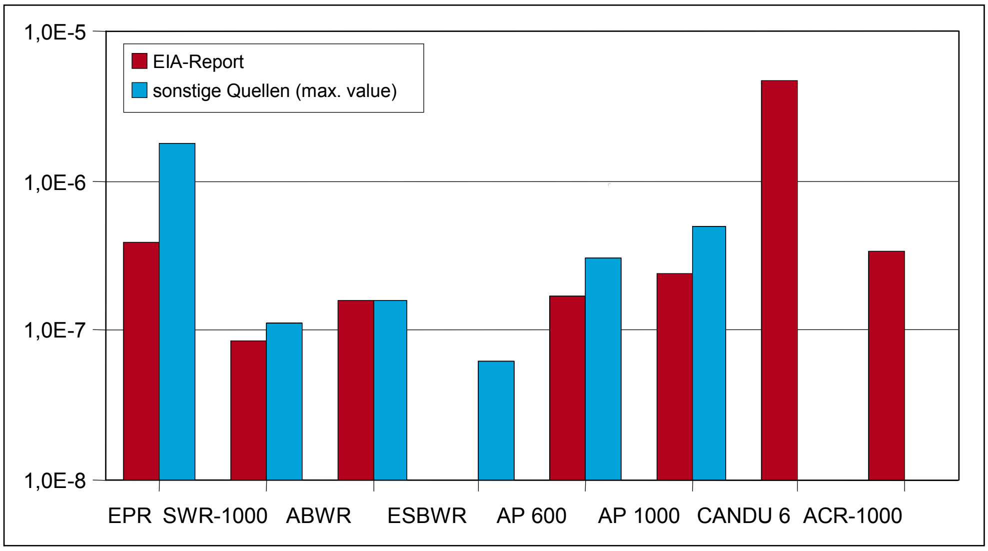

*Abbildung 1: Kernschmelzhäufigkeit (CDF) entsprechend dem UVP-Bericht verglichen mit anderen Quellen.*

**Die Übersicht über die Ergebnisse probabilistischer Sicherheitsanalysen zeigt große Abweichungen und Unsicherheiten und belegt damit, dass es nicht angebracht ist zu sehr den probabilistischen Kriterien zu vertrauen. Die Hauptkriterien für die Bewertung der Reaktortypen sollten deterministisch sein.**

**Eine ausführliche Präsentation der PSA-Ergebnisse der betrachteten Reaktoren wäre von Interesse (einschließlich der Beiträge verschiedener auslösender Ereignisse und des Betriebszustands der Anlage), ebenso wie eine Diskussion einschließlich der ihrer Beschränkungen und der Bandbreite der Unsicherheiten. Auf diesem Hintergrund sollten die oben gezeigten Unterschiede in den Ergebnissen diskutiert und bewertet werden.**

**Darüberhinaus sollte die Bedeutung der probabilistischen und deterministischen Anforderungen für die Bewertung der Reaktordesigns erklärt werden einschließlich des Verhältnisses der beiden Zugänge zueinander.**

Die in Betracht gezogenen Reaktoroptionen spannen ein breites Spektrum auf: beginnend mit Reaktoren, auf Basis eines grundsätzlich ausgetesteten Design und einigen neuen Funktionen bis zu neuen, weitgehend noch nicht ausprobierten Entwicklungen mit vielen neuen Vorrichtungen und Funktionen. Mit den meisten dieser Reaktortypen hat man bisher keine oder nur sehr wenige praktische Erfahrungen.

Manche der neuen Reaktoren vertrauen im Wesentlichen auf aktive Sicherheitssysteme, andere auf passive, manche kombinieren auch beides. Im Allgemeinen wird es als Vorteil angesehen wenn ein Reaktor stärker auf passive Sicherheitssysteme setzt als auf aktive, da dann technische und menschliche Fehler eine geringere Rolle spielen.

Das Konzept der Kühlung des schmelzenden Reaktorkerns im Reaktordruckbehälter (RDB) (in-vessel cooling) als Maßnahme zur Bewältigung schwerer Unfälle erscheint eher Erfolg versprechend und weist nicht so viele Probleme auf wie die Kühlung außerhalb des RDB (ex-vessel cooling). “In-vessel cooling”wurde bereits im KKW Loviisa in Finnland verwirklicht. Allerdings nehmen die Erfolgschancen für diese Maßnahme mit zunehmender Kapazität des Reaktors ab.

Mehr Details und Diskussion der verschiedenen Reaktortypen sind in Kapitel 8 zu finden.

## 4.5 Unfallanalyse

Das Kapitel Risikoanalyse und Bewertung des UVP-Berichts enthält eine Klassifizierung von Ereignissen nach Eintrittswahrscheinlichkeit und möglichen Folgen. In diesem Kapitel werden auch das Risiko von Auslegungsstörfällen (DBA) und darüber hinausgehenden Störfallszenarien behandelt. Die in Tabelle 10.2.3 des UVP-Berichts präsentierte Klassifizierung unterscheidet zwischen den geringen Eintrittswahrscheinlichkeiten: alle Störfälle deren Eintrittswahrscheinlichkeit kleiner als 1E-3/a ist werden als „unwahrscheinlich“ klassifiziert. Das steht im Widerspruch zur internationalen Praxis. IAEA, EUR, the Finnish and also the Lithuanian Regulation unterscheiden probabilistische Ziele mit weit geringerer Eintrittswahrscheinlichkeit.

Es wäre aufschlußreicher mehr konkrete Informationen aus PSA und Sicherheitsberichten zur Verfügung zu stellen, die die Strahlengefahr angemessen illustrieren anstelle eines Rankings das angemessen wäre zur Beurteilung weniger riskanter industrieller Aktivitäten.

### Quellterme für schwere Unfälle

Der Quellterm von 100 TBq Caesium 137 und 1.000 TBq Iod 131, der im UVP-Bericht als „repräsentativ“ für schwere Unfälle für einen Generation III-Reaktor ausgewählt wurde, wird in keiner Weise begründet. In der Finnischen Gesetzgebung gilt die Emission von 100 TBq Cäsium als Grenzwert für den Strahlenschutz. Eine große Freisetzung (die dieses Limit übersteigt) soll eine Eintrittswahrscheinlichkeit kleiner 5.0E-7 pro Jahr aufweisen.

PSA-Ergebnisse für den EPR belegen dass 9 % aller Kernschmelzunfälle zu spätem und 6 % zu frühem Containmentversagen führen. Diese Unfallszenarien sind genau jene, die für die Analyse grenzüberschreitender Auswirkungen relevant sind. Die Freisetzungsraten für Iod und Cäsium solcher schwerer Unfälle liegen im Bereich von 2 % bis 20 %. Schon eine Freisetzungsrate von 1 % ergäbe eine Emission von mehr als 1.000 TBq Cs-137 und mehr als 10.000 TBq I-131 bezogen auf das Kerninventar des APWR aus dem UVP-Bericht. Das zeigt, dass der im UVP-Bericht unterstellte Quellterm für den schweren Unfall zur Untersuchung der Unfallauswirkungen ziemlich gering ist. Für die österreichische Analyse grenzüberschreitender Auswirkungen wurde eine Freisetzung von 5 % des Cs-137 Kerninventars von 714 PBq aus dem UVP-Bericht unterstellt, was einer Freisetzung von 35.5 PBq entspricht. Unserer Meinung nach ist eine Freisetzungsrate von 5 % nicht übertrieben konserativ, da der schlimmste Fall eine wesentlich höhere Emission sein könnte.

### Untersuchung der weit reichenden Auswirkungen

Der UVP-Bericht enthält Karten der 98er Perzentile verschiedener radiologischer Parameter, wie Bodenkontamination und verschiedene Dosiswerte, abgeleitet aus der Ausbreitungssimulationen von je 730 Freisetzungen bei Tag und bei Nacht. Daraus folgt, dass die oberen 2 %, deren Untergrenze in den Karten zu sehen ist, ca. 2x15 Fälle ergeben. Diese Landkarten im UVP-Bericht wurden für den Auslegungsstörfall (Kühlmittelverlust) und für den schweren Unfall erstellt. Die Simulationen wurden mit dem SILAM Modell ausgeführt, das vom Finnischen Meteorologischen Institut entwickelt wurde (http.//silam.fmi.fi). Die Ausbreitungsberechnungen wurden mit Daten des ECMWF-Archivs der Jahre 2001 und 2002 ausgeführt.

Es ist begrüßenswert, dass die AutorInnen des UVP-Berichtes diese Analyse der Unfallauswirkungen präsentieren. Diese Analyse ist besser als die der meisten vergleichbaren UVP-Berichte, sowohl wegen der Realitätsnähe des Modells als auch wegen der Verwendung realer meteorologischer Bedingungen. Trotzdem müssen wir festhalten, dass weitere Details zur Modellierung im UVP-Bericht nicht erläutert sind.

Die AutorInnen des UVP-Berichtes argumentieren, dass nur das 98ste Perzentil und nicht das Maximum (d. h. das 100ste Perzentil) verwendet werden sollte, da dieses eine zu hohe Sensitiviät für die statistische Abweichungen aufweist. Im Prinzip ist das richtig. Allerdings zeigen die Karten, dass schon das 98ste Perzentil große statistische Fluktuationen aufweist. Die im UVP-Bericht vorgestellten Ergebnisse zeigen, dass innerhalb der höchsten 2 % eine große Variabilität vorhanden ist, was bedeutet das im schlimmsten Fall die maximale Kontamination deutlich höher ist als das 98ste Perzentil.

### Die österreichische Analyse

Die Methode der österreichische Untersuchung der potentiellen Auswirkungen eines schweren Unfalls im vorgeschlagenen neuen litauischen KKW beruht auf Ausbreitungsgrechnungen, die mit dem Modell FLEXPART (Lagrange-Partikel-Dispersionsmodell) im Projekt RISKMAP eingesetzt wurde. In diesem Projekt wurden 88 Fälle aus dem Jahr 1995 untersucht. Die Verteilung der Gesamtdeposition von Cäsium 137 (trocken und nass) über Europa wurde ermittelt. Abbildung 2 zeigt das Ergebnis für der maximalen Kontamination aus diesen 88 Simulationen einer Emission am Standort des Litauischen KKW, berechnet mit einem Quellterm von 5 % des Cs-137 Inventars.

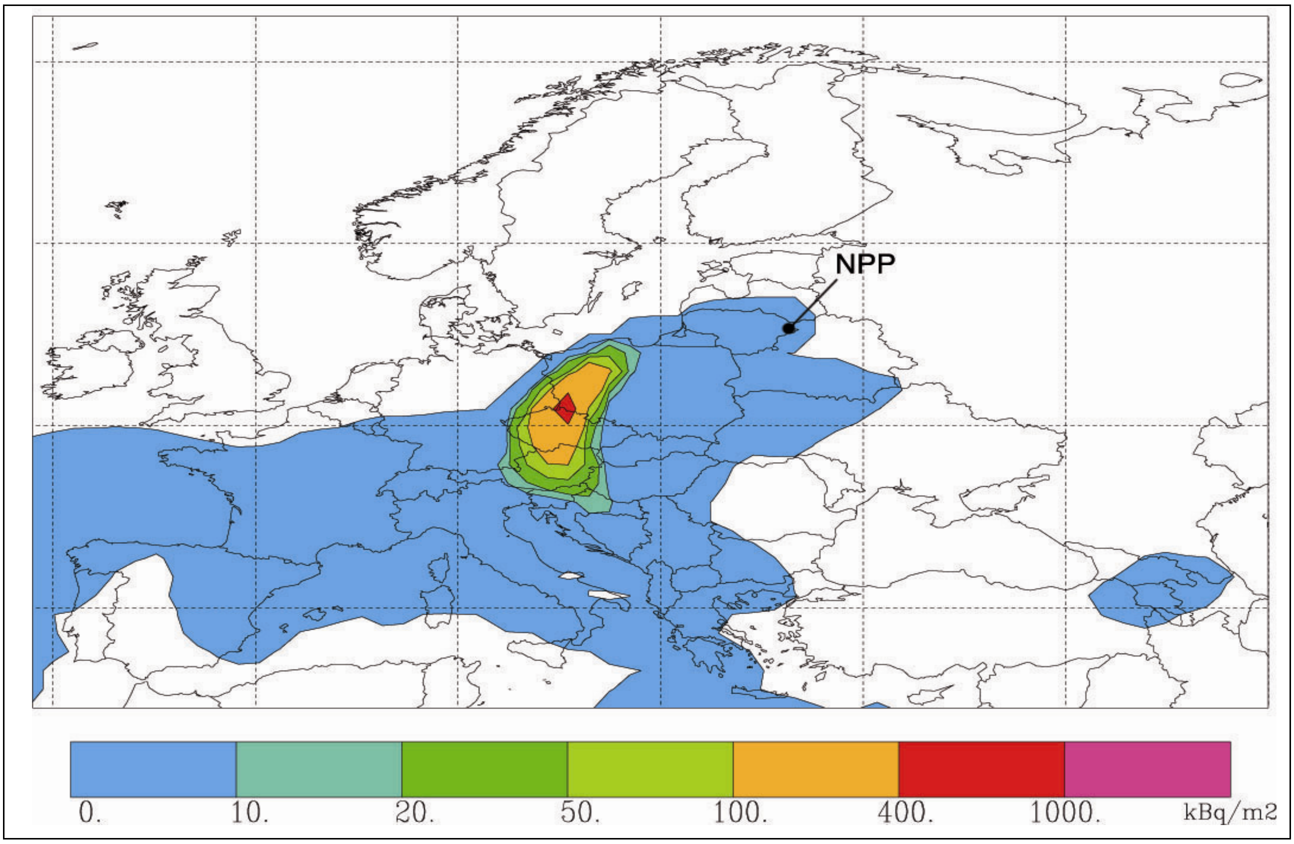

*Abbildung 2: Beispiel der Cs-137 Deposition über Europa als Folge eines hypothetischen schweren Unfalls im neuen KKW Ignalina, bei einer angenommenen Freistzung von 35.5 PBq in der Stunde nach 1995-06-25 14:56; die Größe des Ausgabenetzes ist 1°, die äußere Grenze des blauen Bereichs ist 0.1 kBq/m².*

Die Abbildung zeigt die von der Kontamination betroffene von KKW abgelegene Region, die sich über Polen, die Tschechische Republik und Österreich bis in das Gebiet des früheren Jugoslawien erstreckt. In Österreich liegt die Deposition über dem Wert von 100 kBq/m² in einem großen Teil von Oberösterreich. Bei dieser Kontamination sind Maßnahmen zum Schutz der Bevölkerung vor Strahlenbelastung zu ergreifen. Der Verbleib in geschützten Räumen oder sogar die Einnahme von stabilem Kaliumiodid als Prophylaxe könnte angeordnet werden. Im Frühling und Sommer Beschränkungen bei der Nutzung einheimischer Nahrungsmittel und in der Viehzucht könnten nötig sein, sollte eine solche Situation Realität werden.

Aus österreichischer Sicht ist es nicht gerechtfertigt zur Untersuchung grenzüberschreitender Auswirkungen eines schweren Unfalls als Quellterm einen willkürlich ausgewählten Emissionensgrenzwert anzunehmen.

**Vorrangig empfehlen wir für die Sicherheitsanalyse einen deterministischen Zugang zu wählen und herauszufinden welche Emissionen auftreten können. Anhand veröffentlichter Daten zu „Generation III"-Reaktoren haben wir gezeigt, dass Containmentversagen nicht ausgeschlossen werden können und dass auch frühes Versagen des Containment einen Beitrag zur Eintrittswahrscheinlichkeit großer Emissionen liefert. Große Emissionen – soweit publiziert – zeigen, dass die Freisetzungsraten für flüchtige Aerosole im Bereich von 2 % bis 20 % des Kerninventars liegen, was wesentlich höher ist als das gewählte Limit von 100 TBq Cs-137.**

In Hinblick auf die klimatologische Wahrscheinlichkeit der Kontamination ist eine unfallbedingte Emission vom Standort des neuen litauischen KKW von höherer Relevanz als eine vom Standort Tschernobyl ausgehende, und das vor dem Hintergrund der Erfahrung mit der Katastrophe von Tschernobyl, von der Österreich signifikant betroffen war.

# 5 DESCRIPTION OF THE PROJECT

## 5.1 Treatment in the EIA Report

### General description

The company Lietuvos Energija AB plans to construct a new nuclear power plant (NPP). The new NPP will be constructed next to the operating Ignalina NPP (INPP), which is located in the north-east of Lithuania on the south bank of Drūkšiai Lake, six kilometres from the town of Visaginas and next to the border to Latvia and Belarus.

Two RBMK units are located at the Ignalina NPP site. Each reactor unit has a net electrical capacity of 1,300 MW. Operation of these reactors has started in 1977 and 1978, respectively. Unit 1 has been closed at the end of 2004, unit 2 is scheduled for shutdown at the end of 2009.

The new NPP shall replace unit 1 and 2. Electric capacity of the new NPP Unit shall be up to 3,400 MWe. It will consist of one to five units.

Finalization of the new NPP is planned for 2015, operation time will be approximately 60 years or more. Decommissioning will be done in 20 to 100 years.

### EIA procedure

The EIA procedure is based on the Lithuanian "Law on the assessment of the impact of proposed economic activities on the environment" (EIA LAW 2005). COUNCIL DIRECTIVE 85/337/EEC (amended by DIRECTIVE 2003/35/EC) has been implemented by this law. According to both the Directive and the Lithuanian EIA Law a nuclear power plant is subject to an assessment.

In the EIA Report the following chapters are discussed: A general description of the proposed activity, the description of the EIA procedure, communication and participation, alternatives (including only location and cooling alternatives), plant type options, waste, a comparison of the present state of the environment and an assessment of potential impacts, transboundary impacts, monitoring and risk analysis.

In a separate table all comments that were given during the scoping phase from other countries including Austria were answered (EIA REPORT 2008, p. 57ff.).

### The site

In chapter 4 of the EIA report alternatives for the site of the proposed plant are discussed. Two location sites are described, both in the territory of the existing Ignalina plant.

For cooling three different water inlets and two outlets are discussed.

(Technological alternatives are discussed in chapter 7 of this expert statement.)

### Waste

Amounts and types of radioactive and non-radioactive waste are listed in chapter 6 of the EIA Report. Existing facilities for management of radioactive waste will be utilised to the greatest possible extent. In chapter 1.8.4 (EIA REPORT 2008, p. 43) this utilisation for radioactive waste is described as follows: A new solid waste management facility will be commissioned in 2010. This facility could not only be used for solid radioactive waste from Ignalina NPP, but also for operational waste from the new NPP.

Furthermore, a near-surface repository for LILW is projected, a site near Ignalina has been already been chosen. This repository will be designed for LILW from the existing NPP Ignalina: According to the EIA Report solid waste which will be stored in the before mentioned solid waste management facility will be transferred to this LILW repository, and after that LILW from the new NPP could be stored until 2060 in the solid waste management facility.

For liquid radioactive waste a new treatment facility will be built, the existing one will be decommissioned (EIA REPORT 2008, p. 43)

The capacity of the spent fuel storage of the existing NPP Ignalina is almost spent (EIA REPORT 2008, p. 29). Management of interim storage of spent fuel is not decided by now. Three different options are given: wet storage, dry storage or reprocessing in UK, France or Russia. Today reprocessing is prohibited by Lithuanian legislation (EIA REPORT 2008, p. 129).

Also long-term storage of spent fuel is uncertain. The following options are possible:

- disposal in a national deep geological repository
- disposal in a regional deep geological repository
- transfer and disposal in other countries
- storage for 100 years and more (EIA REPORT 2008, p. 129)

Long-term storage and disposal of spent fuel will be subject of a separate EIA procedure and are therefore not discussed in the EIA Report (EIA REPORT 2008, p. 128)

For decommissioning the strategies proposed by IAEA are presented in general: immediate dismantling, deferred dismantling and entombment. Preferences for an option are not indicated. (EIA REPORT 2008, p. 130 f.)

Cost estimations are only mentioned for decommissioning: Necessary financing will be accumulated in a decommissioning fund. It is not clear if this fund already exists.

### Monitoring

A detailed monitoring concept is presented. Emission data for INPP as well as for the new one are included in the EIA Report.

Data for crude death rate comparison are also presented, but data about cancer are missing. Health data are mostly given for the years 2000–2005.

## 5.2 Discussion

### General description

The focus of this expert statement lies on safety questions, especially in a transboundary context. Therefore we focussed in the discussion of the EIA report on emissions that could be relevant for Austria and on questions about the justification of the construction of a NPP this order of magnitude. Other aspects of the EIA procedure are only discussed here in context to the questions we submitted in the scoping phase (WENISCH & MRAZ 2008) and to assess if the EIA Report is complete.

### EIA procedure

By Directive 2003/35/EC public participation as guaranteed in the Aarhus Convention was improved in environmental assessment procedures. Especially the status of NGOs was highlighted by the definition of „the public concerned“: "… for the purposes of this definition, non-governmental organisations promoting environmental protection and meeting any requirements under national law shall be deemed to have an interest" (DIRECTIVE 2003/35 EC, Art. 3). This definition can also be found in the Lithuanian EIA Law in Art. 2.

During the scoping stage of the EIA procedure a stakeholder group was organized. The stakeholders "acted as experts in their particular fields" (EIA REPORT 2008, p. 53).

In the Statement for the EIA scoping (WENISCH & MRAZ 2008) it was asked why no environmental groups and societal NGOs were invited to send their experts to this stakeholder group. Also it was remarked that the difference between stakeholders and relevant parties to the EIA was not explained properly.

This question was answered as follows: "The environmental and societal NGOs have the opportunity to express their opinion about the EIA Report (as well as the EIA program) as part of the public participation … The relevant parties include governmental institutions, responsible for health protection, fire-prevention, protection of cultural assets, development of economy and agriculture, and municipal administrations … Stakeholders include all the persons, groups and organizations who effect or can be affected by the economic activity assessed in this EIA." (EIA REPORT 2008, p. 59).

This definition of stakeholders would have allowed NGOs to take part in the stakeholders´ groups.

In the second stage of the EIA procedure, there are no stakeholder groups foreseen. But the experts from the stakeholder group were consulted during the preparation of the EIA report (EIA REPORT 2008, p. 53). If NGOs would have been members of the stakeholder group, their opinions would have had a better chance to be implemented into the EIA Report in an early stage.

It is highlighted in the EIA Report that the role of NGOs was specially appreciated because NGOs and community groups could provide experience unavailable to consultants, developers or public authorities (EIA REPORT 2008, p. 49). This seems to be in contradiction with the exclusion of NGOs from the stakeholder group. Moreover, in COUNCIL DIRECTIVE 85/337EEC it is stated in Art. 6.4 that "the public concerned shall be given early and effective opportunities to participate in the environmental decision-making procedures…”. Certainly it would have been effective for environmental and societal NGOs to be part of the expert stakeholder group who could give its opinion to the EIA Program several months before the public and also during the preparation of the EIA Report.

Information which shall be included in an EIA report are summarised in COUNCIL DIRECTIVE 85/337/EEC (Art. 5).

### The site

For transboundary impacts questions of location and cooling are not of high relevance for Austria.

Nevertheless, in the Statement for the EIA scoping (WENISCH & MRAZ 2008) two questions were asked. First, the impacts and potential interferences of simultaneous activities at the site (decommissioning of the existing NPP, construction and later operation of the new NPP) were asked to be considered in the EIA Report. A timetable for both activities was demanded. The total inventory of radioactive material at the site was asked to be estimated for the different phases.

This question was answered as follows (EIA REPORT 2008, p. 57): “The simultaneous activities at the site are taken into account in the parts of the assessment where potential interference might be expected, for example the impacts from traffic. The potential radioactive emissions from the new NPP and other existing and planned objects in the same area are evaluated in Section 7.10.”

It is not possible to limit the discussion about interferences to traffic because natural disasters or other events as fire or explosions could also affect waste storage and treatment facilities.

### Waste

The management concept for LILW is only described until 2060. But the planned operation time of the new NPP will be approximately 2075.

Spent fuel management is not described properly in the EIA Report. After spent fuel will be removed from the storage pools at the NPP, the description of future management becomes very vague: “SNF could be transferred to off-site facilities” (EIA REPORT 2008, p. 128). Today there are no interim storage capacities available for future spent fuel, and no plans for construction of new interim storage facilities are discussed in the EIA Report.

Also a concept for long-term storage of spent fuel is missing in the EIA Report. This is explained with a planned special EIA procedure. But no timetable is given for this planned EIA.

In the scoping report it was asked that the EIA Report should include a preliminary estimation of cost for long-term treatment of SNF and radioactive waste. The answer to this question was that long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future. Therefore no information about costs were made available as was asked for.

The National Strategy on Radioactive Waste Management from 2002 is mentioned once (EIA REPORT 2008, p. 129). But this strategy is not available in English language from the homepage of RATA because of a broken link. Therefore it could not be verified if in this strategy more information is given about spent fuel management.

Information can only be derived from another EIA Report (GNS-RWE & LEI 2006). There it is stated that "a deep geological repository is not available in Lithuania and likely will not be available at least until the middle of this century."

Information about the future quantity and radioactive inventory of HLW and spent fuel at the site of the new NPP is missing. Because of the missing information environmental impacts of spent fuel and HLW management, and also potential interferences between old and new facilities at the site cannot be assessed.

### Monitoring

In the scoping report (WENISCH & MRAZ 2008) several requests have been made concerning monitoring. Most of the requests were answered in chapter 9.

Because Ignalina NPP is operating since 30 years a time series of health data should be given, especially for monitoring of radiation induced health effects like thyroid cancer and leukaemia. Unfortunately, only some data on death rate are presented.

## 5.3 Conclusion

Most of the questions that were raised in the scoping phase were answered, some of them not as detailed as asked for.

The relevance of most of these aspects for transboundary impacts is not a priority for Austria.

### Waste

Management of spent fuel and HLW is not described adequately. Options for interim storage of spent fuel and for long-term storage are only discussed in general, but there is no management concept presented. It is only referred to a special EIA procedure, but there is no timetable given.

Therefore it is questionable if this EIA Report is in accordance with the ESPOO-Convention and the EIA Directive of the EU (COUNCIL DIRECTIVE 85/337/EEC).

# 6 NEED FOR NEW POWER PRODUCTION CAPACITY

## 6.1 Treatment in the EIA Report

The EIA report justifies the need for new capacities in consequence of closing down Ignalina NPP by the lapidary statement that otherwise – i.e. in the case of the so-called zero option – the county's energy security will not be ensured. As illustration for that statement a simplistic top down forecast of the electricity demand by 2025 differentiated in three scenarios is presented (see chapter 4.4 of the EIA report).

The analysis in the EIA report, however, does not include

- a description of the actual capacities in place (inside the country as well as in the Baltic sea region);
- an analysis of the driving forces behind increasing electricity demand based on a sectoral and technology-oriented bottom-up model;
- an analysis of the effects of the implementation of the European regulation on energy efficiency on electricity demand;
- an assessment of the development of the load profile as a consequence of the structural changes in the Lithuanian industry resp. of expected economic development;
- the temporal development of the need for new electricity production capacities (if any need is observable after having assessed the points mentioned above in detail).

## 6.2 Electricity demand forecast

The collapse of the Soviet Union was followed by a significant reduction in electricity consumption. Consumption bisected from more than 14 TWh in 1991 to about 7 TWh in 1996. Since then we see a fluctuating demand pattern till 2002 (still around 7 TWh in 2002) and a following increase up to roughly 9 TWh in 2005.

In order to work out a more reliable forecast for the development of the electricity demand it seems indispensable to rely on a comprehensive sectoral and technology-oriented bottom-up analysis. By this the impact of the following potentially important factors on electricity demand development can be assessed in a reliable way:

- The ex-post-analysis shows that since 1991 the power demand was mainly driven by structural changes in the Lithuanian economy. For a demand forecast it is important to know if the structural changes will go further on or if the main shifts between sectors and branches have been coming to an end. The considerable fluctuations in power demand since 1996 might be caused by structural changes still ongoing.
- Following to the adoption of the EU Directive on Energy Efficiency and Energy Services Lithuania is obliged to increase its efforts in improving the energy efficiency of its economy. Till 2017 measures and activities need to be implemented in order to achieve a 9% saving target compared to the average consumption in the period 2001–2005 (i.e. an increase of energy efficiency by 9%). In July 2007

the Ministry of Economy has submitted an Energy Efficiency Action Plan that includes also measures in the field of electricity demand, such as introduction of an excise tax for electricity or provisions for energy efficient procurement in the public sector etc. The package of energy efficiency facilitating measures – which we can expect to get intensified after the interim reporting to the EU in 2011 – will at least contribute to a limitation of the increasing trends in electricity demand.

- The consumption profile fluctuating considerably between years seems to point to a considerable share of electricity use for heating, potentially partly as a supporting heating source in badly insulated buildings. Electric heating is one of the demand segments which can be comparably easily cut down by fuel switch on the one hand and building refurbishment on the other hand. In this case it is also important to notice that the already mentioned EU Directive on Energy Efficiency and Energy Services for the future prohibits sales-promotional energy tariffs which still can be often found in the case of electric heating systems.

## 6.3 Relevance of the development of load profiles

Nuclear power plants produce base load electricity. For economic as well as for technical reason they are scheduled for a continuous operation. The yearly electricity consumption therefore is not a good benchmark to demonstrate a possible need for the construction of a base load capacity. The important issue in this context is the development of base load demand.

Usually the transformation of the economy from heavy industry towards light industry resp. towards an enlargement of the service sector leads to reduced share of base load consumption and a higher share of medium and peak load.

The EIA report gives no information whether a shift towards medium and peak load in the total electricity consumption has also happened in Lithuania resp. on the level of base load consumption at time being as well as expected for the future.

## 6.4 Existing electricity production capacities

The EIA report states that the closure of Ignalina NPP causes a gap in electricity production not only because of increasing electricity demand but also because of a lack of existing production capacity in the country.

The Baltic power system was designed as an integral part of the wider Soviet system. As a result many key assets serve for the wider region leading to overdeveloped infrastructure from the perspective of the single markets.

As relates the Lithuanian power market by its own at the moment there is a generous surplus of generation capacity. The closure of INPP will tighten the situation but will not lead to an abrupt generation gap. The existing generation capacity excluding INPP is around 3,700 MW and is capable to produce around 15 TWh per year. The prevailing part of this capacity operates on a thermal basis; the most important power plant is the LPP (Lithuanian Power Plant) with an installed capacity of 1,800 MW, which operates on the basis of gas and fuel oil.

Even after the closure of Ignalina NPP there actually remains a comfortable surplus in the system:

- With respect to installed capacity (peak load) the present production system can be assumed sufficient. At the moment to peak load is around 2000 MW, therefore even with very dynamic increase in the peak load at the necessary security margin can be kept at least till 2020 probably even to 2025.
- With to production the situation is tighter and more dependent on the development of the demand. With very intensively increasing demand patterns we might expect a capacity gap in 2015 at the earliest; assuming a less dynamic demand development the production capacity will be sufficient until 2025.
- In any case the planned construction of additional transmission lines to Poland and Scandinavia will reduce the risk of capacity shortcomings considerably.

## 6.5 Conclusion

The EIA report demonstrates the need for the proposed NPP project only in a superficial way. A more comprehensive analysis, however, shows that the need for an additional base load capacity of at least 1,600 MW is questionable up to the year 2025 because of the following reasons:

- The yearly final energy consumption has been fluctuating considerably between 1996 and 2006. The driving forces behind these fluctuations remain unclear and can be only forecasted on the basis of a comprehensive sectoral and technology-oriented bottom-up analysis (which is missing in the EIA report);
- Due to the adoption of the EU Directive on Energy Efficiency and Energy Services Lithuania is obliged to increase its efforts in improving the energy efficiency of its economy. Therefore we have to expect a number of measures facilitating power savings leading to a limitation of the increasing trends in demand;
- Since the proposed NPP project for economic reasons has to deliver base load electricity it is important to differentiate between base load, medium load and peak load demand. Due to the structural changes in the Lithuanian economy we may expect a more dynamic development of the medium and peak load demand as compared to the base load demand. It is therefore questionable if the proposed NPP will be able to operate at full capacity if the base load demand lags behind a potential overall increase of electricity demand.
- The Baltic power system was designed as an integral part of the wider Soviet system, a fact that has caused overdeveloped infrastructure from the perspective of the single markets. Even after the closure of Ignalina NPP there actually remains a comfortable surplus in the system on the capacity level (MW) as well as on the level of potential production (GWh). With very intensively increasing demand patterns we could expect a small capacity gap in 2015 at the earliest; assuming a less dynamic demand development the installed capacity will be sufficient until 2025. In any case the planned construction of transmission lines to Poland and Scandinavia will reduce the risk of capacity shortcomings considerably.

# 7 COST EFFICIENCY OF THE PROPOSED NPP PROJECT

## 7.1 Treatment in the EIA Report

The EIA report does not include any consideration about the cost effectiveness of the proposed NPP compared to alternative power production options. The authors of the EIA report justify this by the fact that the NPP project company has been established exclusively for constructing and operating a new NPP in Lithuania and it has therefore no mandate to occupy itself with any other kind of power plants.

In this context it has to be highlighted, however, that the EIA process does not only look at the market based need of a proposed project but it addresses also the economic meaningfulness resp. the cost efficiency of the project presented. This is necessary in order to avoid the installation of overcapacities – and thus an extra burden to the environment – in the case that the proposed project is not cost effective and additional projects may push on the market. An energy economic assessment is therefore seen as an indispensable and integral part of any EIA of power plants. The institutional setting of the organiser of the proposed economic activity is of no relevance in that context.

## 7.2 Economic risks of the proposed NPP project

### 7.2.1 Construction costs

Lietuvos Energija AB is planning to build a generation III reactor. For the moment no reliable data on construction costs of this NPP types is available. On the one hand this depends on the general uncertainties inherent to NPP construction in general – each NPP is a prototype to a certain extent – on the other hand this is related to generation III design in particular, since no generation III reactor has been finished so far.

As refers to (overnight) construction cost estimates different sources come up with very different figures:

- The project proposer Lietuvos Energija AB assumes construction cost of about € 2,000/$kW_{el}$, which is the most optimistic figure (NW 25-Sep-08),
- An assessment for the case of Switzerland estimates construction cost of € 1,900 to 2,700/$kW_{el}$; (PROGNOS 2008),
- For the generation III plant under construction at Olkiluoto, Finland, the actual cost estimate is around € 2,800/$kW_{el}$ (THOMAS 2008)
- Moody's investor service estimates the construction cost for new NPP in the US at US$ 5,000 to 7,000/$kW_{el}$; (KIDD 2008); if this cost estimate seems high one has to have in mind the long tradition of cost overrun in the nuclear industry. In the US predicted construction cost of 75 reactors has been US$ 45 billion, whereas the actual construction cost turned out to be US$ 145 billion (DOE 1986). In India, the country with the most recent and current construction experience, completion cost of the last recent 10 reactors have averaged at least 300 per cent over budget (RAMANA et al. 2005).

Therefore we can summarise, that any figure presented as construction cost has to be seen as a rough guess for the moment. We can, however, declare that there is a high probability of cost overrun due to the following market characteristics (KIDD 2008):

- Due to the decline of nuclear industry during the last 2–3 decades only a handful supplier left on the market. For certain components the market is even confronted with monopoly situation (e.g. for reactor pressure vessels), which pushes the price up;
- Labour cost have been rising sharply because generation III reactors need much more labour input to complete to plant;
- In general, we observe a boom in the power plant industry, which will increase prices for deliveries such as turbines equipment.

### 7.2.2 Construction time

The picture concerning the NPP construction time of generation III reactors is similar to that of the construction cost. There is a considerable uncertainty because of the little experience in constructing NPP in Europe during the last 2–3 decades. The delays at both EPR projects in Finland and France suggest that also this area represents a considerable risk factor (PROGNOS 2008).

It has to be underlined, however, that construction time overruns have very serious consequences on the cost efficiency of NPP

- As capital-intensive power plant with a very long construction time the interest during construction is a very important part of the total cost of NPP. Any delay increases this cost element considerably;
- The delay does not only cause a cost increase but it also causes a reduction of revenues in time where the NPP is still under construction whereas competing options would already deliver to the grid.

In cost comparison calculations of different power plant options the completion time is very often one of the most influential factors. And is has to be stated, that the risk for completion delays is considerable higher for NPP as compared to other power plant types.

### 7.2.3 O&M cost

Since at the moment no generation III reactor is operating in Europe it is impossible to give reliable figures on their future O&M cost. History of nuclear industry, however, shows that O&M cost has been very frequently underestimated. A comprehensive analysis on this issue for Switzerland shows a considerable range of O&M cost, as follows (PROGNOS 2008):

- "ordinary" O&M cost of € 50 to 85 per $kW_{el}$ and year (which relates to € 8 to 13 per MWh produced, which is about in the range of the fuel costs);
- additional back-fitting cost of € 300 to 900/$kW_{el}$ during the whole life-time of the power plant.

In any case, also the area of operation and maintenance there is considerable uncertainty about the final cost level.

### 7.2.4 Decommissioning and nuclear waste disposal costs

The costs for decommissioning and for nuclear waste disposal are very uncertain, because there is only little experience with decommissioning of commercial-scale NPP plants and practically no experience with long-term nuclear waste disposal.

The issue that are relevant to this cost item are as follows:

- During the last 2 decades the cost estimates for decommissioning and long-term nuclear waste disposal have been steadily and quite sharply rising. This trend is further going on;
- This is the reason why the funds which in most countries have been created for the back-end cost will not be sufficient from today's point of view. Therefore the question remains if the lacking funds will have to be procured by the NPP plant operators or by the tax payers.
- In cost (comparison) calculations the most important issue is the interest rate applied to the back-end cost. Starting from the assumption that the back-end funds have to be set aside and placed in secure way we may suppose low interest rates applicable to back-end costs.

## 7.3 Alternative options in the case of Lithuania

In general the most important alternative options are fuel power plants:

- Coal power plants (brown coal as well as hard coal): With access to the sea Lithuania has in principle were good conditions for the cost efficient construction of coal power plants. As refers to fuel prices, coal is the only fossil fuel for which we can expect a rather stable development with only hardly any increase till 2025 (ENERGIEWIRTSCHAFTLICHES INSTITUT KÖLN 2005). The disadvantage of coal power plants related to its emissions, mainly to its $CO_2$ emissions. Any new coal power plant would be part of the emission trading scheme and would therefore need emission allowances for its operation. At the moment estimates for emission allowance cost are between € 20 and 40 per t, which accounts for "extra" fuel cost of € 17 to € 34/MWh input and by far exceeds to "usual" fuel cost. An additional disadvantage of coal power plants is that they need to be comparably big (at least 800 MW per unit), which in practice reduces their potential for the use of waste heat (e.g. in district heating systems).
- Gas-fired power plants are much more flexible with respect to their unit size, therefore they very often gain advantage from a high overall plant efficiency if integrated in a heat supply network. This aspect is important with respect to the cost efficiency of Combined Cycle Gas Turbines (CCGT) and other gas-fired CHP options. The emission allowance cost for bigger gas-fired power plants can be estimated at 8 to 15 €/MWh input.
- The National Energy Strategy 2007 supports the extension of power produced from cogeneration in the district heating sector. By 2020 up to an amount of at least 35% of the total power balance shall be produced by CHP plants. Several bigger CHP projects with a total capacity of 400 $MW_{el}$ are explicitly mentioned in the Energy Strategy 2007. But with a total heat capacity of over 1,300 $MW_{th}$ the potential for CHP in district heating can be assumed to be considerably higher than that.

- In addition some potential for CHP in the industrial sector may be assumed, but this would need further assessment. It has to be stressed, however, that industrial CHP is even more cost efficient than CHP in the district heating sector if base load heat is required.

In addition to fossil fuel fired power plants the following options are relevant in the case of Lithuania:

- Following to the European Directive on electricity production from renewables Lithuania has fixed a target of 7% share of renewable electricity by 2010, which represents a short-term increase by 4%. Furthermore it has to be expected that higher targets will be adopted in the period from 2010 to 2020. In the field of renewable electricity production Lithuania has considerable potential: The use of biomass has been already common in the district heating sector. Therefore the extension towards biomass CHP plants should not be an overburdening step. In addition there is considerable potential for wind energy, prevailingly along the cost. The target capacity for 2010 is 200 MW from wind farms, the potential might be at least four times as high (EUROPEAN COMMISSION 2007).
- DSM Measures are dealt with in chapter 6.2 on the electricity demand forecast.

Another important aspect with respect to alternative supply option is the interconnection to the regional and international power systems. At the moment the connection to the Russian system is predominant. But with the planned construction of additional transmission lines to Poland and Scandinavia there will be a direct connection to the UCTE and to the Nordic system. This includes also a direct access to the capacities installed in these systems and therefore a broader scale of potential imports.

Therefore comparing the proposed NPP project only to alternative supply options in Lithuania itself would be a narrow and misleading approach, since the competitors may be also situated in other countries in the wider region.

### 7.3.1 Competiveness in a Liberalised Market

Nuclear power is amongst the most capital intensive power generation technologies with a share of at least 50% of capital cost in total power production cost. In a competitive liberalised market, which is inevitably characterised by higher interest rates than the regulated market model, capital-intensive technologies face a significant disadvantage. In the case of NPP specific risk factors – such as the complex nature of the project, the prototype character and the long-term cost risks related to decommissioning waste management – add up to a risk uplift to the interest rate which is inherent only to NPP projects.

This additional financing risk can be reduced only by an engagement of the state in the project – by means of a cap for decommissioning and waste management costs or by loan guarantees. In this context it is symptomatic that the IAEA supports the view, that there is only very limited probability for any new constructed NPP without direct government support (IAEA 2008). The US Nuclear Power 2010 programme chooses the instrument of extensive loan guarantees. And also in the case of the EPR construction in Olkiluoto, Finland, comprehensive loan guarantees have been applied in order to reduce the interest rate by transferring risk to the tax payer.

It has to be underlined, however, that in a liberalised market, there exists strict regulation for government aid and therefore only limited potential for government support.

## 7.4 Conclusions: Preliminary assessment of the cost efficiency of the proposed NPP project compared to alternative options

The EIA report does not compare the proposed NPP project to alternative options. It has to be underlined, however, that the economic meaningfulness of the proposed NPP project has to be demonstrated in comparison to other options. This is all the more the case in liberalised electricity markets where the economic success of the project is no longer a matter of regulation but of its cost efficiency compared to its competitors.

The economic meaningfulness and cost efficiency of the proposed NPP project is questionable for a number of reasons:

- It was not the mandate of this assessment to catch up with the shortcoming of the EIA report by presenting a comprehensive Least Cost Analysis of power supply extension in Lithuania. But in any case conclusions by analogy may be driven from similar cases. Preliminary calculations on a **full cost basis**[2] show that a newly constructed NPP has a chance to be cost effective compared to other power plant options only under very specific framework conditions: Overnight construction cost of maximum 2,000 to 2,200 €/kW$_{el}$; O&M cost (except possible cost for backfitting) in a range up to € 70/kW$_{el}$a; avoidance of construction time overrun; reliable operation with at least 7,500 h operation time per year; low interest rate of 4–5%.
- All these assumptions by themselves are risky; assuming them as a package is highly risky, in particular for generation III NPP, where basically no practical construction and operation experience exists. In fact, we may assume that the risk for cost overruns as well as for completion delays is very high. The cost risk during operation may be assumed somewhat lower. Potential risks relating to decommissioning and nuclear waste management are not taken into account at this point because usually they play only a minor role in the investment decision.
- In a liberalised market the specific risk factors of NPP as described above may add up to a risk uplift to the interest rate compared to other less risky power supply options.
- When proceeding to the **electricity system level** additional aspects show up that will further deteriorate the cost effectiveness of the proposed NPP by reducing the its probable running time which is a crucial factor in this context:

  In Lithuania itself several “must-run” power plants will be implemented with high probability within the next five to ten years. Firstly in the district heating sector, for which the National Energy Strategy 2007 targets at considerable extension of power produced from cogeneration up to an amount of at least 35% of the total power balance by 2020. In addition some potential for CHP in the industrial sector may be assumed.

  Following to the European Directive on electricity production from renewables Lithuania will increase its share of renewable electricity up to 7% by 2010, and for the further future till 2025 we may expect even a higher share, since there is considerable potential for electricity production from biomass as well as from wind.

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[2] Full cost comparisons come up with more favourable results for a base load NPP than calculations on a system level that take into account the country-specific load profiles.

- In addition the integration of the Baltic electricity system to the Nordic and the UCTE systems will be enforced by two new transmission lines to Poland and Scandinavia which are under preparation. Together with the already existing strong integration to the Russian system (including Kaliningrad), this will add to a much easier access to base load power from those markets – and thus to more competition with imported base load.

# 8 REACTOR TYPES

Two RBMK units form the Ignalina NPP site. Each reactor unit has a net electrical capacity of 1,300 MW. Operation of these reactors has started in 1977 and 1978, respectively. Unit 1 has been closed at the end of 2004, unit 2 is scheduled for shutdown at the end of 2009.

The new NPP shall replace Ignalina unit 1 and 2. Electric capacity of the new NPP shall be up to 3,400 MWe. In the EIA Report 11 different reactors are presented, which are offered by Areva, General Electric-Hitachi, Westinghouse-Toshiba, Atomic Energy of Canada Ltd., Mitsubishi Heavy Industries and Atomstroyexport.

Nucleonics Week reports that a spokesman for the company Lietuvos Energija AB charged with organizing the investment said in an interview (NW 25-Sep-08) that four Western reactor vendors are being considered to supply the new Ignalina NPP: Areva, Westinghouse, General Electric Hitachi and Atomic Energy of Canada Ltd. Even if this is confirmed by the Lithuanian responsible authorities, a considerable number of reactor options must be evaluated.

## 8.1 Treatment in the in the EIA Report

Section 5.1 of the EIA Report begins with a general description of the basic principles of a nuclear power plant, and of three basic design types (PWR, BWR and CANDU) in particular.

A detailed specification of technical requirements is not presented in the EIA Report, since such specifications will be developed separately as the project proceeds. However, the European Utility Requirements (EUR) are described in section 5.1 as a principal source of technical requirements for the new NPP project. The development of EUR, the document structure and key safety requirements are presented.

In section 5.2, a general description of the design and key safety features for the 11 reactor designs being considered for the new NPP is presented. For each reactor type, development history and basic design features are briefly described. Core damage frequency (CDF) and large release frequency (LRF) are provided in most cases, as well as information on efficiency, fuel enrichment and burn-up, MOX capability and spent fuel arisings.

The status of certification processes is also presented, as well as information on expected construction times. A schematic figure is included for each reactor type.

The description of the various reactor types in the EIA Report is fairly uniform; however, in some case data are missing.

A selection of important information for each reactor type is presented in the tables 2 to 11 below. This information is taken from the EIA Report and supplemented from the published literature.

Section 5.3 contains the fundamentals of nuclear safety. After a brief overview of the history of nuclear power in Lithuania and the laws and international Conventions related to nuclear energy which are implemented in this country, the IAEA Safety Principles as published in the IAEA Safety Standards Series No. SF-1, 2006, are described.

This is followed by a very general discussion of defence in depth, high-quality operation and safety culture, provisions for accidents and incidents, prevention of radioactive releases, development of reactor safety systems through the reactor generations I to III+ and safety assessment.

Nuclear safety administration in Lithuania is briefly described, including requirements for nuclear power plants laid down by the licensing authority VATESI and by IAEA. Again, it is pointed out the relevant documents for the new nuclear power plant will be defined under a later stage of the project.

It is made clear that in any case, the new nuclear power plant will have to meet the following requirements regarding core damage frequency (CDF) and large release frequency (LRF) by a significant margin: CDF<1E-5/yr, LRF <1E-6/yr. The plants must be designed to withstand external threats and terrorism, including the collision with a large passenger airplane.

Finally, the steps in the development of the projects are explained:

- EIA procedure
- Government Resolution and ratification by Parliament (at this time, neither the plant supplier nor the safety standards in detail will be chosen)
- Selection of plant type
- Compilation of preliminary safety analysis report, submission to VATESI
- Construction license
- Final safety analysis report compiled, and reviewed by VATESI
- Operating license

### 8.1.1 Information on reactor types

Information on the reactor types discussed in the EIA Report is presented in the following tables 2-12.

Part of this information is taken from the EIA Report; additional information was researched by the authors, mostly from publications of plant designers and other nuclear industry sources, and from IAEA.

The reactor types are listed in the tables in the same order they are listed in the EIA Report. Information for which no source is explicitly mentioned is taken from the EIA Report.

For the row “Certification”, EUR certification, NRC certification and the current UK safety assessment has been taken into account.

The row “Units existing” includes units in operation, under construction or firmly planned with start-up of construction in the near future.

In the row “Special features”, the most important features which go beyond Generation II plants are listed.

*Table 2: European Pressurized Water Reactor*

| EPR | European Pressurized Water Reactor |
|---|---|
| Basic type, output | PWR, 1,660 MWe |
| Manufacturer | AREVA NP (France/Germany) |
| Origin | Developed from the German KONVOI and French N4 PWR types |
| Certification | EUR certified<br>NRC certification process ongoing<br>UK assessment ongoing |
| Units existing | 2 units under construction:<br>Olkiluoto-3 (Finland); start of construction 2005, original estimate of start-up 2009. Due to problems with quality control in 2006 and further delays in 2007, the schedule slipped to about 2011 so far (NEIMAG 2007).<br>Flamanville (France); start of construction 2007, expected start-up 2012 (WNIH 2008). Schedule threatens to slip due to problems with quality control similar to those at OL-3. |
| Basic data | Efficiency 36–37%<br>Enrichment 5%, up to 100% MOX capability<br>Burnup 65 MWd/t<br>Spent fuel arisings 27.7 t/yr<br>Construction time 45 months |
| Safety principle | Evolutionary design; mostly active safety systems |
| Special features | Core-catcher for reactor core in case of meltdown<br>In-containment refuelling water storage tank (combines coolant storage and sump function – switchover from safety injection to sump recirculation is avoided)<br>(EDF 2006)<br>Double containment (inner hull pre-stressed concrete with metallic liner; outer hull reinforced concrete) |
| PSA results | Olkiluoto-3 CDF (external and internal initiators, operation and outages) = 1.8E-06/yr<br>Frequency of exceeding release limit (100 TBq Cs-137, plus other nuclides) = 1.0E-07/yr<br>(STUK 2005)<br>Flamanville CDF (ext. and int. initiators, op. and out.; seismic analysis not complete, internal explosions not included) = 1.33E-06/yr (EDF 2006)<br>The same value is given for the EPR applied for in the UK (UK-EPR 2008)<br>EIA Report: CDF <3.9E-07/yr, LRF <6.0E-08/yr |

*Table 3: Siedewasserreaktor 1000*

| **SWR-1000** | **Siedewasserreaktor (Boiling Water Reactor) 1000** |
|---|---|
| Basic type, output | BWR, 1,254 MWe |
| Manufacturer | Siemens/AREVA NP (France/Germany) |
| Origin | Developed by Siemens-KWU in the 1990s, based on the concept of the SWR-300<br>The SWR-300 was developed in the 1980s as a small, inherently safe BWR |
| Certification | EUR certified |
| Units existing | No units are in operation, under construction or firmly planned today |
| Basic data | Efficiency 37%<br>Enrichment 3.54% (AREVA 2008)<br>Burnup 65 MWd/t<br>Spent fuel arisings 24.6 t/yr<br>Construction time <48 months |
| Safety principle | Extensive use of passive safety systems |
| Special features | Passive safety systems – e. g. containment cooler, passive flooding and emergency condensers for core cooling, passive pulse generator for initiation of safety systems<br>(The reactor, however, does not entirely rely on passive systems for accident control; there is a combination of active and passive measures. It is claimed that passive systems and active systems each are alone sufficient to provide adequate cooling of the reactor core in case of an accident.)<br>In-vessel retention of damaged core – external cooling of RPV by flooding of the reactor shaft (passive via the containment cooler)<br>(BRETTSCHUH & SCHNEIDER 2001)<br>Increased water inventory in the reactor pressure vessel.<br>Simplified systems – e.g., removal of feedwater tank. |
| PSA results | CDF for internal events = 1.1E-07/yr (5.0E-08/yr for power operation, 6.0E-08/yr for shut-down)<br>(BRETTSCHUH & MESETH 2000, BRETTSCHUH & SCHNEIDER 2001)<br>EIA Report: CDF <8.4E-08/yr, LRF <8.4E-09/yr |

*Table 4: Advanced Boiling Water Reactor*

| **ABWR** | **Advanced Boiling Water Reactor** |
|---|---|
| Basic type, output | BWR, 1,300 MWe |
| Manufacturer | Hitachi/Toshiba/General Electric (Japan/USA) |
| Origin | Originally designed by GE, developed from older GE BWR designs |
| Certification | EUR certified<br>NRC certified<br>UK assessment ongoing |
| Units existing | 5 in operation, all in Japan (begin of commercial operation):<br>Kashiwazaki-Kariwa-6 (1996), -7 (1997)<br>Hamaoka-5 (2005)<br>Higashidori-1 (2005)<br>Shika-2 (2006)<br>4 under construction (2 in Japan, 2 in Taiwan):<br>Fukushima-Daiichi-7, J (start-up planned 2006?)<br>Shimane-3 (2011), J<br>Lungmen-1, -2, T (2009, 2010)<br>2 “firmly planned” in Japan: Kaminoseki-1, -2 (start of construction 2009/2012, operation 2014/2017) (WNIH 2008) |
| Basic data | Efficiency 33%<br>Enrichment 2.22% initial (GE 2008). Burnup ??<br>Spent fuel arisings 28.7 t/yr<br>Construction time 39 months |
| Safety principle | Evolutionary type; mostly active safety systems |
| Special features | “Simplified active safety systems”. In case of LOCA, plant response has been fully automated and operator action is not required for 72 hours, the same capability as for passive plants (DNE 2008)<br>Some passive severe accident mitigation features (BEARD 2007)<br>Spreading area in lower drywell and passive drywell flooding system to guarantee coolability of core debris (IAEA 2004, BEARD 2007)<br>This latter feature seems to apply to the US ABWR only. The sources above are not fully clear in this respect, but a paper on Kashiwazaki-Kariwa does not mention a capability of ex-vessel core cooling (TSUJI 1998).<br>Internal recirculation, reduced number of forgings. |
| PSA results | Internal events CDF = 1.6E-07/yr, high seismic margins claimed, LRF <1.0E-9/yr<br>(The contribution of mode 6 (refuelling) to CDF is reported to be 99%, so no level 2 (PSA) would be required.) (BEARD 2007)<br>EIA Report: CDF <1.6E-07/yr (LRF – typing error) |

*Table 5: Economic Simplified Boiling Water Reactor*

| **ESBWR** | **Economic Simplified Boiling Water Reactor** |
|---|---|
| Basic type, output | BWR, ca. 1,550 MWe |
| Manufacturer | General Electric (USA) – Hitachi (Japan) |
| Origin | Developed from GE SBWR (Simplified BWR) and ABWR (see above) |
| Certification | NRC certification process ongoing, design certification expected 2009 or 2010 (WNA 2008) |
| Units existing | No units are in operation, under construction or firmly planned today |
| Basic data | Efficiency 34.7%<br>Enrichment 4.2%<br>Burnup 60 GWd/t<br>Spent fuel arisings 30.2 t/yr<br>Construction time 36 months |
| Safety principle | Extensive use of passive safety systems |
| Special features | Passive safety systems (e. g. passive core cooling with GDCS (gravity-driven cooling system); passive containment cooling system<br>No operator action needed for design basis accidents for 72 hours (IAEA 2004)<br>Core catcher with passive flooder (HINDS & MASLAK 2006)<br>Generally – reduced and simpler systems, reduced materials and buildings. |
| PSA results | CDF = 3.0E-08/yr (no specification internal/external or plant state) (HINDS & MASLAK 2006)<br>CDF = 6.16E-08/yr (without external hazards; 45% at-power, 55% shutdown; 34% internal events, 66% internal hazards) (UK-ESBWR 2008)<br>EIA Report: No data provided |

*Table 6: Advanced Passive Reactor 600*

| **AP-600** | **Advanced Passive Reactor 600** |
|---|---|
| Basic type, output | PWR, 600 MWe |
| Manufacturer | Westinghouse (USA) – Toshiba (Japan) |
| Origin | Designed as part of the Advanced Light Water Reactor (ALWR) Program in the USA in the 1990s.<br>More innovative than other reactor types discussed here; not directly developed from a Generation II plant |
| Certification | EUR certified<br>NRC certified |
| Units existing | No units are in operation, under construction or firmly planned today |
| Basic data | Efficiency 33%<br>Enrichment ??<br>Burnup ??<br>Spent fuel arisings 10 t/yr<br>Construction time |
| Safety principle | Extensive use of passive safety systems |
| Special features | Passive safety systems for emergency core cooling and containment cooling.<br>In-containment refuelling water storage tank for long-term core cooling.<br>In-vessel retention of damaged core – passive flooding of reactor cavity from in-containment refuelling water tank.<br>“Simplified design” with fewer valves etc. – as for AP 1000, see below (WEC 2008). |
| PSA results | CDF = 3.0E-07/yr (no specification internal/external or plant state) (VIJUK 1999)<br>EIA Report: CDF <1.7E-07/yr, LRF <1.0E-08/yr |

*Table 7: Advanced Passive Reactor 1000*

| **AP-1000** | **Advanced Passive Reactor 1000** |
|---|---|
| Basic type, output | PWR, 1,117 MWe |
| Manufacturer | Westinghouse (USA) – Toshiba (Japan) |
| Origin | Developed from AP-600. |
| Certification | NRC certified<br>UK assessment ongoing |
| Units existing | No units in operation or under construction yet.<br>4 units "firmly planned" in China. Sanmen-1, -2: Start of construction 2009, commercial operation 2013; Haiyang-1, -2: No data given (WNIH 2008) |
| Basic data | Efficiency 32.7%<br>Enrichment 4.95%, 100% MOX capability<br>Burnup ??<br>Spent fuel arisings 18.6 t/yr<br>Construction time 36 months |
| Safety principle | Extensive use of passive safety systems |
| Special features | Relies on passive safety systems to a large extent – e. g. passive core cooling, containment isolation, containment cooling system, MCR emergency habitat system. Most, but not all valves aligning the safety systems are fail-safe<br>"Simplified design" (50% fewer valves, 35% fewer pumps, 80% less pipes, 45% less building volume, 70% less cable)<br>Increased safety margins in case of DBAs<br>In-vessel retention of damaged core external cooling of RPV with inventory from in-containment refuelling water storage tank<br>(BRUSCHI 2004, WEC 2007) |
| PSA results | CDF = 5.0E-07/yr, LRF = 6.0E-08/yr (WEC 2007)<br>CDF = 4.0E-07/yr (BRUSCHI 2004)<br>LRF = 1.95E-08/yr (IAEA 2004)<br>(in all three cases, no specification regarding inclusion of external/internal, operation/shutdown are provided)<br>EIA Report: CDF <2.4E-07/yr, LRF <3.7E-08/yr |

*Table 8: Enhanced CANDU 6*

| **Enhanced CANDU 6** | **Enhanced Canadian Deuterium Uranium Reactor 6** |
|---|---|
| Basic type, output | PHWR, 740 MWe |
| Manufacturer | Atomic Energy Canada Limited (AECL) |
| Origin | CANDU 6 is a Generation II reactor type.<br>The first CANDU 6 plants went into service in Canada in the early 1980s.<br>The Enhanced CANDU 6 is still under development (AECL 2008) |
| Certification | -- |
| Units existing | Many units of CANDU 6 are operating in 5 countries (e.g. Romania).<br>No unit of the Enhanced CANDU 6 is operating, under construction or firmly planned. |
| Basic data | Efficiency 35%<br>Enrichment – natural Uranium, MOX capability<br>Burnup 7.5 GWd/t<br>Spent fuel arisings 100 t/yr<br>Construction time ?? |
| Safety principle | Combination of active and passive safety systems |
| Special features | Incorporates passive safety systems, e.g. an emergency coolant injection system. |
| PSA results | EIA Report: CDF <4.6E-06/yr, LRF <1.0E-08/yr |

*Table 9: Advanced CANDU Reactor (ACR-1000)*

| **ACR-1000** | **Advanced CANDU Reactor 1000** |
|---|---|
| Basic type, output | PHWR, 1,085 MWe |
| Manufacturer | Atomic Energy Canada Limited (AECL) |
| Origin | ACR has been developed from CANDU 6. |
| Certification | -- |
| Units existing | No units in operation, under construction or firmly planned yet. |
| Basic data | Efficiency 37%<br>Enrichment 1–2%<br>Burnup >20 GWd/t (PETRUNIK 2007)<br>Spent fuel arisings 72.1 t/yr<br>Construction time 42 months |
| Safety principle | Combination of active and passive safety systems |
| Special features | Light-water-cooled, heavy-water-moderated pressure-tube reactor.<br>Safety systems similar to those of the Enhanced CANDU 6.<br>Water-filled reactor vault for severe accident mitigation; cooling by natural circulation, initiated manually (PETRUNIK 2007).<br>Steel-lined containment building, wall thickness 1.8 m (PETRUNIK 2007). |
| PSA results | EIA Report: CDF <3.4E-07/yr, LRF “correspondingly lower” |

*Table 10: Advanced Pressurized Water Reactor*

| **APWR** | **Advanced Pressurized Water Reactor** |
|---|---|
| Basic type, output | PWR, 1,600–1,700 MWe |
| Manufacturer | Mitsubishi Heavy Industries |
| Origin | Developed from Mitsubishi PWRs (Westinghouse was involved earlier)<br>For the US market, MHI developed the US-APWR, a slightly modified APWR complying with US regulations |
| Certification | EUR certification process ongoing (submitted for design certification March 2008 (AUA 2008))<br>NRC certification process ongoing |
| Units existing | Two units are definitely planned in Japan (Tsuruga-3 and -4, start of construction reported as 2007, start of operation 2014 and 2015) (WNIH 2008)<br>License application for the first two US-APWRs (site in Texas) expected for 2008 (NEI 2007) |
| Basic data | Efficiency 39%<br>Enrichment max. 5% (MHI 2007a)<br>Burnup 62 GWD/t<br>Spent fuel arisings 24 t/yr<br>Construction time ?? |
| Safety principles | Combination of active and passive safety systems |
| Special features | Simplified ECCS – integrating low pressure injection systems and accumulators<br>In-containment refuelling water storage tank (combines coolant storage and sump function – switchover from safety injection to sump recirculation is avoided)<br>Floor below reactor cavity with 1 m thick protective layer of concrete for molten debris; to be cooled there from the fire service water system. Molten debris will be coolable; erosion of concrete can be prevented. Outlet from RPV cavity to containment considered to be constructed like a labyrinth.<br>(IAEA 2004)<br>In-vessel retention of molten core can be attempted by external pressure vessel cooling; however, it is not credited for the US-APWR (MHI 2007b). |
| PSA results | CDF expected to be at least one order of magnitude lower than for existing 4-loop PWRs, i.e. about 1.0E-07/yr (IAEA 2004)<br>EIA Report: CDF <1.0E-05/yr, LRF <6.0E-08/yr |

*Table 11: Vodo-Vodyanoy Energeticheskiy Reactor 1000*

| **VVER-1000/392M (AES-2006)** | **Vodo-Vodyanoy Energeticheskiy Reactor 1000/392M** |
|---|---|
| Basic type, output | PWR, ca. 1,150 MWe |
| Manufacturer | Gidropress/Atomenergoproekt (Russia) |
| Origin | AES-2006 was developed from the AES-92; the AES-92 was developed from the standard VVER-1000/320 |
| Certification | EUR certified (GENERALOV 2007) |
| Units existing | Two units under construction in India (Kundankulam-1 and -2).<br>Two units under construction in Russia (contract signed June 2007): Novovoronezh-2 units 1 and 2 (commercial operation planned 2012/2013). (In the World Nuclear Industry Handbook, the first unit is listed as "under construction", the second one as "reasonably firmly planned".)<br>(WNIH 2008) |
| Basic data | Efficiency ??<br>Enrichment 4.3%<br>Burnup 47 GWd/t<br>Spent fuel arisings 21 t/yr<br>Construction time 54 months |
| Safety principle | Combination of active and passive safety systems |
| Special features | Combination of passive and active safety mechanisms (e. g., passive SG heat removal, passive core cooling systems)<br>Core-catcher for reactor core in case of meltdown ("melt retention in a special device located beneath the reactor vessel").<br>Double containment (two concrete hulls)<br>(GENERALOV 2007) |
| PSA results | "(G)eneral frequency of core damage at a level of 1.0E-07 (/yr)." (GENERALOV 2007)<br>All categories of initiating events, power and shutdown: CDF = 5.4E-08/yr (IAEA 2004)<br>EIA Report: CDF <5.0E-06/yr, LRF <1.0E-08/yr |

*Table 12: Vodo-Vodyanoy Energeticheskiy Reactor 1500*

| VVER-1500/392M | Vodo-Vodyanoy Energeticheskiy Reactor 1500/448 |
|---|---|
| Basic type, output | PWR, ca. 1,500 MWe |
| Manufacturer | Gidropress/Atomenergoproekt (Russia) |
| Origin | The VVER-1500 is at present being developed from the VVER-1000. |
| Certification | -- |
| Units existing | No units in operation, under construction or firmly planned |
| Basic data | Efficiency 31%<br>Enrichment ??<br>Burnup 62 GWd/t<br>Spent fuel arisings 23 t/yr<br>Construction time ?? |
| Safety principle | Combination of active and passive safety systems |
| Special features | Passive systems for boron injection and heat removal.<br>Double containment (two concrete hulls).<br>Both in-vessel and ex-vessel cooling of the molten core are possible.<br>Passive systems can perform all safety functions without contribution of active systems or operator intervention for at least 24 hours (ANTIPOV 2006). |
| PSA results | EIA Report: CDF <5.4E-08/yr, LRF "smaller" |

## 8.2 Discussion

At first an overview on the basic data given in the EIA Report is presented, in order to show which information is missing. This summary is focused on the reactor types of the four manufacturers considered by the Lithuanian company LEO.

*Table 13: Overview of information*

| type | EPR | SWR-1000 | ABWR | ESBWR | AP | AP 1000 | CANDU 6 | ACR-1000 |
|---|---|---|---|---|---|---|---|---|
| manufacturer | AREVA | | GE – Hitachi | | Westinghouse | | AECL | |
| el. capacity | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| constr. time | ✓ | ✓ | ✓ | ✓ | X | ✓ | X | ✓ |
| efficiency | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| enrichment | ✓ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ |
| burnup | ✓ | ✓ | | ✓ | X | X | ✓ | X |
| fuel/yr | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| certification | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X | X |
| CDF | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| LRF | ✓ | ✓ | ?? | X | ✓ | ✓ | ✓ | X |

*(X = Missing, ✓ = provided)*

### 8.2.1 Safety Standards

The general statements regarding functioning of NPPs and principles of nuclear safety in the EIA Report are of very basic character and do not require further comments.

Regarding safety standards, it is obvious that standards for new plants have not been stipulated yet, in detail, in Lithuania.

The European Utility Requirements (EUR) clearly are playing an important role since they are described in some detail in the EIA Report. It is emphasized, however, that they are a source for requirements only, and not binding as such.

The development of standards for new plants will apparently proceed in parallel with the development of the project itself – no details of such standards are mentioned in the EIA Report, and there is no reference to documents which containing further information concerning standards for new plants. This could potentially lead to problems – it could create pressure of time for the compilation of new standards, and furthermore, there is the potential danger that standards will be tailored to suit the project.

The probabilistic safety targets for core damage frequency (CDF <1.0E-5/yr) and large release frequency (LRF <1.0E-6/yr) roughly correspond to those recommended by the IAEA (INSAG 1999). It is stated that new plants have to meet those requirements “by a significant” margin; however, it is not specified what would constitute such a margin.

It is noteworthy that new plants must be designed to withstand the collision with a large passenger airplane. Again, however, this requirement is not specified in detail.

### 8.2.2 Safety Aspects of Reactor Types

#### 8.2.2.1 Dependence on active and passive safety systems:

Among the candidate reactor types, some rely primarily on active safety systems, as do Generation II plants; some are more innovative and depend mostly on passive safety systems. Most types, however, are equipped with a combination of active and passive systems both of which are required to function in case of an accident:

*Table 14: Overview on active and/or passive safety systems in the reactor types*

| Use of active/passive | No. of types | types |
|---|---|---|
| Mostly active | 2 | EPR, ABWR |
| Combination | 5 | Enhanced CANDU 6, ACR-1000, APWR, VVER-1000/392, VVER-1500/448 |
| Mostly passive | 4 | SWR-1000, ESBWR, AP 600, AP 1000 |

In the EIA Report, Generation III reactors with extensive use of passive systems are denominated as Generation III+. However, this terminology is not applied in a consistent manner in the EIA Report; for example, the EPR is listed as “III+” in Table 5.2-1.

It is generally regarded as advantageous if a reactor type depends more on passive rather than active safety systems since technical failures as well as human errors play a considerably smaller role in case of passive systems. On the other hand, active systems can offer more chances of intervention, particularly in case of unforeseen accident sequences.

#### 8.2.2.2 Dependence on in-vessel and ex-vessel cooling of molten core:

It can be attempted to control core melt accidents by cooling and stabilizing the already molten core. Two basic concepts are applicable for reactors with a pressure vessel containing the whole core.

The terminology used here alludes to the location of the core at the time cooling is applied: The concept is called “in-vessel” cooling if the molten core is still in the reactor pressure vessel and it is attempted to stabilize it inside the vessel; “ex-vessel” cooling refers to cooling after the reactor pressure vessel has failed and the melt has left the vessel. (This is the most common use of those terms; they are sometimes also used in a different manner.)

For pressure-tube reactors which do not possess a single reactor pressure vessel, the concepts are clearly not applicable.

*Table 15: Concepts for cooling of molten core*

| In-vessel/ex-vessel cooling | No. of types | types |
|---|---|---|
| In-vessel | 3 | SWR-1000, AP 600, AP 1000 |
| Both | 1 | VVER-1500/448 |
| Ex-vessel | 5 | EPR, ABWR, ESBWR, APWR, VVER-1000/392 |
| Not applicable | 2 | Enhanced CANDU 6, ACR-1000 |

There is little experience in the realization of a “core catcher” for ex-vessel cooling. It appears that the ABWRs taken into operation so far do not have this feature and that only future plants of this type will be equipped with it.

Fundamental problems regarding the functioning of a core catcher have been reported in the last years. For details, see the Austrian Expert Statement to the Loviisa-3 EIA Report (WENISCH et al. 2008).

The concept of in-vessel cooling seems to be more promising and not beset with so many problems. In-vessel cooling has already been implemented as severe accident management measure at the Loviisa NPP (2 units with 488 MWe (net) each) in Finland (CSNI 2002).

However, in-vessel cooling is difficult to implement in larger reactors, due to the surface-to-volume ratio getting less favorable with increasing power. In fact, for the reactor types considered here, there is a tendency of in-vessel cooling being planned for the smaller ones, ex-vessel cooling for the larger.

It is not clear why in-vessel cooling should be possible (as one option) for the VVER-1500/448, which is one of the largest reactor types under consideration here. It is notable that for the APWR, also a large reactor type, there are provisions for in-vessel cooling (filling the reactor cavity with coolant water); but in-vessel retention is not credited for the US-APWR severe accident treatment (MHI 2007b).

### 8.2.2.3 PSA results

PSA results as reported in the EIA Report are compiled for overview in the following table. In the EIA Report, those results are presented in the form “<1.0E-6”. The “smaller than” sign is taken by the authors of this statement to imply that the results are conservative; for simplicity, it is omitted in the table.

Other PSA results which are readily available in the published literature, as already included in the tables for the various reactor types, are also included.

*Table 16: Overview on PSA results*

| Reactor type | CDF (per yr) | | LRF (per yr) | |
|---|---|---|---|---|
| | EIA Report | Other sources | EIA Report | Other sources |
| EPR | 3.9E-7 | 1.33–1.8E-6 | 6.0E-8 | 1.0E-7 |
| SWR-1000 | 8.4E-8 | 1.1E-7 (internal events) | 8.4E-9 | |
| ABWR | 1.6E-7 | 1.6E-7 | --+) | 1.0E-9 |
| ESBWR | -- | 3.0–6.2E-8 (internal events) | -- | |
| AP 600 | 1.7E-7 | 3.0E-7 | 1.0E-8 | |
| AP 1000 | 2.4E-7 | 4.0–5.0E-7 | 3.7E-8 | 1.95 - 6E-8 |
| Enh. CANDU 6 | 4.6E-6 | | 1.0E-8 | |
| ACR-1000 | 3.4E-7 | | -- | |
| APWR | 1.0E-5 | 1.0E-7 | 6.0E-8 | |
| V-392 | 5.0E-6 | 5.4E-8–1.0E-7 | 1.0E-8 | |
| V-448 | 5.4E-8 | | -- | |

+) *The EIA Report states “<1x10$^{-6}$/reactor year”; clearly a typing error.*

For some reactor types, differences between CDF and LRF as reported in the EIA Report and from other sources are considerable. For example, the CDF of the EPR is considerably lower (about ¼) than results published for current EPR projects. On the other hand, CDF of the APWR is very high in the EIA Report (possibly a typing error), and CDF of the V-392 is also notably higher than other published results.

An evaluation and comparison of the numbers as provided in the EIA Report leads to the following observations:

1. CDF varies widely among reactor types – the maximum value (APWR) is higher by a factor of almost 200 than the minimum value (V-448). (Even without the result for the APWR, CDFs span about two orders of magnitude.)
2. There is less variation in the reported LRFs (less than one order of magnitude).
3. The ratio between CDF and LRF varies considerably – from a factor of 6.5 (AP 1000) to factors of 460 (Enhanced CANDU 6) and 500 (V-392).
4. It is stated in the EIA Report that all candidate reactor plants meet the probabilistic requirements (CDF below 1.0E-5/yr, LRF below 1.0E-6/yr) “by a significant margin”. It appears, however, that the requirement for CDF is not fulfilled by APWR, V-392 and Enhanced CANDU-6. (Due to the uncertainties inherent in PSAs, a “significant margin” should be about one order of magnitude.)

The relevance of the different CDF values for the assessment of different reactor types and their candidate status is not discussed in the EIA Report; not even in cases where the CDF as reported in the EIA Report is close to the probabilistic requirement.

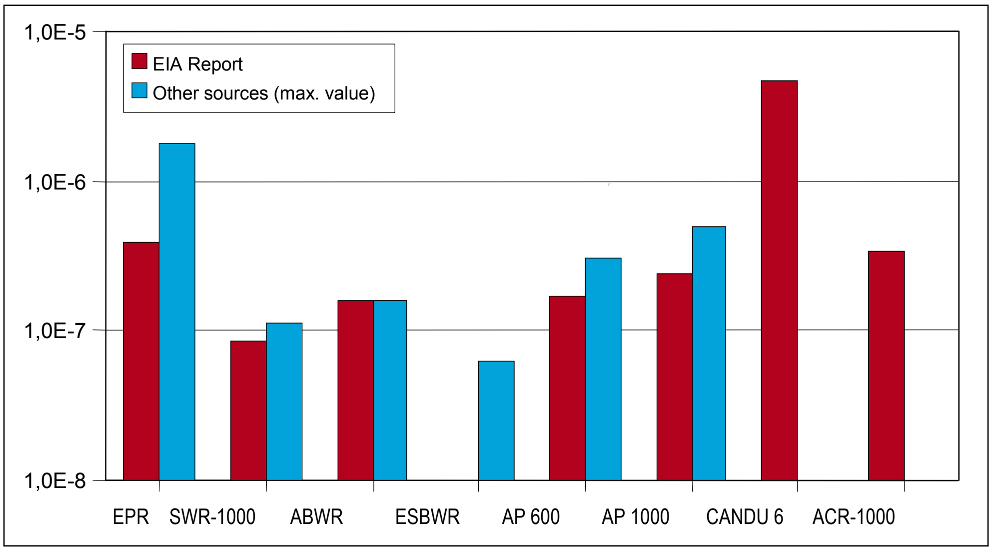

*Figure 3: Core damage frequency as reported in the EIA Report compared to other sources.*

Furthermore, there is no discussion of the variations regarding the CDF/LRF ratio, and reason for the variations. Differences in the CDF/LRF ratio could indicate fundamental differences in reactor design, particularly regarding the control of core damage accidents. On the other hand, they could also be indicative of methodological inconsistencies and/or of high bandwidths of uncertainty in the level 2 PSAs of some reactor types.

Altogether, the synopsis of PSA results with their high variations and uncertainties (and possibly, inconsistencies) shows that it is not appropriate to rely too strongly on probabilistic criteria. The main criteria for the assessment of the reactor types should be deterministic, with the results of probabilistic studies as a supplement only.

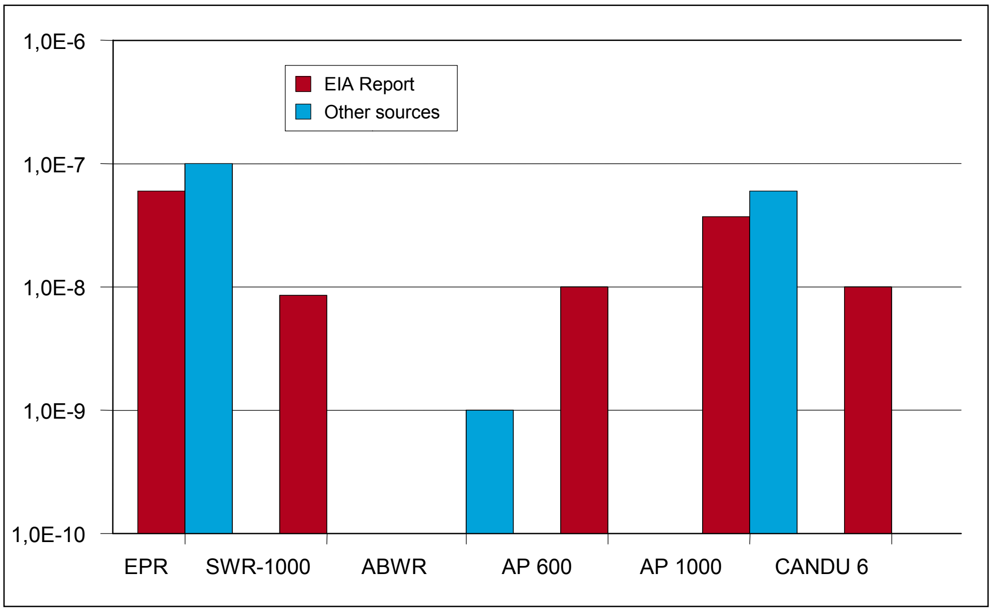

*Figure 4: Large release frequency as reported in the EIA Report compared to other sources.*

### 8.2.3 Other Aspects of Reactor Types

There is little experience with the candidate reactor types considered in the EIA Report, as the following table shows:

*Table 17: Experience with Generation III reactors*

| **Status** | **No. of types** | **types** |
|---|---|---|
| In operation | 1 | BWR |
| Under construction | 2 | EPR, VVER-1000/392 |
| Firmly planned | 3 | AP 1000, APWR, VVER-1500/448 |
| None of the above | 5 | SWR-1000, ESBWR, AP 600,<br>Enhanced CANDU 6+), ACR-1000 |

+) *Basic CANDU 6 (not enhanced) plants in operation since 1980s.*

The only reactor type which has been completely built and taken into operation so far is the ABWR (it appears, however, that provisions for ex-vessel cooling of the molten core will only be implemented at future ABWRs).

Hence, the construction times reported in the EIA Report can only be regarded as very rough estimates. They vary from 36 months (ESBWR, AP 1000) to 54 months (V-392).

For the ABWR, a construction time of 39 months is given in the EIA Report. The construction times for the 5 units operating in Japan (from start of construction to first power) lie between 47 and 75 months (more than half a year more from start of construction to commercial operation) (WNIH 2008).

For the two EPRs under construction, the schedule has already slipped and expected construction time will be considerably longer than 45 months as reported in the EIA Report.

It could be argued that construction times will be gradually reduced as more units of one reactor type are built. However, given the fact that there are many competing types world-wide, it is possible that it will take decades before this effect can be felt, if nuclear units are built at all in large numbers. In any case, projects which will be started in the next few years cannot profit from this effect.

Given this background, the differences in construction times as reported in the EIA Report cannot be regarded as particularly relevant or meaningful.

No numbers are provided regarding the expected availabilities and costs of the various candidate reactor types. This is understandable since such estimates would be at least as hypothetical as estimates for construction times. Cost overruns must be expected when NPPs of new reactor types, for which there is little or no experience, are built. Economic pressure and pressure of time could furthermore lead to problems at the beginning of the operating phase, lowering availability. Any estimate could only be highly speculative.

## 8.3 Conclusions

Safety standards for new nuclear power plants appear to be in a very early stage of development in Lithuania.

The development of standards for new plants will apparently proceed in parallel with the development of the project itself. This could potentially lead to problems – it could create pressure of time for the compilation of new standards, and furthermore, there is the potential danger that standards will be tailored to suit the project.

In as much as there are already considerations regarding standards for new plants in Lithuania, it would be of interest to obtain more information about this topic. Furthermore, a more detailed description of the procedure to develop those standards would be of interest, including an explanation of how this procedure will be timed in relation to the new NPP project, and how it will interact with the development of the project.

The candidate reactor types span a broad spectrum ranging from reactors with a basically tested design and only a few new features, to new, largely untried designs with many new features. However, there is no or very little practical experience for most reactor types.

Some reactor types rely mostly on active safety systems, some on passive systems; some on a combination of both.

It is generally regarded as advantageous if a reactor type depends more on passive rather than active safety systems since technical failures as well as human errors play a considerably smaller role in case of passive systems. On the other hand, active systems can offer more chances of intervention, particularly in case of unforeseen accident sequences.

Furthermore, there is far more general practical experience with active systems. Therefore, it is difficult to judge whether plants with mostly passive safety systems are indeed significantly less susceptible to accidents than plants with active systems.

It would be of interest to have a more detailed description of all candidate reactor types, focusing on the safety systems, as well as an assessment according to their place in the scale “predominantly active” to “predominantly passive”.

Regarding a central feature of accident mitigation, the cooling of the molten core to stabilize the situation and avoid large releases, smaller plants tend to rely on in-vessel cooling of the melt, larger plants on ex-vessel cooling (this feature does not apply to pressure tube reactors like the CANDU).

The concept of in-vessel cooling seems to be more promising and not beset with so many problems as ex-vessel cooling. In-vessel cooling has already been implemented as severe accident management measure at the Loviisa NPP (2 units with 488 MWe each) in Finland. However, the chances of success of in-vessel cooling decrease the larger the capacity of a plant.

A detailed description of the provisions for molten core cooling and stabilizing for all candidate reactor types would be of interest, together with an explanation why in-vessel or ex-vessel cooling was selected (if applicable). Furthermore, an assessment of the chances of success of core stabilization with discussion of the problems to be expected for each reactor type would be helpful to get a picture how susceptible the candidate types are to core melt accidents with large releases.

For most reactor types, PSA results (CDF and LRF) are provided in the EIA Report. In some cases, differences between those and the results reported in other sources are considerable. For example, in the EIA Report the CDF of the EPR is lower by a factor of 4 than results published for current EPR projects.

An evaluation and comparison of the numbers as provided in the EIA Report leads to the following observations:

1. CDF varies widely among reactor types – by a factor of almost 200.
2. There is less variation in the reported LRFs (less than one order of magnitude).
3. The ratio between CDF and LRF varies considerably – from a factor of 6.5 to a factor of 500.
4. The probabilistic requirements appear not to be fulfilled for CDF by APWR, V-392 and Enhanced CANDU-6.

The relevance of the different CDF values for the assessment of different reactor types and their candidate status is not discussed in the EIA Report; not even in cases where the CDF as reported in the EIA Report is close to the probabilistic requirement.

Furthermore, there is no discussion of the variations regarding the CDF/LRF ratio, and reason for the variations. Differences in the CDF/LRF ratio could indicate fundamental differences in reactor design, particularly regarding the control of core damage accidents. On the other hand, they could also be indicative of methodological inconsistencies and/or of high bandwidths of uncertainty in the level 2 PSAs of some reactor types.

Altogether, the synopsis of PSA results with their high variations and uncertainties (and possibly, inconsistencies) shows that it is not appropriate to rely too strongly on probabilistic criteria.

The main criteria for the assessment of the reactor types should be deterministic. The results of probabilistic studies can be used as supplement, however, to get as complete a picture as possible regarding the susceptibility to accidents of different reactor types.

A detailed presentation of the PSA results of the candidate reactors would be of interest (including the contributions of different events and plant states), as well as a discussion of their limitations and the bandwidths of their uncertainty. With this background, the differences in the results as indicated above should be discussed and assessed.

The overall importance of probabilistic and deterministic requirements for evaluating reactor designs and the relationship of the two approaches should also be explained.

Data on construction time, availability and cost would be of interest as supplementary information, in principle. Estimates for construction time are provided for most reactor types; however, they can only be regarded as hypothetical. There is no information on expected availability and costs in the EIA Report.

This is understandable since such estimates would also be highly hypothetical. They could be meaningful for a comparison of reactor types only if they are determined by the same methods, for types which are in a similar stage of development.

# 9 ACCIDENT ANALYSIS

## 9.1 Treatment in the EIA Report

### 9.1.1 Risk Assessment

Section 10, Risk Analysis and Assessment, presents a classification of events according to their probability of occurrence (PO) and potential consequences:

**Anticipated operational occurrence** (AOO) (no damage to fuel); PO 1E-2 to 1/a

**Design base accident** (DBA): no radiological impact outside the exclusion area (population dose <10 mSv): PO 1E-4 to 1E-2/a

**Beyond design base accident** (BDBA): radiological consequences outside exclusion area within limits; PO 1E-6 to 1E-4/a

**Severe accident** (SA): accident involving damage of a large part of the fuel and release of a large amount of radionuclides into the containment; limit = no acute health effects to the population in the vicinity of the NPP, no long term restrictions on use of land and water; PO <1E-6/a (EIA Report 2008, 479)

Internal initiating events considered in the design basis are not listed in section 10.

External events are listed in sub-section 10.2.2 but without details concerning the design basis of the new NPP.

Following these explanations, IAEA’s International nuclear event scale (INES) is presented in order to illustrate the significance of nuclear accidents.

The conclusion is presented in sub-section 10.2.4 as table 10.2.3 „Risk analysis of potential accidents“. This classification includes consequences to life and health, environment, property, as well as probability of occurrence, speed of development and the prioritization of consequences. Table 10.2.3 also includes preventive measures. The chosen assessment scheme is from the “Recommendations for assessment of potential accident risk of proposed economic activity” and not specified for nuclear facilities.

The ranking (priority) of hazards In table 10.2.3 results in the assessment of extreme events such as aircraft crash and terrorist attacks as BDBA which could cause damage to the NPP building structures and a release of radioactivity. The probability of this event is assessed as “improbable“ (<1E-3/a) and the consequences as ”serious“. Concerning “preventive measures“ it is said to be expected that all new NPPs will demonstrate the capability to withstand the effect of aircraft crash. Another BDBA is described as the simultaneous failure of multiple safety systems during operation resulting in core damage (CDF <1E-4/a and LRF <1E-6/a). Probability of this event is „improbable“, the consequences are assessed as „very serious“. The severe accident is an accident with containment failure which results in catastrophic consequences. More likely severe accident sequences do not result in containment failure for 72 hours, the low frequency sequences do not result in containment failure in less than 24 hours. (EIA REPORT, p 485ff, table 10.2.3)

### 9.1.2 Source term

**Design base accident**

In the EIA Report a source term for a DBA (Loss of coolant accident) is presented, in table 10.3.1 (Time-dependent released activity into environment in case of LOCA (DCD US-APWR, 2007). In this table, the total release is given as 3 TBq Cs-137 and 350 TBq I-131. In the same section it is said that this release can be rated as INES Level 5 event (EIA REPORT p 491), which is defined as external release in quantities radiologically equivalent to 100 to thousands of Terabecquerel of Iodine 131 (EIA Report p 481).

**Severe accident**

Because there are no regulations for releases in case of severe accidents in Lithuania, the EIA report states that the Finnish limit of 100 TBq Cs-137 is used to represent a typical large release scenario. (EIA REPORT, p 491). Table 10.3.2 gives the core inventory and releases of 15 nuclides, among them the release of 100 TBq Cs-137 and 1,000 TBq I-131.

### 9.1.3 Investigations of long-range consequences

**Methodology of the EIA**

The EIA Report contains maps of the 98th percentile of various radiological parameters, such as ground contamination and different doses, derived from dispersion model simulations of 730 cases with day-time and 730 cases with night-time releases. Thus, the upper 2% whose lower boundary is given on the maps are comprised of ca. 2 x 15 cases.

These maps have been constructed for the LOCA DBA and a severe accident (SA), with releases of ca. 3E12 Bq Cs-137 and 3E14 Bq I-131 for the DBA, and 1E14 Bq Cs-137 and 1E15 Bq I-131 for the SA.

The model simulations have been carried out with SILAM system developed by the Finnish Meteorological Institute (http://silam.fmi.fi). This is called a Lagrangian-Eulerian modelling framework in the EIA, but the dispersion model itself is a purely Lagrangian particle dispersion model. It is said that the model was run with meteorological data from the ECMWF operational archive for the years 2001 and 2002. Output was generated on two domains, a small one with 2.5 km grid size, and a large one with 25 km grid size. This approach is in principle a state-of-the-art approach, though we found that further details of the model setup are not provided.

The EIA argues that this approach replaces what it calls the “artificial ‘worst case’” as it would be obtained by running a Gaussian model (with a finite set of possible input parameter combinations, or analytically determined maximum). We agree with the authors of the EIA that the present approach is better, both with respect to the degree of realism of the model and with respect to the fact that meteorological conditions are sampled that really occurred. The argument that the model is more realistic holds especially for transports over distances from 20 km to hundreds or thousands of kilometres which could not be modelled realistically with a Gaussian model. However, for the close neighbourhood, the SILAM model appears to be not fully representing the state of the art and in a way falls even behind the Gaussian model, as it assumes pure random walk in a fully mixed atmospheric boundary layer, implying a simplified treatment of dispersion in the boundary layer. (SOFIEV et al. no year).

The EIA authors argue that the 98th percentile and not the maximum (i.e., the 100th percentile) should be used because the latter is too sensitive to statistical variability. It is of course true that the 100th percentile is more prone to statistical fluctuations than the 98th. However, as is visible in the results, even the 98th percentile maps exhibit a good deal of statistical fluctuations. On the other hand, Fig. 10.3-1 of the EIA shows that towards the south of the site, the 100 Bq/m² (I-131 for LOCA) line moves from a distance of about 150 km in the case of the 98th percentile to about 550 km in the case of the 100th percentile. The authors speak about "significant and irregular jumps" but this pattern does not look irregular. It shows clearly that inside these highest 2% there is still a big variability, or with other words, that the worst case – even among the limited set of situations probed by the calculations – the maximum will be much higher than the 98th percentile, especially at longer distances where the behaviour of the contamination becomes even more episodic.

## 9.2 Discussion

### 9.2.1 Risk Assessment

Section 10, Risk Analysis and Assessment discusses the hazards of DBA and BDBA sequences. The classification in table 10.2.3 does not distinguish between low frequencies of occurrence: all incidents with a frequency of occurrence below 1E -3/a are rated as „improbable". In contrast to that, IAEA targets differentiate clearly between 1E-4 and 1E-5. And also the Lithuanian regulation demands that core damage frequency should not exceed 1E-5/a, and that "an effort should be made to ensure that the probability of the worst possible emergency release of radioactive materials specified in the standards does not exceed 1E-7/a". (VD-B-001-0-97)

It would be more instructive to present more information from PSAs which give an adequate illustration of the radiation hazard instead of a ranking which appears to be adequate for less hazardous industrial activities.

### 9.2.2 Source term

The source term chosen as representative for a severe accident in a Generation III reactor by the EIA Report, is not justified by any arguments. In Finnish regulation the 100 TBq Caesium release is set as limit for radiation protection. It is a probabilistic target for limited releases due to an accident. A large release (exceeding this limit) should have a probability of occurrence of <5.0 E-7/a.

PSA results for the EPR indicate that 9% of all core damage scenarios lead to late containment failure and 6% to early containment failure. (WENISCH et al. 2008) These are the accidents relevant for the assessment of transboundary impacts.

The release rates of such accidents are in the range of 2% to 20% for iodine and caesium as assessed for the EPR. These release rates are derived from the PSA level 2 results for the large German Konvoi reactor (GKN-2). According to this PSA

18% of the large release scenarios are due to late non filtered release from annular space.(WENISCH et al. 2008 b). The release rates for the ABWR are in the same range, according to the design control document for the ABWR (suppression pool bypass scenario) (DCD ABWR). A release rate of about 1% would give more than 1,000 TBq Cs-137 and 10,000 TBq I-131, respectively, if the source term is based on the core inventory of the APWR as given in the EIA Report (EIA report, p 493), showing that the assumed source term of 100 TBq Cs-137 and 1,000 TBq I-131 used in the EIA Report is rather low for the investigation of severe accident consequences. Therefore, for the Austrian evaluation of transboundary impacts a release of 5% of the Cs-137 core inventory of 714 PBq Cs-137 was applied, which amounts to 35,5 PBq. We consider this as a possible release in the case of a severe accident in a "Generation III" reactor.

Section 10, Risk Analysis and Assessment, includes investigations of long-range and transboundary consequences of accidents at the plant, both DBA and so-called severe accidents. This is a very positive step, and in some way it follows the route taken by a nuclear risk assessment method developed in Austria many years ago in the project RISKMAP (ANDREEV et al. 1998, HOFER et al. 2000, RISKMAP no year). In the following, we discuss both the methodology and the results of the analysis, and provide our own view of the possible risk to Austria.

EIA results shown indicate that the territory of Austria would not be affected much: >10 Bq I-131/m$^2$ (Fig. 10.3-8, 10.3-14) and >0.1 Bq Cs-137/m$^2$ (Fig. 10.3-9, 10.3-15) for the SA. However, the assumed release of 100 TBq (1E14 Bq) Cs-137 is rather low for a SA. Given the fact that no construction has been selected for the plant, and that even no reactor of the type suggested exists presently, it would be cautious to also consider larger releases in the PBq range, as explained above. Furthermore, as also explained above, the worst case even just among those cases studied is likely to be considerably higher than the 98th percentile. Therefore, the results shown in the EIA cannot exclude that Austria would be affected by a severe accident in the proposed nuclear power plant.

#### 9.2.2.1 Austrian evaluations

The Austrian evaluations are based on two different methods.

The first method dispersion calculations made with the Lagrangian particle dispersion model FLEXPART (STOHL et al. 1998) in the RISKMAP project (ANDREEV et al. 1998, HOFER et al. 2000, RISKMAP no year). In this project, 88 cases during the year 1995 were studied. On each day, the release was started at a different time of the day, and assumed to last 1 hour. Then the total (wet and dry) deposition of Cs-137 was evaluated over Europe.

In Figures 5 and 6, we show the result for the worst case found among the 88 releases from the Ignalina site, applying a source term of 5% from reactor inventory – see chapter 8.1.5. We consider this a possible release in the case of a severe accident in a "Generation III" reactor. The first illustration (fig 5) gives an overview of the contamination in Europe caused by the release. Fig. 5 shows all of Europe with a coarser output resolution, Fig. 6 shows only central Europe but with an improved resolution of 0.5° in E-W direction and 0.33° in N-S direction. Due to the differences in the underlying resolution, there are also minor differences in the contamination features.

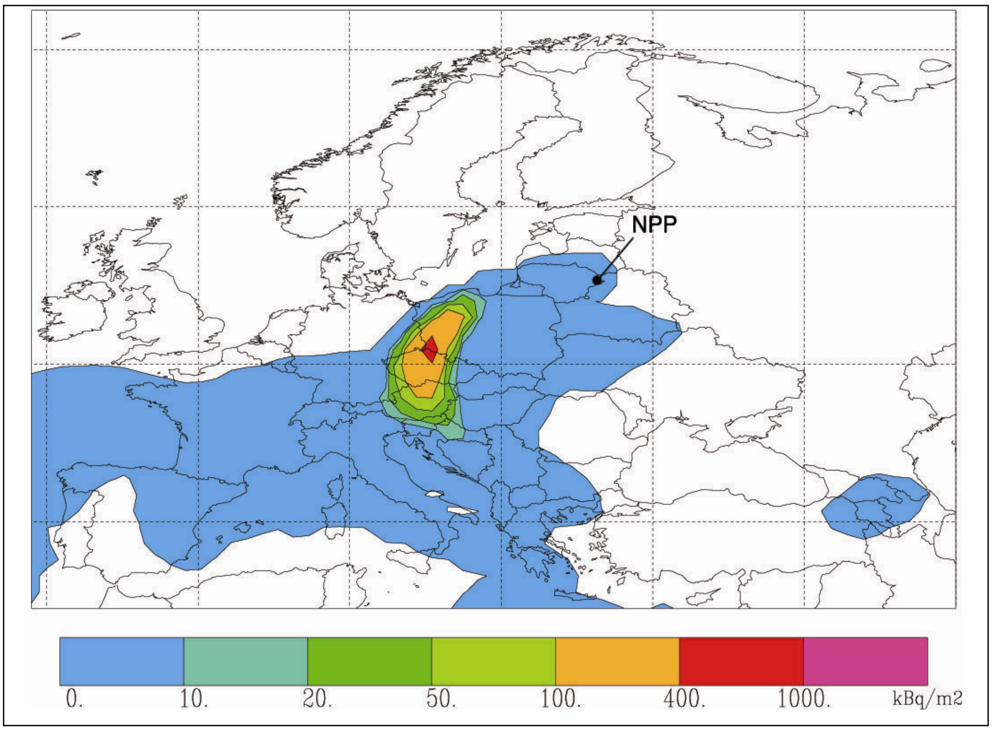

*Figure 5: Example of deposition of Cs-137over Europe resulting from a hypothetical severe accident in the new Ignalina NPP, assuming a release of 35.5 PBq in the hour after 1995-06-25 14:567. Output grid size is 1°. The outer border of the blue colour is at 0.1 kBq/m$^2$.*

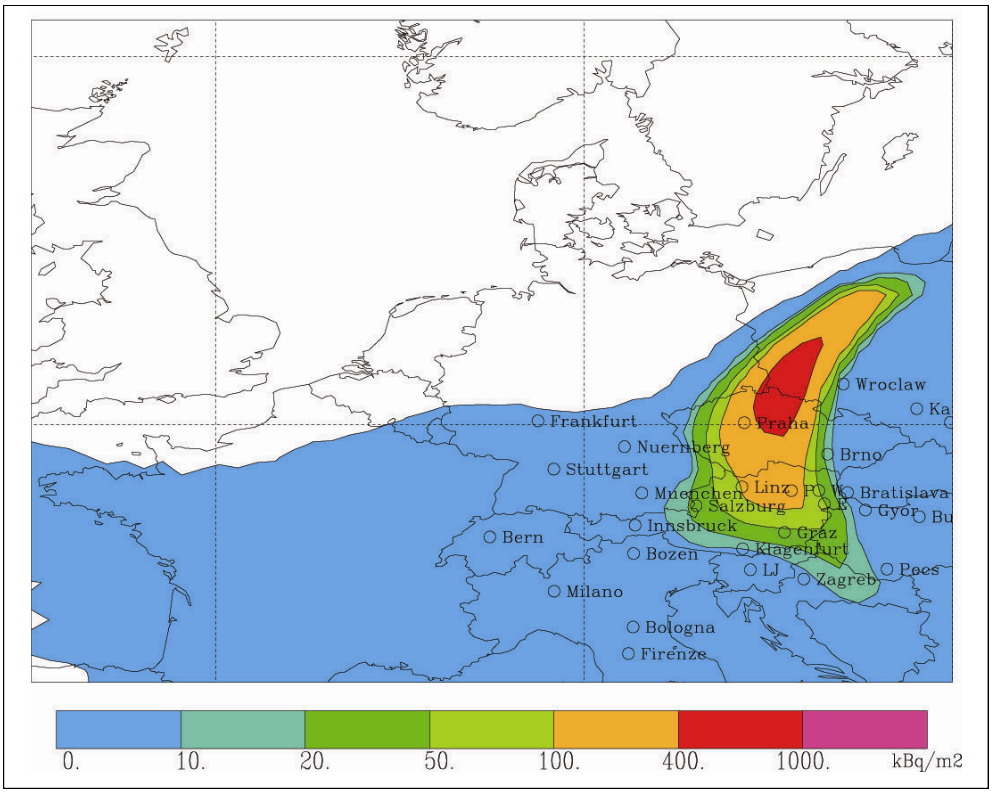

*Figure 6: Example of deposition of Cs-137 as in Illustration X1, but over Central Europe only with a resolution of 0.5° in E-W direction and 0.33° in N-S direction for the output grid.*

We see a detached region of contamination extending through Poland, Czech Republic, and Austria into the region of former Yugoslavia. In Austria, a deposition of 100 kBq/m$^2$ is exceeded in a large part of Upper Austria. At this contamination level radiation protection measures for the population in Austria would be required.

From the pattern of the contamination it is obvious that it was caused by wet deposition in a precipitation field. Deposition values found in the maximum at the Polish/Czech border exceed 400 kBq/m$^2$. It is easily possible that the interplay of timing of the release, flow pattern and development of the precipitation could lead to southward shift of this pattern. Situations with northeasterly winds are often associated with precipitation concentrated on the northern side of the Alps and northeastern Austria (so called Vb synoptic situations, often associated with a strong trough or cut-off low over central Europe). This would mean that values such as those found in the present case at the Polish/Czech border might occur also in Austria.

The second approach is based on an unpublished study carried out on behalf of the Austrian Ministry of Environment (Seibert 2004). It is also based on the RISKMAP data set, but augmented by dose estimates and a 14-year trajectory data set. We can take from this study a climatological probability of the exceedance of the warning levels 2 according to the Austrian emergence preparedness guidelines for nuclear accidents for a source term corresponding to a release of 4.5% of the caesium inventory of a VVER-1000 reactor, accompanied by corresponding releases of other nuclides. The result is a probability of 2.3%, which we consider non-negligible.

It is also interesting to compare the results for the Ignalina site and the Chernobyl site. The climatological probability of a warning level 2 or worse event in Austria is about 50% higher from the Ignalina site than that from the Chernobyl site (based on a 45% release source term, similar to the one occurring in the Chernobyl disaster – for the 4.5% release, no impact at warning level 2 was found from Chernobyl site). In short, this means that the Ignalina site is more dangerous for Austria than the Chernobyl site, and yet Austria has been severely impacted by the Chernobyl disaster, more than any other European country except the Soviet Union and Scandinavia.

## 9.3 Conclusions

It is appreciated that the authors of the EIA present, with their SILAM model simulations, an impact analysis of accident emissions better than in most other EIAs, both with respect to the degree of realism of the model and to the fact that meteorological conditions are sampled that really occurred. The argument that the model is more realistic holds especially for transports over distances from 20 km to hundreds or thousands of kilometres which could not be modelled realistically with a Gaussian model. This approach is in principle a state-of-the-art approach, though we found that further details of the model setup are not provided.

But from the Austrian point of view it is not justified to carry out the investigation of transboundary consequences of a severe accident by choosing an arbitrary emission limit as source term. We recommend first of all to take a deterministic approach in the safety analysis and find out what emissions could occur. From published data on “Generation III” reactors, we have shown that containment failures cannot be excluded and even early containment failure contributes with some per-cent to the large release frequency. The large releases – as far as published – indicate that releases of volatile aerosols could amount from 2 to 20% of the core inventory, which is much more than the chosen limit of 100 TBq Cs-137.

Therefore an investigation of transboundary emissions was carried out with a conservative source term from a severe accident: 5% of the total core inventory of Caesium 137, which is used in most of our analysis as a characteristic nuclide. The result of this analysis (figure 6) indicates that serious impacts to Austria (and other) countries cannot be excluded. In the chosen case study in a large part of upper Austria the ground contamination would exceed 100 kBq/m² in a large part of upper Austria, long-term restrictions for the public and for agriculture would be required if such a situation become real.

In this context we emphasize that with respect to the climatological probability of contamination, releases from the Ignalina site are even more relevant for Austria than those from the Chernobyl site, and this on the background of the experience in the Chernobyl disaster, which Austria.

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# 11 GLOSSARY

| | |
|---|---|
| ABWR | Advanced Boiling Water Reactor |
| AP | Advanced Passive |
| APR | Advanced Power Reactor |
| APWR | Advanced Pressurized Water Reactor |
| BDBA | Beyond Design Base Accident |
| BWR | Boiling Water Reactor |
| CD | Core Damage |
| CDF | Core Damage Frequency |
| Cs | Caesium |
| DBA | Design Base Accident |
| EC | European Commission |
| ECCS | Emergency Core Cooling System |
| EIA | Environmental Impact Assessment |
| EPR | European Power Reactor |
| ERF | Early Release Frequency |
| ESBWR | Economic Simplified Boiling Water Reactor |
| EU | European Union |
| EUR | European Utilities Requirements |
| GDCS | Gravity Driven Cooling System |
| GE | General Electric |
| I | Iodine |
| IAEA | International Atomic Energy Agency |
| LILW | Low and Intermediate Level Waste |
| LOCA | Loss of Coolant Accident |
| LRF | Large Release Frequency |
| LWR | Light Water Reactor |
| MCR | Main Control Room, Master Control Room |
| mSv | Milli Sievert |
| MW | Megawatt |
| MWe | Megawatt electric |
| NGO | Non Governmental Organisation |
| NPP | Nuclear Power Plant |
| NRC | Nuclear Regulatory Commission (USA) |
| PSA | Probabilistic Safety Assessment |

| | |
|---|---|
| PWR | Pressurized Water Reactor |
| RPV | Reactor Pressure Vessel |
| SA | Severe Accident |
| SG | Steam Generation |
| SNF | Spent Nuclear Fuel |
| SWR | Siedewasserreaktor, Boiling Water Reactor |
| Sv | Sievert |
| TBq | Tera Becquerel |
| TWh | Tera-Watthours, $10^{12}$ Wh |
| t/yr | Tonnes per year |
| U | Uranium |
| VATESI | State Nuclear Power Safety Inspectorate |
| VVER = WWER | Vodo-Vodyanoy Energeticheskiy Reactor |
| WNA | World Nuclear Association |

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Within the framework of the cross-border Environmental Impact Assessment (EIA) concerning the construction of new nuclear power plants in Lithuania, an Expert Statement was elaborated on behalf of the Umweltbundesamt.

The Expert Statement stresses the relevance of the proposed project for Austria. Based on data provided by the EIA documentation and publicly accessible information regarding the proposed types of nuclear reactors, dispersal models were used to verify if Austria might be affected. Significant impacts cannot be excluded on the basis of the current know-how about Generation III reactors.

The Expert Statement concludes with recommendations and open questions related to the quantity and quality of the EIA documentation, which should be respected by the Lithuanian authorities.

Documents for download:
http://www.umweltbundesamt.at/uvpkkwlitauen

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