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NPP OLKILUOTO-4

Expert Statement to the EIA Report

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ÖSTERREICHISCHES ÖKOLOGIE INSTITUT

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Antonia Wenisch
Helmut Hirsch
Richard Kromp
Gabriele Mraz

Ordered by the
Federal Ministry for Agriculture, Forestry,
Environment and Watermanagement,
Projectmanagement Department V/6 “Nuclear Coordination“

lebensministerium.at

ÖSTERREICHISCHES
ÖKOLOGIE INSTITUT

REPORT
REP-0162

Wien, 2008

Projectmanagement
Franz Meister, Umweltbundesamt

Authors
Antonia Wenisch, Österreichisches Ökologie-Institut
Helmut Hirsch, technisch-wissenschaftlicher Konsulent
Richard Kromp, Österreichisches Ökologie-Institut
Gabriele Mraz, Österreichisches Ökologie-Institut

Satz/Layout
Ute Kutschera, Umweltbundesamt

Weitere Informationen zu Umweltbundesamt-Publikationen unter: http://www.umweltbundesamt.at/

Impressum

Medieninhaber und Herausgeber: Umweltbundesamt GmbH
Spittelauer Lände 5, 1090 Wien/Österreich

Diese Publikation erscheint ausschließlich in elektronischer Form auf http://www.umweltbundesamt.at/.

ISBN 3-85457-960-8

CONTENT

1 INTRODUCTION

The company Teollisuuden Voima Oy (TVO) plans to construct a new nuclear power plant (NPP) at Olkiluoto Island in the municipality of Eurajoki. Olkiluoto is the location of two operating NPP units and a new one under construction: Olkiluoto-3 (EPR). Electric capacity of the fourth NPP unit shall be 1,000 to 1,800 MWe.

According to the Finnish law the construction of a new nuclear power plant is subject to a decision-in-principle issued by the Government and ratified by the Parliament.

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 to elaborate an Expert Statement on the EIA Program for Olkiluoto-4 (OL-4) NPP. In the second stage of the EIA process the Austrian Institute of Ecology in cooperation with Dr. Helmut Hirsch was engaged by the Austrian Federal Environmental Agency to assess the Environmental Impact Assessment Report of TVO.

The findings of this evaluation are presented in this Expert Statement, which is structured as follows:

Chapter 2 presents the summary of the Expert Statement; Chapter 3 discusses the procedure of the Finnish EIA procedures. Chapters 4 and 5 deal with the project and the reactors considered for Olkiluoto-4. Chapter 6 concerns safety and accident analysis. Chapter 7 and 8 concern the environmental impact of nuclear fuel production and the repository of irradiated fuel. Chapter 9 contains a short evaluation of the information given by the EIA Report on alternative options. Open issues and questions are summarized in chapter 10.

2 SUMMARY

The project under discussion seems not to be elaborated well enough to fulfil the requirements of the EC EIA Directive (EC 97/11) and the ESPOO Convention (ESPOO Convention 1997), because the EIA Report does not present a certain project and alternatives. In the EIA Report TVO examines the construction of a nuclear power plant unit with an approximate net electrical output of 1,000 to 1,800 MW and thermal power of 2,800 to 4,600 MW at Olkiluoto. The reactor type could be a BWR or a PWR. Only a "non binding" list of nine reactor types is presented. This is very vague because reactor type and output are not determined. It is not possible to properly assess transboundary impacts with precise information on power output and reactor type missing.

The missing information per se seems to be available. Meanwhile TVO has submitted the application for the decision-in-principle to the Council of the State and feasibility studies on five nuclear power plants to the Radiation and Nuclear Safety Authority (STUK). According to a press release by TVO of April 25th 2008, these studies describe the essential technical and safety properties of these alternatives.

The application for the decision-in-principle before the completion of the EIA procedure was criticised by the Ministry of Employment and the Economy. The Ministry wants to consider all three applications for a decision-in-principle together (OL-4, LO-3, NPP by Fennovoima Oy). We encourage this approach of the Ministry.

According to the Finnish EIA act, the EIA Directive of the EC and the ESPOO Convention, information about a planned project with potential transboundary impacts has to be given for assessing these impacts. If information about technical and safety properties of the reactor types in discussion is left out, this information cannot be considered complete. Therefore, it might be questionable whether this type of description of the project complies with the legal demands.

According to EC 2003/4 all environmental information should be made available to the public. Therefore the missing information could also be claimed with reference to the Aarhus Convention and the corresponding EC Directive 2003/4, respectively.

It might be questionable if a transboundary EIA can be conducted under these circumstances.

In contrast to the Finnish procedure, a similar consultation process in the UK provides feasibility studies of Generation III reactors at a public website[1]. The British authorities have made comprehensive documents about the reactor types in discussion available to the public.

The Project

The EIA Report presents only general information about the project. The NPP is presented as a black box, which has to meet the Finnish regulations and requirements. Without any description of the NPP's features it is not possible to assess the feasibility of realization of this target.

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[1] http://www.hse.gov.uk/newreactors/reactordesigns.htm, seen 05-08-2008

Furthermore, the EIA Report does not follow the recommendation of the Ministry of Trade and Industry: "In the Ministry's view, the EIA Report should include a review of current nuclear power plants on the market which are suitable for the project under review. Similarly, the safety planning criteria for the prospective plant must be presented with respect to the limitation of emissions of radioactive substances and environmental impacts, alongside an assessment of the feasibility of meeting the safety requirements in force." (MTI 2007).

The EIA Report does not provide sufficient information about the reactors considered for Olkiluoto-4. Based on the information given in the EIA, an evaluation of safety, the maximal source term and its probability of occurrence is not possible. Chapter 5 of this Expert Statement provides basic information on these reactors, researched by the authors using public literature.

There is very little operational experience with the reactor types listed in the EIA. Only one of those types (ABWR) has been in operation so far.

The majority of the reactor types listed rely on ex-vessel cooling (i.e., installation of a core catcher) for the control and mitigation of severe accidents. However, fundamental problems remain regarding the reliable functioning of a core catcher. The concept of in-vessel cooling is basically more promising, but difficult to implement in large reactors.

Safety and Accident Analysis

PSA results for the reactor types can be found in the open literature. Core damage frequencies span two orders of magnitude. The reactor types at the upper limit (EPR, APR-1400) lie in the same range as reported for newer Light Water Reactors of Generation II.

The source term as assumed in the EIA Report for exemplary dose calculations appears questionable regarding the relation between Cs-137 and I-131; and it does not take all nuclides into account, which are required for checking European Utilities Requirements (EUR) release criteria (Criteria for Limited Impact).

Even so, not all EUR criteria are kept by the source term in the EIA Report. Moreover, on April 22nd 2008, nuclear regulatory officials criticized in a comment that the EIA for Olkiluoto-4 does not sufficiently cover the consequences of an accident and how people near the plant would be protected. STUK officials said that TVO's description of emergency response in the event of an accident was "very narrow". They added that the assessment also concentrates on serious accidents but that there should also have been a review of the consequences of less serious accidents and how they would be handled". (NW 2008/04/24) This requirement of STUK is a very important objection. We support the demand for a comprehensive assessment of accidents and emergency measures.

It is beyond the scope of this expertise to discuss whether it can be expected that the reactor types listed in the EIA Report conforms to Finnish regulations. A detailed technical assessment of the reactors would be required to answer this question.

In the EIA Report a dose assessment of the accidental release with the exemplary source term is presented for a region of 100 km. For a distance up to 1,000 km the dose is evaluated by extrapolation. This assessment is not state of the art. For modelling the long-range transport, diffusion and deposition of radionuclides more sophisticated tools are required. There is no long-range transport of an accidental release presented in the EIA. For this kind of assessment a simple dispersion model can not be used.

For an assessment of the potential impact of a severe accident at the Olkiluoto 4 NPP the information of the EIA Report is not sufficient (no worst case, only one source term which can not be proven to be the maximum release).

Nuclear fuel chain

The EIA Report states that the availability of uranium is no obstacle for continuing or expanding the use of nuclear power, only the costs will increase.

But uranium reserves are limited. An increase of uranium production of at least some 50% would be required in order to match only the future demand of current nuclear capacity (EWG 2006) .Thus the low availability of uranium could be an obstacle for continuing or expanding the use of nuclear power. In addition to that, new uranium production will require a much higher price level, and is also a matter of proliferation risk.

The production of nuclear fuel has an immense impact on the land where it is mined and the inhabitants living there. Moreover uranium mining and fuel production need energy and thus emit CO_2. CO_2 emissions depend on the quality of ore and, since high grade ore is scarce, the CO_2-balance of uranium is becoming worse.

Construction of a final repository is intended at Olkiluoto. Meanwhile, the spent fuel is stored in the interim storage at the site. For long-term interim storage the pool is not an optimal technology. Critical aspects are the integrity of the fuel rods and their handling after several decades in the pool. A further extension of the interim fuel storage is envisaged in order to prepare place for the fuel from OL-3 and OL-4. Since it is planned to store the spent fuel in the interim storage over several decades, the disadvantage of the storage pool compared to a dry one should be considered. Furthermore, an assessment of the risk of accidents caused by external impacts to the pool storage should be given.

The EIA Report merely states, that the long-term safety of the final repository has been proven by using a model for the calculations.

According to the state of science and technology final waste disposal for spent fuel can be realized in deep geological formations. But there are large uncertainties in the results of the safety analysis, i.a. resulting from the assessment of the influence of ice-ages with fault movements, land uplift, earthquakes and the creation of new weakness zones.

In particular, the long-term capability of the technical and geological barriers cannot be guaranteed because of the long storage period required. Experience and experiments cannot be carried out for such long periods.

Alternatives and zero option

The zero option and alternatives are discussed in the EIA Report: Alternatives regard the reactor type (boiling or pressurized reactors) and the bandwidth of 1,000 MW to 1,800 MWe.

As alternatives, the EIA Report regards mainly the alternative locations of the outlet and intake of cooling water. Dumping the thermal load of approximately two thirds of the energy produced in the reactor creates without doubt an important environmental impact on the sea and could also cause transboundary impacts due to changes in marine ecosystems.

No alternative options for electricity production or options for investments in energy efficiency are discussed in the EIA Report.

Concerning the zero option, environmental impacts of nuclear energy are compared to the production of the same amount of electricity by the Nordic electricity market. The avoided emissions of greenhouse gases are calculated based on the assumption that "a nuclear power plant does not produce any emissions of sulphur dioxide, nitrogen oxides, carbon dioxides or particles" (TVO 2008, 164).

The EIA Report presents calculations of the material input per amount of electricity produced for different generation technologies: material input (MIPS – Material Input Per Service Unit: 1,160 kg/MWh for coal, 170 kg/MWh for a natural gas, 42 kg/MWh for uranium) and comes to the conclusion that of the electricity generation alternatives studied, nuclear power is by far the most environmentally friendly when measured using the MIPS indicator.

But in order to assess the environmental impact of electricity generation technologies, it is not sufficient to rate the energy content of different fuels. In order to produce more information about the actual environmental impacts of technologies, greenhouse gases, toxicity of emissions and residues and the risk of harmful emissions due to accidents have to be included in a life cycle assessment in order to gain a comprehensive review of environmental impacts.

Beyond that, if the total nuclear chain and the management of all types of radioactive waste are considered, nuclear energy cannot be regarded as CO_2 free and environmentally sound. Uranium mining and fuel fabrication, in particular, cause a significant impact on the environment (see also chapter 7 of this statement). A complete comparison of the real costs and risks of nuclear energy production with those of renewable energy production alternatives proves that there is no advantage of nuclear electricity when compared to renewable energy.

Nuclear Energy also proves to be a comparatively costly measure to reduce CO_2-emissions. Energy efficiency measures, renewable energies and alternative solutions in the wider sense replace 2.5 to 10 times as much CO_2 per unit investment.

3 THE PROCEDURE

3.1 Treatment in the EIA Report

According to the Finnish law the construction of a new nuclear power plant is subject to a decision-in-principle issued by the Government and ratified by the Parliament. The EIA process has to be completed before the decision-in-principle concerning a new nuclear power plant can be issued.

The first stage of the EIA process (assessment programme) was completed with the issuing of the Statement of the Ministry of Trade and Industry[2] in Sept 2007. This Statement included the summarized comments of all organizations on the EIA programme.

The second stage of the EIA procedure started with the preparation of the EIA Report which was submitted in February 2008. This part of the procedure including the ESPOO procedure is still under way. It will be concluded with another Statement of the Ministry of Employment and the Economy that is planned to be issued in June 2008.

3.2 Discussion

On April 25th 2008 TVO issued a press release that an application for a decision-in-principle was submitted to the Council of the State[3]. In this press release TVO declared that "[a]s a part of the decision-in-principle application process, TVO has today submitted to the Radiation and Nuclear Safety Authority feasibility studies on five nuclear power plant alternatives. The Studies describe the essential technical and safety properties of the alternatives."

The application for the decision-in-principle can be submitted even before the EIA is completed. The Minister of Economic Affairs, Mauri Pekkarinen, would have preferred the completion of the EIA process before receiving the application for the decision-in-principle, as he told in a press release of the Ministry of Employment and Economy of April 25th 2008[4]. Concerning the other two expected applications (LO-3 and NPP by Fennovoima Oy) for decisions-in-principle the Minister announced that it was "essential for all applications to be considered at the same time". So even if TVO submitted earlier than the other operators, a joint consideration will take place.

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[2] Since 2008: Ministry of Employment and the Economy.

[3] http://www.tvo.fi/www/page/2855/, seen 04-29-2008

[4] http://www.tem.fi/?89521_m=91497&l=en&s=2471, seen 05-09-2008

On the website of TVO the five reactor types can be found, but no information about the feasibility studies[5]. The following five types of reactors are listed on the website:

1. ABWR Toshiba, BWR, 1,650 MW, Toshiba Westinghouse, Japan-Sweden
2. ESBWR GE Hitachi, BWR, 1,650 MW, GE Hitachi, USA
3. APR1400, PWR, 1,450 MW, Korea Hydro and Nuclear Power, South-Korea
4. APWR Mitsubishi, PWR, 1,650 MW, Mitsubishi, Japan
5. EPR, PWR, 1,650 MW, Areva, France-Germany

For comparison: In the EIA Report TVO is examining the construction of a nuclear power plant unit with approximate net electrical output of 1,000 to 1,800 MW and thermal power of 2,800 to 4,600 MW at Olkiluoto. The reactor type could be a BWR or a PWR (TVO 2008, 37, table 4-1). Four alternative types of BWRs and five types of PWRs are listed. But this listing of the nine types in the EIA Report does not imply a decision for specific reactor types because in the Report TVO declares explicitly that "(…) table 4-1 is not binding, and another supplier may also come into question." (TVO 2008, 37).

In the Austrian Expert Statement for the Scoping Phase (WENISCH & KROMP 2008) it was expected "that the EIA Report will provide detailed information on the type of plants under consideration for OL-4." According to TVO's press release it must be presumed that more information about the reactor types is available by now, but not included in the EIA Report.

In contrast to the Finnish procedure a similar consultation process in the UK provides feasibility studies of Generation III reactors at a public website[6]. The British authorities have made comprehensive documents about the reactor types in discussion available to the public.

More information about the reactor is important because the nuclear inventory is different for a reactor with an output of 1,000 or 1,800 MW. The inventory is of importance for the assessment of potential transboundary impacts also on Austria.

The EIA procedure should be in accordance with the Finnish EIA Act, the ESPOO convention and the Aarhus Regulation.

The *Finnish EIA Act* (EIA Act 2006) corresponds to the EIA Directive of the EC (EC 97/11) by including nuclear power stations into the list of projects that are subject to the EIA legislation. The notification of Member States that are possibly affected by the project has to include information on the project and on any transboundary environmental impact, information on the assessment procedure and the time period for commenting this information.

The *ESPOO Convention* (ESPOO Convention 1997) lists activities that should be subject to a transboundary EIA process. These activities include nuclear power stations. The ESPOO Convention states in Article 6 (Final Decision): "The Parties shall ensure that, in the final decision on the proposed activity, due account is taken of the outcome of the environmental impact assessment."

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[5] http://www.tvo.fi/www/page/2842/, seen 05-05-2008

[6] http://www.hse.gov.uk/newreactors/reactordesigns.htm, seen 05-08-2008

If after the EIA decision additional information becomes available, Article 6.3 of the ESPOO convention regulates how it should be dealt with: "If additional information on the significant transboundary impact of a proposed activity, which was not available at the time a decision was made (…) becomes available to a concerned Party before work on that activity commences, that Party shall immediately inform the other concerned Party. If one of the concerned Parties so request, consultations shall be held as to whether the decision needs to be revised." The decision for five reactor types could be regarded as additional information that is not included in the EIA Report, because different reactor types can cause different transboundary impacts, e.g. in case of accident. Article 6.3 applies to information that is revealed after the decision, but if new information is available even before the decision it would correspond to the basic orientation of the ESPOO Convention if this information was also made available to the EIA partners during the EIA procedure. Therefore it should be made possible that Austria and also other countries could discuss the chosen reactor type and its possible transboundary impacts.

The *Aarhus Convention* guarantees the right of environmental information for the public. The Aarhus Convention is an international legal Convention. The United Nations Economic Commission for Europe (UNECE) "Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters" was adopted on 25 June 1998 in the Danish city of Aarhus and entered into force on 30 October 2001. At the end of 2006 40 parties have signed the Convention, including all Member States of the European Union (HÖRMAYER et al. 2007).

In the Aarhus Regulation (EC 1367/2006) all three pillars of the Aarhus Convention are covered: access to information, public participation, access to justice. In 2003 the European Commission adopted two Directives concerning the first and second pillars of the Aarhus Convention, the right of access to environmental information and the right of public participation. The Directives are implemented into national law of the EU Member States (EC 2003/4 und EC 2003/35[7]).

EC Directive 2003/4 on public access to environmental information (EC 2003/4) grants the right of access to environmental information. Environmental information includes according to Article 2 any information on "factors, such as substances, energy, noise, radiation or waste, including radioactive waste, emissions, discharges and other releases into the environment, affecting or likely to affect the elements of the environment". If a Member State disobeys central elements of the Directives 2003/4/EC and 2003/35/EC, any natural or legal person will be allowed to lodge a complaint with the Commission against this Member State (HÖRMAYER et al. 2007).

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[7] EC Directive 2003/35 deals with the right of public participation in respect of the drawing up of certain plans and programmes relating to the environment (EC 2003/35)

3.3 Conclusion

It is questionable if the project is elaborated enough to fulfil the requirements of the EC EIA Directive (EC 97/11) and the ESPOO Convention (ESPOO Convention 1997), because the EIA Report does not present a certain project and alternatives. In the EIA Report only a “not binding” list of nine reactor types is presented, with an approximate output of 1,000–1,800 MWe. This is very vague because reactor type and output are not determined. It is not possible to properly assess transboundary impacts with this missing information.

The missing information per se seems to be available. According to TVO’s press release of the 25th of April 2008 feasibility studies about technical and safety properties of five reactor types that are considered for a new power plant at Olkiluoto are available. This information is merely not included in the EIA Report.

The application for the decision-in-principle before the completion of the EIA procedure was criticised by the Ministry of Employment and the Economy. The Ministry wants to consider all three applications for a decision-in-principle together (Olkiluoto-4, Loviisa-3, NPP by Fennovoima Oy). We encourage this approach of the Ministry.

According to the Finnish EIA Act, the EIA Directive of the EC and the ESPOO Convention information about a planned project with potential transboundary impacts has to be given for assessing these impacts. If information about technical and safety properties of the reactor types in discussion are left out, this information cannot be considered as complete. Therefore, it is questionable whether this type of description of the project complies with the legal demands.

According to EC 2003/4 all environmental information should be made available to the public. Therefore the missing information could also be claimed with reference to the Aarhus Convention and the corresponding EC Directive 2003/4, respectively.

It might be questionable if a transboundary EIA can be conducted under these circumstances.

4 DESCRIPTION OF THE PROJECT

4.1 Treatment in the EIA Report

The prospective new unit at Olkiluoto will be a light water reactor; either a pressurized water reactor (PWR) or a boiling water reactor (BWR) (TVO 2008, 37). A service life of 60 years is envisaged (TVO 2008, 38), the electric power is planned to be approx. 1,000 to 1,800 MW (TVO 2008, 37).

The EIA Report assumes that the most significant environmental impact of the new nuclear power plant (NPP) is caused by the waste heat released into sea.

"The requirements concerning nuclear safety are practically the same for all plant types, which means that the chosen plant type is of no significance in that regard. Also, the plant types that come into question do not significantly differ from each other with regard to radioactive releases. However, the size of the chosen plant type is of significance with regard to environmental impacts because the size affects the thermal load conducted to the sea." (TVO 2008, 37).

Table 4.1 of the EIA Report lists some plant types on the market. All the reactors listed are generally considered to belong to the Generation III. There is no review of these reactors and no information about technical and safety features in the EIA Report.

4.2 Discussion

Even if the waste heat is an important environmental load, it has to be stated that the NPP's capacity influences the amount of fuel in the reactor core which is 100–150 t, according to the EIA Report (TVO 2008, 37), and, more importantly, the inventory of the fuel. Not only the heat but also the core inventory of radionuclides during operation as well as the amount and inventory of the spent fuel depend on the capacity of the NPP. Thus the capacity determines the potential for the release of radioactive substances in case of a reactor accident and influences the storage conditions of spent fuel.

From this point of view the different reactor projects, their capacity and main safety features should be described in the EIA Report in more detail, as it was demanded by the Ministry of Trade and Industry of Finland in its statement on the scoping report (MTI 2007).

"In the Ministry’s view, the EIA Report should include a review of current nuclear power plants on the market which are suitable for the project under review. Similarly, the safety planning criteria for the prospective plant must be presented with respect to the limitation of emissions of radioactive substances and environmental impacts, alongside an assessment of the feasibility of meeting the safety requirements in force." (MTI 2007).

Since there is no information about the reactors under review for Olkiluoto-4, chapter 4 of this statement provides basic information on this issue.

4.3 Conclusion

The EIA Report presents only general information about the project. The NPP is presented as a black box, which has to meet the Finnish regulations. But without any description of the NPP's features it is not possible to assess the feasibility of realization of this target. It is questionable whether this type of description of the project complies with the EC EIA regulation. Furthermore, the EIA Report does not follow the recommendation of the Ministry of Trade and Industry.

5 REACTOR TYPES FOR OL-4

Table 4.1 of the EIA Report lists some plant types on the market. This table is not binding, however, and other suppliers may also come into question. All the reactors listed are generally considered to belong to the Generation III. (Almost all commercial nuclear power reactors under operation today belong to the Generation II.)

Information on the reactor types mentioned in EIA Report is presented in the following tables. This information was researched by the authors and is taken mostly from publications of plant designers and other nuclear industry sources, and from IAEA.

A discussion of the main features of the reactor types follows. Within the scope of this Expert Statement, this discussion has to remain very limited.

Notes to the tables

NRC certification: Information regarding NRC certification has been taken from a paper of the World Nuclear Association (WNA 2008).

Units existing: This includes units in operation, under construction or firmly planned with start-up of construction in near future.

Special features: The most important features which go beyond Generation II plants are listed.

Table 1: European Pressurized Water Reactor.

EPR	**European Pressurized Water Reactor (Evolutionary PWR)**
Basic data	PWR, ca. 1,700 MWe
Manufacturer	AREVA (France/Germany)
Origin	Developed from the German KONVOI and French N4 PWR types
Certification	EUR certified NRC certification process ongoing
Units existing	2 units under construction: 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). 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.
Special features	Core-catcher for reactor core in case of meltdown In-containment refuelling water storage tank (combines coolant storage and sump function – switchover from safety injection to sump recirculation is avoided) Double containment (two concrete hulls) (EDF 2006)
PSA results	Olkiluoto-3 CDF (external and internal initiators, operation and outages) = 1.8E-06/yr Frequency of exceeding release limit (100 TBq Cs-137, plus other nuclides) = 1.0E-07/yr (STUK 2005) Flamanville CDF (ext. and int. initiators, op. and out.; seismic analysis not complete, internal explosions not included) = 1.33E-06/yr (EDF 2006)

Table 2: Vodo-Vodyanoy Energeticheskiy Reactor.

VVER-1000/392M (AES-2006)	**VVER = Vodo-Vodyanoy Energeticheskiy Reactor**
Basic data	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
Units existing	Two units under construction (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” (WNIH 2008))
Special features	Combination of passive and active safety mechanisms (e.g., passive SG heat removal, passive core cooling systems) Core-catcher for reactor core in case of meltdown (“melt retention in a special device located beneath the reactor vessel”) Double containment (two concrete hulls)
PSA results	“(G)eneral frequency of core damage at a level of 1.0E-07 (/yr).” All categories of initiating events, power and shutdown: CDF = 5.4E-08/yr (IAEA 2004)

Reference: (GENERALOV 2007) unless specified otherwise

Table 3: Advanced Passive reactor.

AP-1000	**AP = Advanced Passive**
Basic data	PWR, 1,100 MWe
Manufacturer	Westinghouse (USA)
Origin	Developed from AP-600. More innovative than other reactor types discussed here; not directly developed from a Generation II plant
Certification	EUR certified NRC design certification December 2005
Units existing	No units in operation or under construction yet. 4 units “firmly planned” in China. Sanmen-1, -2: Start of construction 2009, commercial operation 2013; Haiyang-1, -2: No data given (WNIH 2008)
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 “Simplified design” (50% fewer valves, 35% fewer pumps, 80% less pipes, 45% less building volume, 70% less cable) Increased safety margins in case of DBAs In-vessel retention of damaged core external cooling of RPV with inventory from in-containment refuelling water storage tank (BRUSCHI 2004, WEC 2007)

AP-1000	**AP = Advanced Passive**
PSA results	CDF = 5.0E-07/yr, LRF = 6.0E-08/yr (WEC 2007) CDF = 4.0E-07/yr (BRUSCHI 2004) LRF = 1.95E-08/yr (IAEA 2004) (in all three cases, no specification regarding inclusion of external/internal, operation/shutdown are provided)

Table 4: Advanced Boiling Water Reactor.

ABWR	**Advanced Boiling Water Reactor**
Basic data	BWR, 1,400–1,600 MWe
Manufacturer	Hitachi/Toshiba/General Electric (Japan/USA)
Origin	Originally designed by GE, developed from older GE BWR designs
Certification	EUR certified NRC certified
Units existing	5 in operation, all in Japan (begin of commercial operation): Kashiwazaki-Kariwa-6 (1996), -7 (1997) Hamaoka-5 (2005) Higashidori-1 (2005) Shika-2 (2006) 4 under construction (2 in Japan, 2 in Taiwan): Fukushima-Daiichi-7, J (start-up planned 2006?) Shimane-3 (2011), J Lungmen-1, -2, T (2009, 2010) 2 “firmly planned” in Japan: Kaminoseki-1, -2 (start of construction 2009/2012, operation 2014/2017) (WNIH 2008)
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) Some passive severe accident mitigation features (BEARD 2007) Spreading area in lower drywell and passive drywell flooding system to guarantee coolability of core debris (IAEA 2004, BEARD 2007) This 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).
PSA results	Internal events CDF = 1.6E-07/yr, high seismic margins claimed, LRF < 1.0E-9/yr (The contribution of mode 6 (refuelling) to CDF is reported to be 99%, so no level 2 (PSA) would be required.) (BEARD 2007)

Table 5: Siedewasserreaktor.

SWR-1000	**SWR = Siedewasserreaktor**
Basic data	BWR, ca. 1,000 MWe
Manufacturer	AREVA (Germany)
Origin	Developed by Siemens-KWU in the 1990s, based on the concept of the SWR-300 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
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 (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.) In-vessel retention of damaged core – external cooling of RPV by flooding of the reactor shaft (passive via the containment cooler) (BRETTSCHUH 2001)
PSA results	CDF for internal events = 1.1E-07/yr (5.0E-08/yr for power operation, 6.0E-08/yr for shut-down) (BRETTSCHUH 2000, 2001)

Table 6: Economic Simplified Boiling Water Reactor.

ESBWR	**Economic Simplified Boiling Water Reactor**
Basic data	BWR, ca. 1,600 MWe
Manufacturer	General Electric (USA)
Origin	Developed from GE SBWR (Simplified BWR) and ABWR (see above)
Certification	NRC certification process ongoing
Units existing	No units are in operation, under construction or firmly planned today
Special features	Passive safety systems (e.g. passive core cooling with GDCS (gravity-driven cooling system); passive containment cooling system No operator action needed for design basis accidents for 72 hours (IAEA 2004) Core catcher with passive flooder Generally – reduced and simpler systems, reduced materials and buildings
PSA results	CDF = 3.0E-08/yr (no specification internal/external or plant state; in the same table, 2.0E-07/yr is given for ABWR.)

Reference: (HINDS 2006) unless specified otherwise

Table 7: Advanced Pressurized Water Reactor.

APWR	**Advanced Pressurized Water Reactor**
Basic data	PWR, 1,600–1,700 MWe
Manufacturer	Mitsubishi
Origin	Developed from Mitsubishi PWRs (Westinghouse was involved earlier) 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)) 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) (WNHI 2008) License application for the first two US-APWRs (site in Texas) expected for 2008 (NEI 2007)
Special features	Simplified ECCS – integrating low pressure injection systems and accumulators In-containment refuelling water storage tank (combines coolant storage and sump function – switchover from safety injection to sump recirculation is avoided) 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. (IAEA 2004)
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)

Table 8: Advanced Power Reactor.

APR-1400	**APR = Advanced Power Reactor**
Basic data	PWR, 1,400 MWe
Manufacturer	KHNP (South Korea)
Origin	Developed from the type PWR 80+, which was developed by the US firm ABB
Certification	No EUR or NRC certification PWR 80+ has been certified by NRC (OLSON 1997)
Units existing	Two APR-1400 are firmly planned in South Korea (Shin-Kori 1 and 2, start of construction reported as 2006/2007, operation 2010/2011) (WNIH 2007, 2008)
Special features	External reactor vessel cooling system (ERVCS) for in-vessel retention of corium; plus back-up system (CFS) for flooding corium in the cavity below reactor vessel, if ERVCS fails. CFS is gravity-driven. In-containment refuelling water storage tank (combines coolant storage and sump function – switchover from safety injection to sump recirculation is avoided) Safety systems appear to be mostly active (IAEA 2004)
PSA results	CDF for internal events = 2.25E-06/yr CDF for external events (bounding site characteristics) = 4,36E-07/yr Containment failure frequency from all events: 2.84E-07/yr (possibly for operation only; not clear if shut-down state included) (NEA 2002)

5.1 Discussion of reactor types

There is very little experience with the reactor types listed in the EIA Report; some of them so far exist only on paper.

Table 9: Overview of the status of realization of the reactor types considered in this expertise.

Status	**No. of types**	
In operation	1	ABWR
Under construction	2	EPR, AES-2006
Firmly planned	3	AP-1000, APWR, APR-1400
None of the above	2	SWR-1000, ESBWR

There is still little experience in the realization of a “core catcher” for ex-vessel cooling of a molten core. 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. They include (SEHGAL 2004, SEVON 2005):

- Interaction between molten core and concrete cannot be accurately simulated.
- There are high uncertainties regarding heat transfer rates.
- Cracking of the concrete surface can occur; this has not been studied systematically so far.
- Complications due to H2 generation are possible.
- Cooling with water flooding alone (as generally planned) might be insufficient cooling coils could be required.
- Violent steam explosions can take place before the core reaches the catcher.

The concept of in-vessel cooling, i.e. external cooling of the reactor pressure vessel in case of a severe accident to prevent discharge of the molten core basically 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 about 500 MWe 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 favourable 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, with the AES-2006 being an exception to this rule.

Table 10: Overview of the molten core cooling strategies for each type.

Reactor type	Power (MWe)	
EPR	1,700	ex-vessel cooling
AES-2006	1,150	ex-vessel cooling
AP-1000	1,100	in-vessel cooling
ABWR	1,400–1,600	ex-vessel cooling
SWR-1000	1,000	in-vessel cooling
ESBWR	1,600	ex-vessel cooling
APWR	1,600–1,700	ex-vessel cooling
APR-1400	1,400	in-vessel and ex-vessel cooling

PSA results are reported for all reactor types listed in the EIA Report. Within the scope of the present expertise, it was not possible to research this area in detail. Hence, the results which could be found in the limited time available are not altogether comparable.

Table 11: Overview of core damage frequency and large release frequency as reported in different sources.

Reactor type	CDF per reactor year	LRF per reactor year
EPR (1)	1.33E-06–1.8E-06	1.0E-7
AES-2006 (1)	5.4E-08–1.0E-07	–
AP-1000 (4)	4.0E-07–5.0E-07	1.95E-08–6.0E-08
ABWR (3)	1.6E-07	<1.0E-09
SWR-1000 (3)	1.1E-07	–
ESBWR (4)	3.0E-08	–
APWR (4)	1.0E-07	–
APR-1400 (2)	2.69E-06	2.84E-07 (containment failure)

(1) internal and external initiators, operational and shutdown states

(2) internal and external initiators; not clear if shutdown states included

(3) internal initiators, operational and shutdown states

(4) no specification regarding events and states

Core damage frequencies as reported span about two orders of magnitude, with the APR-1400's CDF of about 2.7E-06/yr as the highest– and the ESBWR's CDF of 3.0E-08/yr. as the lowest.

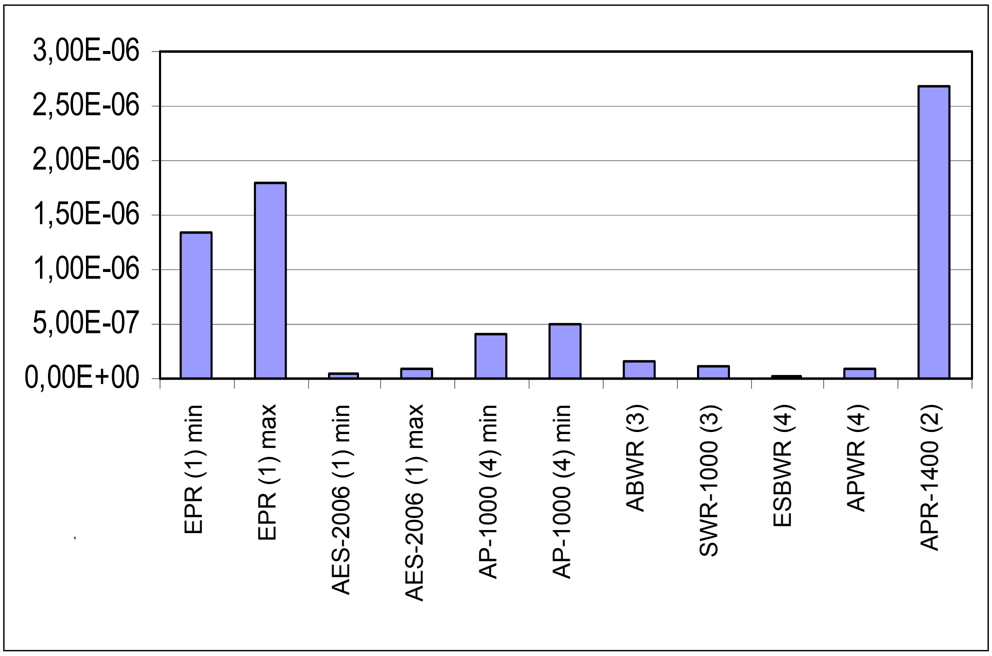

Figure 1: Core damage frequency of different Generation III reactors.

The CDF of the EPR is the second highest, only slightly below that of the APR-1400.

It is interesting to note that the CDF of APR-1400 and EPR lies in the same range as the CDF reported for operating light water reactors from Generation II. For example, CDF for the newer German PWRs and BWRs is about 2.0E-06–2.7E-06 per reactor year (CNS 2002).

When comparing the numbers, it has to be taken into account that in some cases (including the ESBWR) it is not clear how complete the PSA leading to the reported result has been. Furthermore, no ESBWR units are in operation, under construction or firmly planned so far. Due to this comparatively early planning stage, PSA results might be less reliable than results for further developed types.

On the other hand, a rather low number (about one order of magnitude below the EPR's) is also reported for the ABWR which is the only reactor type among those listed in the EIA Report already in operation. Within the scope of this expertise, it is not possible to obtain more detailed information on the ABWR's PSA results, and their trustworthiness.

5.2 Conclusion

The EIA Report does not provide sufficient information about the reactors considered for Olkiluoto 4. From the presentation in the EIA, an evaluation of safety, the maximal source term and its probability of occurrence is not possible.

There is very little operational experience with the reactor types listed in the EIA. Only one of those types (ABWR) has been in operation so far – and only as an earlier variant of the type marketed today.

The majority of the reactor types listed relies on ex-vessel cooling (i.e., installation of a core catcher) for the control and mitigation of severe accidents. However, fundamental problems remain regarding the reliable functioning of a core catcher. The concept of in-vessel cooling is basically more promising, but difficult to implement in large reactors.

PSA results for the reactor types can be found in the open literature; only limited research was possible within the scope of this statement. Core damage frequencies span two orders of magnitude. The reactor types at the upper limit (EPR, APR-1400) lie in the same range as reported for newer LWRs of Generation II.

6 SAFETY AND ACCIDENT ANALYSIS

6.1 Treatment in the EIA Report

Chapter 10 of the EIA Report in a general manner deals with the safety of the new NPP at Olkiluoto. General principles like "defence in depth", "multiple barriers", precautions for external hazards and for severe accidents are mentioned.

"... safety requirements applicable to the new plant are clearly stricter than requirements that were applied during construction of existing Finnish NPPs" (TVO 2008, 149). The design shall include precautions for extensive reactor core damage, which concerns primarily the design of the containment. (TVO 2008, 150)

Impacts of accidents are also treated in chapter 10 of the EIA Report. (TVO 2008, 153) with reference to (GD 395/1991) the dose limits for the population are given:

- For an anticipated operational transient (Class 1 postulated accident with a frequency of occurrence of 1E-3 to 1E-2): 0,1 mSv/a
- For postulated accidents (Class 2 postulated accident with a frequency of occurrence < 1E-3): 5 mSv/a
- For events handled as extension of postulated accidents, i.e. a common cause failure or a complex combination of failures without severe fuel damage: 20 mSv/a

In this government decision GD 395/1991 the specified release limit for a severe accident is such that no immediate health hazards and no long-term restrictions are caused to the surrounding population. Fulfilling the requirements of GD 395/1991 includes proving that the frequency of exceeding this limit is extremely small, i.e. below 5 E-7 per year (TVO 2008, 152).

For exemplary dose calculations, the source term for the severe accident is assumed to be 100 TBq Cs-137 (plus a corresponding proportion of other caesium isotopes), 1,500 TBq I-131 (plus a corresponding proportion of other iodine isotopes) and 100% of noble gases. Release height is assumed to be 100 m (TVO 2008, 153).

With this source term the radiation dose for the population has been assessed for the EIA Report. There is no information on the computer program used for the assessment and no information what type of dispersion calculation is used by the program. The weather conditions for the dispersion calculation are not explained, too. The references listed in the EIA Report are in Finnish, and one is completely missing (TVO 2008, 153). Therefore the results in Table 10.1 are not understandable. In the scoping report it was announced that the impact will be assessed up to distance of 1,000 km; But there is no such assessment presented in the EIA Report.

6.2 Discussion

Requirements for Severe Accidents (Source Term, Frequency)

According to the EIA Report (section 10.4.1), the limits for a severe accident are laid down in the Government Decision 395/1991. A new Government Decree replacing 395/1991 is at present in the draft stage; however, the limits for severe accidents will not be changed.

Besides the Finnish YVL guides the European Utility Requirements are mentioned as essential in the EIA Report.

The Government Decision (395/1991) specifies the following (STUK 2005):

“The limit for the release of radioactive materials arising from a severe accident is a release that causes neither acute harmful health effects to the population in the vicinity of the nuclear power plant nor any long-term restrictions on the use of extensive areas of land and water. For satisfying the requirement applied to long-term effects, the limit for an atmospheric release of caesium-137 is 100 TBq. The combined fall-out consisting of nuclides other than caesium-isotopes shall not cause, in the long term, starting three months from the accident, a hazard greater than would arise from a caesium release corresponding to the above-mentioned limit. The possibility that, as a result of a severe accident, the above-mentioned requirement is not met, shall be extremely small.”

According to the Radiation and Nuclear Safety Authority’s Guide YVL 2.8, the expectation value for the frequency of a caesium-137 release exceeding 100 TBq assessed by a PSA should be below 5E-7/yr (STUK 2005).

Source Term

The source term assumed for exemplary dose calculations in the EIA Report is considerably smaller than the term for a worst-case accident with early containment failure (which would be in the order of magnitude of 300,000 TBq Cs-137 and 1,800,000 TBq I-131). Very effective measures of accident mitigation are required to reliably achieve such a comparatively low source term.

In relation to the Cs-137 releases, the releases of I-131 appear to be rather small (at least for a PWR; the situation for a BWR could be different).

For example, for German PWRs, considerably higher releases of I-131 are reported for accident scenarios with comparable Cs-137 releases (SSK 2004):

- DRS Phase A, release category “AF-Leckage ND*”: Released amount of I-131 higher by a factor of 125 than the release of Cs-137
- PSA level 2 for GKN-2 – release category FKE: Release of I-131 higher by a factor of 55–1,400 than the release of Cs-137

It is likely that special mitigation measures would be required to reduce iodine releases. There is no discussion of such measures in the EIA Report.

Furthermore, it is questionable whether the restriction to Cs-137 (and other Cs isotopes), I-131 (and other I isotopes) and noble gases is sufficient, even for a rough assessment of accident consequences. In the “Criteria for Limited Impact” of the European Utility Requirements, nine nuclides are listed to be taken into account when determining whether the criteria are fulfilled – (EUR 2001), see also the annex to this chapter.

Taking the source term from the EIA Report (while keeping in mind that the consistency and sufficiency of this source term are questionable), it is possible to check whether the EUR criteria are kept.

There are four Criteria for Limited Impact:

1. No emergency protection action beyond 800 m
2. No delayed action beyond 3 km
3. No long-term action beyond 800 m
4. Limited economic impact

For the criteria 1–3, the releases of nine nuclides have to be multiplied with weight coefficients and added. The sums have to be below a given limit. There are different coefficients for elevated release (from stack, release height 100 m or more) and for ground releases (release height below 100 m).

For criterion 4, the maximal permissible release for each of three reference isotopes (I-131, Cs-137 and Sr-90) is specified.

The sums for criteria 1–3 can be calculated with the source term of the EIA Report and divided by the limits according to EUR.

For criterion 1, the limit is exceeded by the source term – by a factor of 10 for ground release, and a factor of 1.8 for elevated release (for a combination of the two release forms, the factor will be between those two values). For criteria 2 and 3, the weighted sum is well below the limit – at least by a factor of 15.

For criterion 4, the limit for Cs-137 is exceeded by a factor of 3.3.

(For more details of the comparison of the EIA Report source term with EUR criteria, see the annex to this chapter.)

Frequency of exceeding the limit

According to EUR, the expected frequency of a release higher than specified in the Criteria for Limited Impact has to be 1E-6/yr.

The frequency limit according to Finnish regulations is half of this value. Taking into account the uncertainties and limitations of PSAs (HIRSCH 2006), this difference appears to be of little significance.

6.3 Conclusions

The source term as assumed in the EIA Report for exemplary dose calculations appears questionable regarding the relation between Cs-137 and I-131; and it does not take all nuclides which are required for checking EUR release criteria (Criteria for Limited Impact) into account.

Even so, not all EUR criteria are kept by the source term in the EIA Report. Criterion 1 (no emergency protection action beyond 800 m) is not fulfilled; Criterion 4 (limited economic impact) is not fulfilled for the release of Cs-137.

Within the scope of this expertise, it cannot be discussed whether it can be expected that the reactor types listed in the EIA Report conform to Finnish regulations. A detailed technical assessment of the reactors would be required to answer this question.

In the EIA Report a dose assessment of the accidental release with the exemplary source term is presented for a region of 100 km from the NPP. For a distance up to 1,000 km the dose is evaluated by extrapolation. This assessment by extrapolation is not state of the art.

There is no long-range transport of an accidental release presented in the EIA. For this kind of assessment a simple dispersion model can not be used. For modelling the long-range transport, diffusion and deposition of radionuclides more sophisticated tools are required, such as the Lagrangian particle dispersion model FLEXPART. FLEXPART is a model suitable for the meso-scale to global-scale calculations, which is freely available and used by many groups all over the world (STOHL 1998).

For an assessment of the potential impact of a severe accident at the Olkiluoto 4 NPP the information of the EIA Report is not sufficient (no worst case, only one source term which can not be proved to be the maximum release).

Moreover, on April 22th 2008, nuclear regulatory officials criticized in a comment that the EIA for Olkiluoto-4 does not sufficiently cover the consequences of an accident and how people near the plant would be protected. „STUK officials said that TVO's description of emergency response in the event of an accident was "very narrow." They added that the assessment also concentrates on serious accidents but that there should also have been a review of the consequences of less serious accidents and how they would be handled“. (NW 2008/04/24)

ANNEX Explanation of Criteria of Limited Impact

The following table shows the nine nuclides which are taken into account by the EUR when determining whether the Criteria for Limited Impact are kept, as well as the weight coefficients for ground and elevated releases, for Criterion 1.

Below is the formula being used to determine acceptance.

Isotope group	Coefficients for ground level releases C_{ig}	Coefficients for elevated releases C_{ie}
Xe_{133}	**$6{,}5.10^{-8}$**	**$1{,}1.10^{-8}$**
I_{131}	$5{,}0.10^{-5}$	$3{,}1.10^{-6}$
Cs_{137}	$1{,}2.10^{-4}$	$5{,}4.10^{-6}$
Te_{131m}	$1{,}6.10^{-4}$	$7{,}6.10^{-6}$
Sr_{90}	$2{,}7.10^{-4}$	$1{,}2.10^{-5}$
Ru_{103}	$1{,}8.10^{-4}$	$8{,}1.10^{-6}$
La_{140}	$8{,}1.10^{-4}$	$3{,}7.10^{-5}$
Ce_{141}	$1{,}2.10^{-3}$	$5{,}6.10^{-5}$
Ba_{140}	$6{,}2.10^{-6}$	$3{,}1.10^{-7}$

The acceptance criterion is that:

$$\sum_{i-1}^{9} R_{ig} * C_{ig} + \sum_{i-1}^{9} R_{ie} * C_{ie} < 5 * 10^{-2}$$

Criteria 2 and 3 are following the same scheme, whereas Criterion 4 specifies the limits for three reference nuclides, each of which must not be exceeded (4,000 TBq for I-131, 30 TBq for Cs-137 and 400 TBq for Sr-90).

7 NUCLEAR FUEL PRODUCTION

7.1 Availability of uranium

7.1.1 Treatment in the EIA Report

Regarding availability of uranium the EIA Report states, that currently the nuclear reactors in the world require a total of some 70,000 t/yr of uranium. At the moment, the production of new natural uranium covers about 60%-70% of the demand. The rest is covered by emptying stockpiles, by producing fresh fuel through the reprocessing of spent fuel and by diluting the large stockpiles of weapon-grade uranium. "The known uranium resources that can be exploited at reasonable costs (some 5 million tons) will last for well over 60 years at the current consumption rate. There are plenty of potential uranium deposits. These additional resources are estimated to be many times bigger than the currently known resources. The availability of uranium is not an obstacle for continuing or expanding the use of nuclear power, but new uranium production will require a higher price level than that prevailing in the 1990's." (TVO 2008).

7.1.2 Discussion

Contrary to this, the analysis of data on uranium resources, as discussed in the paper EWG series No 1/2006 of the Energy Watch Group (EWG 2006), leads to the assessment that discovered reserves are not sufficient to guarantee the uranium supply for more than thirty years.

Production of new natural uranium

„Eleven countries have already exhausted their uranium reserves. In total, about 2.3 Mt of uranium have already been produced. At present, only one country (Canada) was left having uranium deposits containing uranium with an ore grade of more than 1%, most of the remaining reserves in other countries have ore grades below 0.1% and two thirds of reserves have ore grades below 0.06%. This is important as the energy requirement for uranium mining is at best indirect proportional to the ore concentration." (EWG 2006) In Olympic Dam, the Australian mine TVO procures uranium from, the ore grades are even as low as 0.044% (BOSSEL 2007) to 0.053% (DIEHL 2006). To extract 1 kg of uranium out of 1% ore containing material needs the processing of 100 kg. Extracting the same amount from 0.01% ore needs the processing of 10,000 kg.

At the annual demand of 2006, the proved reserves (below 40 $/kg U extraction cost) and stocks are going to be exhausted within 30 years. Possible resources (which contain all estimated discovered resources with maximal 130 $/kg extraction costs) will be exhausted within 70 years. There are problems and delays with the biggest new mining projects (e.g. disastrous water brake-in at the mines of Cigar Lake in Canada), which are causing doubts whether these extensions can be realized at all. If not, then even before 2020 supply problems are likely. Otherwise, if all estimated known resources up to 130 $/kg U extraction cost can be converted into production volumes, a shortage can at best be delayed until about 2050 (EWG 2006).

Emptying stockpiles

Only 42,000 t/yr of the 67,000 t/yr current uranium demand are supplied by new production, the rest of about 25,000 t/yr is drawn from stockpiles. The stock consists of stocks at mines, reactor sites, conversion of nuclear weapons and reprocessing of nuclear waste. While in 2002 the amount of uranium in stocks was estimated to be some 390,000–450,000 t, it should be reduced to about 210,000 t of uranium or even less by the end of 2005. These stockpiles have been accumulated before 1980 and will be exhausted within the next 10 years. Therefore uranium production capacity must increase by at least some 50% in order to match future demand of current capacity (EWG 2006).

Reprocessing of spent fuel

The reprocessing of nuclear fuel comes together with nuclear weapons proliferation risk. „The technology of reprocessing is described in open literature, and there was sufficient open literature on nuclear weapons even in the mid-1960ies to allow three graduate students in the US to successfully design an implosion weapon with a 15 kiloton yield with two man-years of effort. No other bulk electrical energy or process heat source (coal, oil, natural gas, hydroelectric power, wind power, solar power, biomass, etc.) has such proliferation concerns associated with it.” (BMLFUW 2007) With a focus on the commercial nuclear fuel cycle, reprocessing of spent fuel is one of the four principal points of vulnerability for nuclear weapons proliferation.

In the following figure the relation of possible uranium production profiles, reported reserves and resources and the annual uranium fuel demand of reactors are shown, where the “reference scenario” represents the most likely development, the “alternative policy scenario” represents the scenario based on policies to increase the share of nuclear energy with the aim of reducing carbon dioxide emissions. The calculations are based on data from the Nuclear Energy Agency, the forecasts are based on the 2006 scenarios by the International Energy Agency (EWG 2006).

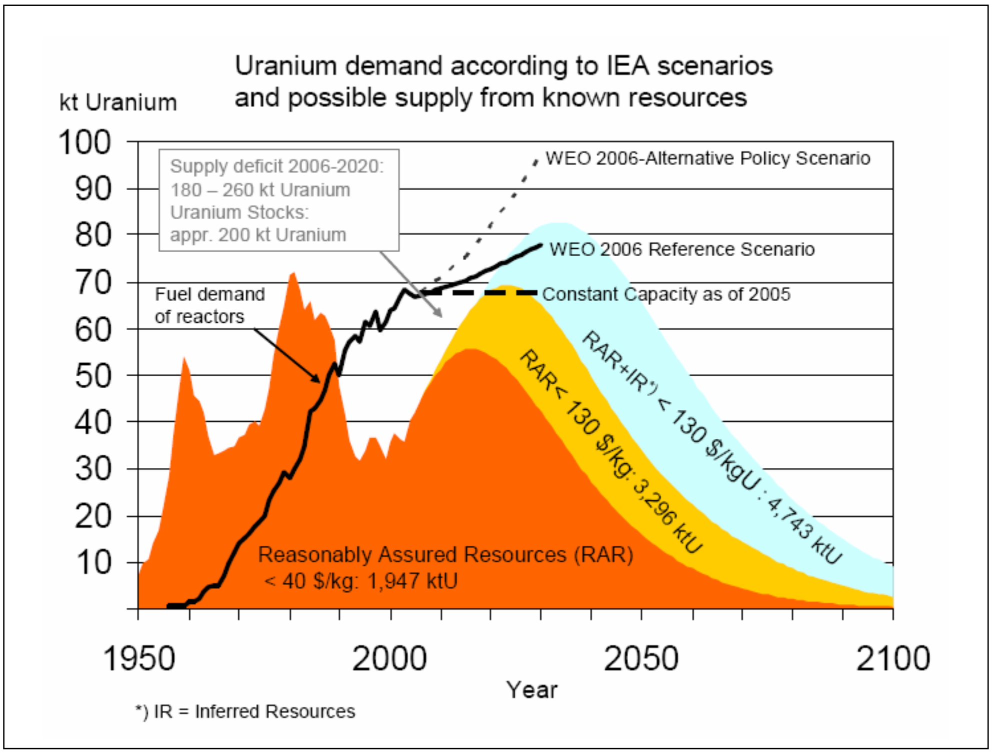

Figure 2: Past and projected uranium production. The black line shows the fuel demand of reactors currently operating together with the latest scenarios in the World Energy Outlook 2006 of the IEA.

7.1.3 Conclusion

While summarizing the facts, we have to assess that the availability of uranium is awfully well an obstacle for continuing or expanding the use of nuclear power. In addition to that, new uranium production will require a much higher price level, and – as stated in the assessment of the Austrian nuclear advisory board (BMLFUW 2007) – is also a matter of proliferation risk and is definitely not a CO_2-free technology.

7.2 Impacts of nuclear fuel production

7.2.1 Treatment in the EIA Report

Regarding impacts of nuclear fuel production the EIA Report states, that TVO has been monitoring and supervising the environmental matters of its uranium suppliers throughout its history in business. "During recent years, Canada and Australia have accounted for about half of the world's uranium production. TVO has procured about half of it's uranium from Canadian suppliers and 20% from Australia." (TVO 2008) The EIA Report further states that in Australia TVO procures uranium from the Olympic Dam mine. There are no old communities near the mining area, and the nearest aboriginal community is about 200 km away. "In Australia mining companies pay the aboriginals rent for use of their land and provide employment opportunities for them. The aboriginals also get to share the profits of the mining operations." (TVO 2008) Regarding the same issue, the EIA Report states, that in Kazakhstan, uranium is produced using in-situ leaching, where uranium is produced using solution leaching directly from the soil. "This production method is efficient and only produces minimal environmental impacts because nearly all other materials besides uranium remain in the ground." (TVO 2008) The EIA Report also states, that the new plant unit (OL-4) will consume approximately 20 to 40 tons of enriched uranium fuel per year. This equals approximately 200 tons of raw uranium material.

7.2.2 Discussion

So far, a part of the uranium used in Finland is supplied by countries, where the uranium mining probably yields ethical problems. For example, 20% of the uranium bought by TVO is supplied by Australia. There most of the Aborigines communities get inadequate leases, as compared with the permanent destruction and contamination of their land. Despite the fact that the Olympic Dam mine in South Australia is on a freehold lease and is not affected by any native title claim itself, it should be considered that the Great Artesian basin - an ancient reservoir of groundwater whose nearest extractable location is about a hundred kilometres from the mine site - is territory of the Aboriginal group named Arabanna. "Apart from being a perennial source of water for subsistence, the mound springs were of immense cultural and spiritual significance to the Aborigines. Particular associations with the topography of certain areas constitute their perennial mythology. The Great Artesian basin also was considered to be a non renewable resource whose water should not be used for industrial development." (SALEEM 2000) "The mine's use of Great Artesian Basin water — over 30 million litres per day — has adversely effected the region's fragile mound springs by reducing their water flow (BNI 2006).

Some 20% or 30% of the uranium bought by TVO are supplied most likely by Niger, the 4th biggest uranium producing country in the world, where only 10% of the population has access to electricity, and where the mine workers conditions are off humanity.

Environmental impact of uranium ore mining and mining waste

The more important fact is, that the 185–220 tons of raw uranium needed for the production of some 20 tons of isotope-enriched uranium for one unit equal 15,500–18,700 tons of ore containing 1% uranium, which first have to be mined, then transported from the mine to the enrichment plant, and last but not least deposited. The mining under humane conditions can not be guaranteed as long as the production of uranium is outsourced to sub companies with the motivation to achieve dumping prices (e.g. Niger). The transport generates CO_2, too. But the final disposal of uranium mining waste is probably the biggest problem of uranium mining: As discussed in (WENISCH et al. 2007), the Uranium extraction itself generates 80% of today's radioactive waste (by mass; not by radioactivity). The amount of radioactive tailings left behind in the uranium mine area is of corresponding volume. For example, the affected regions of New Mexico (USA) and Wismut (former GDR) must cope with more than 100 million tons of radioactive waste from uranium extraction on the surface (BMLFUW 2007).

During mining, uranium is removed from geological deposits that usually are geochemically stable. Residual uranium and all the separated decay products are left at the site and stored on the surface in form of dumps or as mud in simple basins. The waste products of uranium mining contain hazardous substances like thorium-230 with a half-life of 77,000 years. Thorium decays to radium and gaseous radon. "The isolation periods required for final disposal of these wastes are comparable to those of wastes from the operation of nuclear power plants. But in this case, geological storage is not taken into consideration due to the large amount of material." (BMLFUW 2007).

Since opening, the Olympic Dam mine has produced over 60 million tons of radioactive tailings waste, a figure currently growing at a rate of 10 million tons per year. Eighty percent of the radioactivity of the original ore remains in the tailings, as well as a range of other toxic materials. The tailings waste is stored on site at Olympic Dam with no plans for its long-term management. A large number of bird deaths recorded in a 2004 survey attests to the toxicity of the tailings. The radioactive tailings dams were the focus of a 1996 parliamentary inquiry following revelations that five trillion litres of liquid tailings waste had leaked over a period of several years (BNI 2006).

In-situ leaching

When the uranium mining companies make use of in-situ leaching (ISL) mining technique, it means pumping acid into an aquifer in order to dissolve the uranium ore and other heavy metals and pump the solution back to the surface. The separation of the small amount of uranium is performed at the surface. "The liquid waste – which contains radioactive particles, heavy metals and acid – is simply dumped in groundwater. Inert and immobile in the ore body, the radionuclides and heavy metals are then bio available and mobile in the aquifer." (BNI 2006).

7.2.3 Conclusion

In so far the production of nuclear fuel has an immense impact on the land where it is mined and the inhabitants living there.

The mining regions, which are often inhabited by indigenous people, have the dangerous substances and health problems, left by companies which sell the uranium (and other mineral resources) to industrialized countries.

The production of nuclear fuel has an immense impact on the land where it is mined and the inhabitants living there. If the environmental impact of mining would be taken as seriously as the impact of cultivation of plants for energy use instead for food, both activities would have to be stopped.

8 SPENT FUEL MANAGEMENT

8.1 Interim storage of spent nuclear fuel

8.1.1 Treatment in the EIA Report

Regarding interim storage of spent nuclear fuel, the EIA Report states, that after a few years of cooling in the water pools of the power plant unit, the fuel bundles are taken to the interim storage for spent fuel (KPA store) located at the power plant site for intermediate storage. The heat transferred from the fuel to the water in the KPA store is further transferred to an intermediate cooling circuit. Intermediate storage will continue for decades until the disposal of the spent fuel (TVO 2008, 71).

8.1.2 Discussion

There is strong evidence, that wet intermediate storage of spent fuel is not the best solution for long-term storage, since there is evidence that fuel bundles stored in a spent fuel pool over a long period are much more difficult to handle with than fuel bundles stored in a dry storage cask. Moreover, "The potential consequences of an accident or terrorist attack on a dry cask storage facility are lower than those for a spent fuel pool: There is less fuel in a dry cask than in a spent fuel pool and therefore less radioactive material available for release.” (NRC & COMMITTEE 2006).

„Radioactive material releases from a breach in a dry cask would occur through mechanical dispersion. Such releases would be relatively small. Certain types of attacks on spent fuel pools could result in a much larger dispersal of spent fuel fragments. Radioactive material releases from a spent fuel pool also could occur as the result of a zirconium cladding fire, which would produce radioactive aerosols. Such fires have the potential to release large quantities of radioactive material to the environment." (NRC & COMMITTEE 2006).

8.1.3 Conclusion

For a long-term storage the pool is not an optimal technology. Critical aspects are the integrity of the fuel rods and their handling after several decades in the pool. A further extension of the interim fuel storage is envisaged in order to prepare place for the fuel from OL-3 and OL-4. Since it is planned to store the spent fuel in the interim storage over several decades, the disadvantage of the storage pool compared to a dry one should be considered. Furthermore an assessment of the risk of accidents caused by external impacts to the pool storage should be given.

8.2 Final disposal of spent nuclear fuel

8.2.1 Treatment in the EIA Report

The final repository of spent fuel from TVO's and Fortum's NPPs is intended to be located 400–500 m underground in the bedrock at Olkiluoto. An EIA concerning this project was competed in 1999. After a positive decision in principle Posiva Oy, a company own by the operators and responsible for the spent fuel management, started preparation of an underground research facility called ONKALO at Olkiluoto. The objective of this project is to obtain detailed information concerning the bedrock for the purpose of designing the disposal facility and assessing its safety. The spent fuel will be packed into airtight metal canisters before being transferred into the repository. Posiva intends to supply the application for a construction licence for the Spent fuel repository by the end of 2012. The disposal of spent fuel into the repository is scheduled to start in 2020.

Regarding impacts of the final disposal of spent nuclear fuel, the EIA Report states, that the conditions in the final repository are almost totally void of oxygen (the original text „void of oxygen-free“ does not make sense). Research indicates that copper will withstand corrosion in the repository conditions for at least 100,000 years. Further research results indicate that hundreds of meters down in the bedrock, the groundwater is virtually void of oxygen and flows very slowly. Hence its corroding effect on the canisters and the spent nuclear fuel is very small. "If spent fuel would come into contact with groundwater, the substances dissolved from it would mainly remain in the bentonite buffer and bedrock surrounding the canisters." (TVO 2008 73) The EIA Report states, that the safety of the final disposal of spent fuel is based on technical and natural barriers that prevent and slow down the release of radioactive materials from the final repository to the bedrock and living nature. Also regarding impacts of the final disposal of spent nuclear fuel, the EIA Report states, that the long-term safety of the final repository is proven using models based on empirical studies. The analysed events even include disturbances of very small low expected probability, such as ice-ages with fault movements, land uplift, earthquakes and the creation of new weakness zones (TVO 2008, 74).

8.2.2 Discussion

At present Finland investigates the bedrock at Olkiluoto in order to locate the repository there. An underground research laboratory prepares the required information for the design and construction of a spent fuel repository. This is assumed to be ready for disposal in 2020. There is no discussion in the EIA Report of alternatives if the bedrock reveals to be not adequate for long-term safety. The safety analysis for deep geological repositories contains large uncertainties, in particular regarding the long-term function of technical and geological barriers.

An international exercise resulted in the following dose impact of deep spent-fuel disposal in a granite environment after more than 10,000 years: "The impact is zero in the first 10,000 years following sealing of the facility. Then highly mobile iodine-129 is the first isotope to reach the outlet and contributes most to the dose. After several hundreds of thousands of years, the heavy atoms (226Ra, 230Th) from decay chains 4N[8] (232Th chain), 4N+1 (241Am and 237Np chain), 4N+2 (238U chain) and 4N+3 (235U chain) take over the running." (BONIN 2002).

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[8] "N" means the number of nucleons. This system is used to identify the different radioactive decay chains.

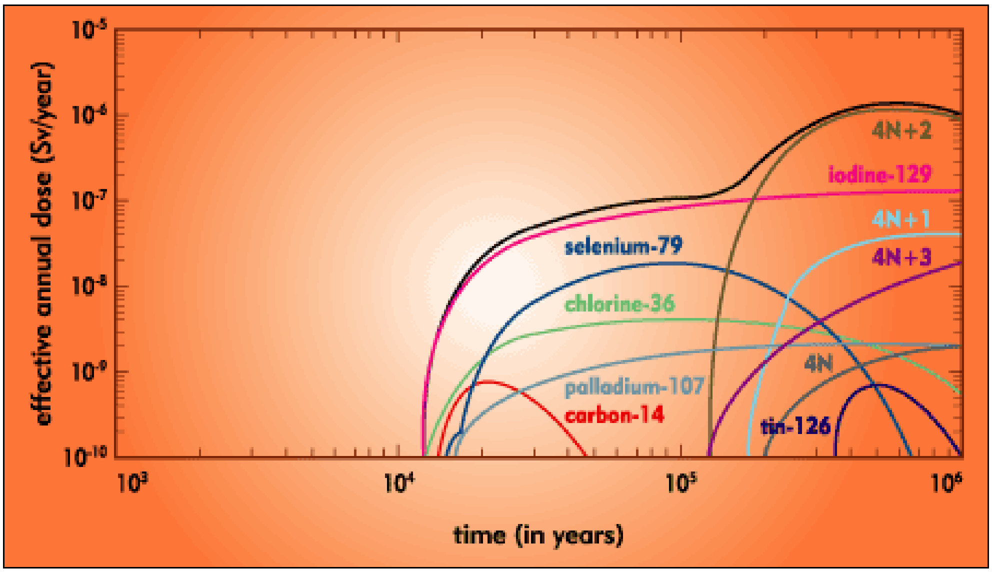

Figure 3: The dose impact of deep spent-fuel disposal in a granite environment (BONIN 2002).

Since final disposal of spent nuclear fuel is a matter of time-span of several hundreds of thousands of years, even a very slow water flow towards the canisters means also a (very slow) flow away from it. Even this slow water stream is able to carry radioactive substances away from the bedrock surrounding potential damaged canisters – in case of any unforeseen circumstances such as stronger corrosion of canisters due to water break-in and coincident changes in oxygen content of the groundwater – and could result in a strong impact to environment and living nature.

8.2.3 Conclusion

The EIA Report states, that the long-term safety of the final repository has been proved by using a model for the calculations.

According to the state of science and technology final waste disposal for spent fuel can be realized in deep geological formations. Great advances have been made concerning the accomplishments of safety analysis. The deep geological repository of high level waste can be rated as the most safely way to treat radioactive waste. Anyway there are large uncertainties in the results of the safety analysis. The assessment of the influence of ice-ages with fault movements, land uplift, earthquakes and the creation of new weakness zones also contributes to these uncertainties.

In particular, the long term capability of the technical and geological barriers cannot be guaranteed, because of the long storage period required. Experiences and experiments cannot be carried out for such long periods.

There is no discussion in the EIA Report of alternatives if the bedrock reveals to be not adequate for long-term safety.

9 ALTERNATIVES AND ZERO OPTION

9.1 Treatment in the EIA Report

The discussion of environmental impacts of the zero option compares nuclear energy to the production of the same amount of electricity by the Nordic electricity market. The avoided emissions of greenhouse gases are calculated in chapter 11 of the EIA Report (TVO 2008, 165) based on the assumption that „a nuclear power plant does not produce any emissions of sulphur dioxide, nitrogen oxides, carbon dioxides or particles" (TVO 2008, 164).

Chapter 9 of the EIA Report presents calculations of the material input per the amount of electricity produced for different generation technologies: material input of fuel compared to the amount of electricity produced (MIPS – Material Input Per Service Unit) was 1,160 kg/MWh for a new Finnish coal condensate power plant, 170 kg/MWh for a natural gas combination power plant, and 42 kg/MWh for a nuclear power plant. "Of the electricity generation alternatives studied, nuclear power is by far the most environmentally friendly when measured using the MIPS indicator." (RISSANEN et al 2001, cit. in TVO 2008, 66).

Alternatives are discussed in chapter 12 of the EIA Report. Regarding the NPP Boiling or Pressurized reactors are mentioned and the bandwidth of 1,000 MW to 1,800 MWe. The impact of dumping the thermal load of approx. two third of the energy produced in the reactor is discussed in detail and alternatives for the outlet and intake of cooling water are presented. Without doubt this is an important environmental impact to the sea, and could also cause transboundary impacts due to changes in marine ecosystems.

9.2 Discussion

As discussed in (WENISCH et al. 2007), nuclear electricity production is not CO_2 free if the whole uranium fuel cycle is taken into consideration. Using current uranium ore grades (~ 2% concentration) results in 33 g of CO_2 equivalent per kWh of nuclear electricity in Germany. In France, it is only 8 g, while it is higher in Russia and in the USA, 65 g and 62 g respectively. One reason for this is the quality of uranium ore: the lower the grade, the more CO_2. A substantial increase of nuclear electricity generation would require the exploitation also of lower grade uranium ores and thus would increase the CO_2-emissions up to 120 g, which is more than other energy technologies: natural gas co-generation 50–140 g, wind power 24 g, hydropower 40 g, energy conservation 5 g CO_2 eq/kWh_{el} (FRITSCHE 2007).

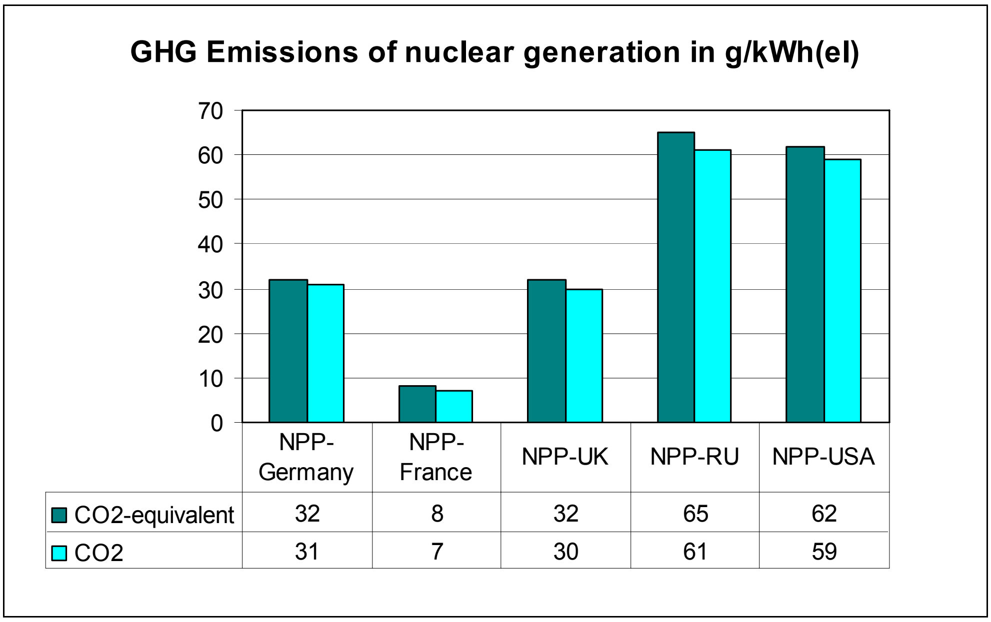

Figure 4: Greenhouse gas Emission of Nuclear Generation, Data (FRITSCHE 2007).

"The MIPS is, in detail, the sum of the mass of the product and the mass of its 'ecological rucksack' divided through the utility of the product. The ecological rucksack means the mass of natural materials moved from their original location in the natural ecosystem – which mass is required by the (final) product in addition to its own weight during its whole life cycle. Simple and clear, but it does not take into account the harmfulness of materials nor the way how the residual material is processed. It does not as such express the amount of environmental impacts. The used water and air are not included in the rucksack nor the raw materials needed for the construction of the fabrication machinery of the product. Furthermore, the material use for the waste management is excluded in the examination." (TARJANNE 2006).

It is not an unexpected fact, that of the electricity generation alternatives studied, nuclear power is environmentally friendly when measured using the MIPS indicator, since the MIPS does not take into account neither toxicity, nor water and air impact.

The material input coefficient of nuclear fuel is highly dependent of the mining technology, the uranium content of the ore and other characteristics of the mine.

9.3 Conclusion

In order to assess the environmental impact of electricity generation technologies it is not sufficient to rate the energy content of different fuels. The material input per MWh electrical energy produced is only one illustrative measure similar to the ecological footprint. In order to produce more information about the actual environmental impacts of technologies, GHG, toxicity of emissions and residues and the risk of harmful emissions due to accidents have to be included in a life cycle assessment in order to gain a comprehensive review of environmental impacts.

If the total nuclear chain and the management of all types of radioactive waste is considered nuclear energy can not be regarded as CO_2 free and environmentally sound .In particular uranium mining and fuel fabrication cause a significant impact on the environment.(see also chapter 6 of this statement). A complete comparison of the real costs and risks of nuclear energy production with those of renewable energy production alternatives proves that there is no advantage of nuclear electricity towards renewable energy (BMLFUW 2007).

Nuclear energy also proves to be a comparatively costly measure to reduce CO_2-emissions. Energy efficiency measures, renewable energies and alternative solutions in the wider sense replace 2.5 to 10 times as much CO_2 per unit investment (BMLFUW 2007).

10 QUESTIONS

Procedure

1. When will TVO reach a decision regarding the reactor type?
2. Has the European Commission acknowledged that the implementation of an EIA procedure previous to the decision about the reactor type is in accordance with the EC EIA Directive?
3. Are the feasibility studies for five reactor types submitted by TVO to the Radiation and Nuclear Safety Authority available for the interested public?
4. What is the formal framework, in which foreign states participating in the cross border EIA on Olkiluoto-4 will have access to these documents?
5. Why is the information about the reactor types in discussion not made public, especially as in a similar UK procedure the availability of comprehensive information is obviously possible?

Reactor types

1. The reactor types listed in the EIA Report as being in “non binding” consideration for Olkiluoto-4, are in different stages of development; most of them are still at the design stage, only one of them (ABWR) has operational experience. Especially the accuracy and reliability with which the hazards can be assessed will also vary considerably and should therefore be described in detail. How will the Finnish authorities address this circumstance during the EIA process and follow-up decisions?
2. The "core catcher" (ex-vessel cooling) as foreseen in most of the reactor types is still under development; basic problems regarding its functioning have been reported. Is it assumed that all those problems will be resolved in the short term and will be reflected within the EIA process?
3. Core damage frequencies (CDF) and early release frequencies (ERF) vary considerably (by two orders of magnitude) for the reactor types listed. How will this be evaluated within the EIA process or at a later stage of the licensing?
4. Is a lower CDF/lower ERF seen as a substantial advantage of a reactor type?
5. Which criteria has TVO defined for the selection of the reactor? Can they be described and reported to the public before a governmental decision is taken?

Safety and accidents

1. The exemplary source term in the EIA Report contains, in relation to the releases of Cs-137, a rather small amount of I-131. How can this be justified?
2. The exemplary source term in the EIA Report does not contain important nuclides like Sr-90, Ru-103 and others. How can it be justified that the calculations of consequences nevertheless yield meaningful results?
3. The exemplary source term does not fulfil all EUR Criteria for Limited Impact. To which extent are those criteria binding; which role do the EUR generally play in the licensing procedure?

4. What is the maximum release due to a worst case accident in the new NPP?
5. Method and input data for the dose assessment are not explained in the EIA Report. Please, provide a description of the dispersion model and the weather data used for the assessment.

Spent fuel management

1. The interim storage of spent fuel in a pool over long periods seems not to be an optimal solution. An enlargement of the interim storage is envisaged. Considering the disadvantages of wet storage, would dry storage not be a safer option?
2. At present an underground laboratory is investigating the suitability of the bedrock at Olkiluoto as a location for the final spent fuel repository. What alternatives are considered, if the investigation reveals that the bedrock is not adequate to guarantee the safe long term storage of high level nuclear waste?

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Internet links are subject of change. We advise the reduction of the complete address to the shortest possible (=main) address, and then start to search for the document.

12 GLOSSARY

ABWR	Advanced Boiling Water Reactor
APWR	Advanced Pressurized Water Reactor
BDBA	Beyond Design Basis Accident
BWR	Boiling Water Reactor
CDF	Core Damage Frequency
DBA	Design Basis 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
GHG	Greenhouse Gases
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection
IEA	International Energy Agency
LOCA	Loss of Coolant Accident
LO 3	Loviisa Unit 3
LRF	Large Release Frequency
LWR	Light Water Reactor
MIPS	Material Input Per Service Unit
MTI	Ministry of Trade and Industry
MW	Megawatt
MWe	Megawatt electric
NGO	Non Governmental Organisation
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission (USA)
OL-4	Olkiluoto Unit 4
PSA	Probabilistic Safety Assessment
PWR	Pressurized Water Reactor
RPV	Reactor Pressure Vessel
SNF	Spent Nuclear Fuel
TVO	Teollisuuden Voima Oy
WNA	World Nuclear Association
YVL	Regulatory Guides on Nuclear Safety

Umweltbundesamt GmbH
Spittelauer Lände 5
1090 Wien/Österreich

Tel.: +43-(0)1-313 04
Fax: +43-(0)1-313 04/5400

office@umweltbundesamt.at
www.umweltbundesamt.at

ISBN 3-85457-960-8

Zeitschrift/Journal: Publikationen des Umweltbundesamtes, Wien

Jahr/Year: 2008

Band/Volume: REP_162

Autor(en)/Author(s): Wenisch Antonia, Hirsch Helmut, Kromp Richard, Mraz Gabriele

Artikel/Article: NPP-Olkiluoto-4. Expert Statement to the EIA Report. 1-46