Barsebäcksoffensiv's (BBOFF) position paper of June 11th 2004 on the Barsebaeck nuclear power plant's application for an environmental permit

Background: Pursuant to Article 3 in the Espoo-convention[1] and Article 7 in the *Directive 2001/42/EC of the European Parliament and of the Council on the assessment of the effects of certain plans and programmes on the environment*[2] and similar Swedish provisions – chapter 6 in the Environmental Act (SFS 1998:808) and the statutory instrument (SFS 1998:905) on descriptions of environmental effects – the Danish authorities have decided that Denmark will participate in the trans-national consultation process with respect to the Barsebaeck nuclear power plant's application for an environmental permit, cf. letters March 29th and April 2nd between the Swedish Environmental Protection Agency and the Danish Forest and Nature Agency, the Spatial Planning Department[3].

As a part of this consultation process BBOFF issues the following position paper on the transboundary environmental impact assessment of the Barsebaeck nuclear power plant on behalf of the following NGOs: *The Danish Ecological Council, NOAH – Friends of the Earth Denmark, The Danish Society for the Conservation of Nature, The Danish Organisation for Renewable Energy, Eco-net, Nature and Youth* and *Copenhagen's Environmental and Energy Office.*

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[1] *Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991),* http://www.unece.org/env/eia/eia.htm
[2] http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/l_197/l_19720010721en00300037.pdf
[3] Cf. http://www.lpa.dk/Venstremenuen/Planemner/Miljokonsekvensvurderinger/VVM/Barsebaeck/svensk_notific_29mar04_.pdf and http://www.lpa.dk/Venstremenuen/Planemner/Miljokonsekvensvurderinger/VVM/Barsebaeck/Kvittering_Naturvaardsverket_SNS_2apr04_.pdf

SUMMARY AND RECOMMENDATIONS

On the basis of the information presented in this position paper BBOFF recommends that the Barsebaeck nuclear power plant should not be given an environmental permit. In stead the Danish and the Swedish government should intensify their efforts to shut down the plant as quickly as possible.

The reason for this recommendation is **shortcomings with respect to the physical protection and the safety level of the plant**, including:

- Lack of physical protection against **a terrorist attack in the form of an airplane crash**. Both the plant management and the regulatory authorities are in an impossible position as regard the implementation of precautionary measures in order to enhance the security level.

- Lack of physical protection against **a terrorist attack on the ground** at the Barsebaeck nuclear power plant as well as at all other nuclear power plants in Sweden.

- That the direct and indirect parameters for the level of safety during normal operation – including PSA-analyses, INES figures, accessibility, the frequency of quick-stops and discharge of radiation into the environment – give the impression of a nuclear power plant that is old, outdated and worn-down.

- That the **basic choices in the reactor design** are such, that Barsebaeck 2 would not have been granted an operation permit in the USA.

- That there are indications that **the safety culture** at the plant is the single largest safety risk during normal operation (in this context it should be remembered that the accidents at Chernobyl and Three Mile Island were caused by human errors).

The recommendation not to give the Barsebaeck nuclear power plant an environmental permit, but in stead to decommission the plant as quickly as possible, is also based on **an assessment of the effects of a serious accident at the plant**. In this connection BBOFF emphasizes the fact

- That the Barsebaeck nuclear power plant is situated at the centre of the most densely populated area in Scandinavia, only 20 km east of the Danish capital Copenhagen and 15 km north of Malmoe. **It could be argued that this is the worst location of any nuclear power station in the world**.

- That an analysis of Barsebaeck 2's reactor inventory – particularly with respect to its content of **caesium-137** – indicates a possibility of **release scenarios just as serious or more serious than the releases from Chernobyl**. The reason is that even though Barsebaeck 2's reactor core is smaller than Chernobyl 4's, it has a higher burn-up rate.

- That the possibility of consequence scenarios for the worst possible accident at the Barsebaeck nuclear power plant similar to or worse than the Chernobyl disaster **are confirmed by reports from the Swedish nuclear regulatory authorities that are the basis of the Danish nuclear rescue preparedness**.

- That **an exclusion zone within a radius of 30 km from the release source** – similar to the one around the Chernobyl reactor – around Barsebaeck would include in **Sweden** Malmoe, Lund, Landskrona, Esloev, Staffanstorp and at least more than twenty villages and in **Denmark** all of Amager, Copenhagen K, Frederiksberg, Vesterbro, Noerrebro, Oesterbro, Vanloese, Broenshoej, Valby, Vigerslev, Hvidovre, Avedoere Holme, Broendbyoester, Roedovre, Utterslev, Nordhavn, Bispebjerg, Hellerup, Husum, Moerkhoej, Gladsaxe, Soeborg, Buddinge, Bagsvaerd, Vangede, Gentofte, Charlottenlund, Skovshoved, Jaegersborg, Ordrup, Lyngby, Sorgenfri, Virum, Klampenborg, Taarbaek, Raadvad, Soelleroed, Holte, Gl. Holte, Oeveroed, Naerum, Troeroed, Skodsborg, Vedbaek, Sandbjerg, Isteroed, Ravnsbjerg, Hoesterkoeb, Braadebaek, Hoersholm, Usseroed, Valleroed, Rungsted and Kokkedal.

- That the reports from the Swedish nuclear regulatory authorities that are the basis of the Danish nuclear rescue preparedness include consequence scenarios implying **exclusion zones within a distance of 20, 50, 60 and 100 kilometres from the release source dependent of the weather conditions**.

- That the Chernobyl disaster so far has cost Ukraine and its neighbouring country Belarus that was hit the hardest in the order of **3000 billion DKK**. However, in 2001 the GNP per capita in Copenhagen and Frederiksberg was almost 16 times higher than the year 2000 GNP per capita in Ukraine and 8 times higher than the year 2000 GNP per capita in Belarus.

- The above-mentioned estimates of the possible economic losses caused by a serious accident at the Barsebaeck nuclear power plant are moderate **compared to official American assessments of the financial losses deriving from a serious nuclear accident at an U.S. nuclear power station**. These estimates put the losses in the order of **between 40% and 180%** above the losses that have so far been registered from the Chernobyl accident. **The German authorities estimate that the financial losses from the worst possible accident at a German nuclear power station are approximately 14 times higher than the figures currently known with respect to the Chernobyl disaster**.

- That the **financial losses in Denmark** originating from the worst possible accident at the Barsebaeck nuclear power plant will either **not be compensated** or compensated **in the order of a quarter or half of a per cent** of the actual losses by the operator and the Swedish state.

Contravening a recommendation of an environmental permit for the Barsebaeck nuclear power plant is the fact that **there are several environmentally friendly alternatives to its activities**. This is affirmed by the fact

- That the conditions which the Swedish Parliament has set for decommissioning the Barsebaeck nuclear power plant – namely that a shutdown of the plant **has no negative consequences for the effect balance, the electricity price, the industry's access to electricity or the climate or the environment –** have been met long ago.

- That surveys and analyses made by **the Swedish and Danish authorities** have established that **Barsebaeck's electricity production can be dispensed with**.

BBOFF finds it significant that both the Espoo-Convention and the EIA-Directive stipulate that the environmental effects of a serious nuclear accident should be taken into consideration in the transboundary consultation process[4]. Thus, BBOFF recommends that **risk and consequence scenarios for the worst possible accident at the Barsebaeck nuclear power plant** should be a part of the environmental impact assessment that is the basis of the plant's application for an environmental permit. In our opinion these scenarios can be described the following way:

I. Risk and consequence scenarios for the worst possible accident at the Barsebaeck nuclear power plant

Crucially important for the risk scenarios is the plant's security level concerning (A-B) the physical protection against external and extraordinary events, which it is difficult and perhaps even impossible to prevent and (C) as regards the possibility that an accident occurs during normal operation.

A. A worst-case scenario: An airplane crashes into the Barsebaeck nuclear power plant

One of the worst if not the worst of all the risk scenarios that might lead to a meltdown of the reactor core is an airplane crash into the Barsebaeck nuclear power plant, either accidentally or deliberately. In assessing **the accidental aircraft crash probability** the guidelines and principles set out by the US Department of Energy are generally adopted[5]. Essentially, this approach assumes some form of loss of control of the aircraft in question, its subsequent deviation from the intended flight path and the chance of it crashing into the target nuclear plant. The nuclear plant is defined as a *crash area* and the parameters relating to this are calculated from the *effective fly-in*, *footprint*, *shadow* and *skid areas* that are determined from established codes. Applied to a civil airliner operating at altitude and passing along a prescribed flight path, this *a posteriori* probabilistic approach adopts rates drawn from actual crash incidents, yields a very low accidental crash probability.
However, in the context of a terrorist attack it has to be noted that all the probability calculations that for 50 years have been at the bottom of any discussion on the possibility of an airplane crash into a nuclear power plant are now outdated. After September 11th terrorist attacks can no longer be categorized as a rest risk. Consequently, the possibility of the occurrence of such an attack cannot be determined by classical *a priori* probabilistic means. **Thus, it is only realistic to apply chance to the success of the attack once it has been initiated.** Put another way, applied to the terrorist attack of 11th September the *Phit* or success rate was 3 out of 4 airborne aircraft, (*Phit* = 0,75). If the aircraft that crashed in Pennsylvania is discounted, the *Phit* for those aircraft on their target run was 3 out of 3 or 100%. In other words, the hijackers had obtained

[4] E.g it is explicitly mentioned in Annex II of the EIA-Directive – "Criteria for determining the likely significance of effects referred to in Article 3(5)" (which defines the scope of application of the Directive) that among other things especially " the risks to human health or the environment (e.g. due to accidents)", should be taken into consideration, cf. item 2.

[5] *Accident Analysis for Aircraft Crash into Hazardous Facilities*, DOE-STD-3014-96, 1996. See also for practical application *NUREG-0800, Section 3.5.1.6 Aircraft Hazards*, Nuclear Regulatory Commission, 1981 which suggests a crash rate in the absence of other data to be **3.66x109 per flight mile**.

sufficient flying skills to ensure that, once that the aircraft has been commandeered, the mission would have a high, almost certain rate of achieving its objective[6].

One also has to remember that in the context of air security the Barsebaeck nuclear power plant holds a special position. The plant is situated less than 30 kilometres from Kastrup airport. A general plane flying at 100m/s would cover the distance between Kastrup airport and Barsebaeck in about 5 minutes and it would take a commercial airliner, flying at 200 m/s, only half this time. If terrorists hijack a fully tanked airplane in Kastrup in order to attack the plant, counter measures cannot be implemented before the disaster is a reality. It is therefore of paramount importance to try to answer the following question: *What are the consequences of an airplane crash into the Barsebaeck nuclear power plant ?*

Generally, there is a consensus that nuclear power plants are not constructed to withstand airplane crashes. In March 2002 US government regulators conceded that neither a deliberate nor an accidental airplane crash was factored into the designs of 96 per cent of U.S. nuclear plants and the same correlation could apply to the Swedish nuclear power stations. At those plants where the threat was considered, design changes were aimed at smaller airplanes traveling at slower speeds (cf. the so-called Markey report mentioned in section I.B. below). Even the Danish Emergency Management Agency admits to this fact in its *Memorandum of 21st of September 2001 on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebaeck nuclear power plant*. It also establishes that based on "information from among others the Swedish nuclear authorities and the International Atomic Energy Agency (IAEA) (…) **a crash from a fully tanked larger traffic airplane or a military fighter would – if the reactor itself takes a hit – probably cause a destruction of the reactor system** (BBOFF's accentuation)".

The German assessments seem to be applicable in Sweden as well, not least with respect to the physical protection of the Barsebaeck nuclear power plant. As recent as February 2004 Wolfram König, president of the *German Radiation Protection Agency* (BfS)[7] demanded that the nuclear power station Brunsbuettel and four other of the oldest nuclear reactors in Germany should be closed down "prematurely" because they would not be able to withstand a terrorist attack in the form of an airplane crash, in some cases not even from a small plane. The phasing out could take place if the utilities used the possibility in the German decommissioning plan to disconnect the five old reactors from the net and transfer their production capacity to younger and safer installations.

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[6] John Large & Mycle Schneider, *International Terrorism - The Vulnerabilities and Protection of Nuclear Facilities*, First presented at the Oxford Research Group Nuclear Terrorism in Britain: Risks and Realities seminar at Rhodes House, Oxford of 4 December 2002, p. 4-5, http://www.wise-paris.org/english/reports/conferences/030102NukeTerrorORGFinalJL.pdf

[7] **BFS** is an independent scientific and technical public authority within the resort of the German Ministry of Environment, Nature Protection and Reactor Safety. The authority was founded in 1989 in order to combine the competences in the areas of radiation protection, nuclear safety, transport and storage of radioactive waste. With this purpose in mind, among others the following institutions have been integrated in the BfS: *Das Institut für Strahlenhygiene*, *das Institut für Atmosphärische Radioaktivität* (Freiburg), *die Abteilung Sicherstellung und Endlagerung radioaktiver Abfälle der Physikalisch-Technischen Bundesanstalt* (Braunschweig), parts of *Gesellschaft für Reaktorsicherheit* (Köln) as well as the so-called *Messnetz* with more than *2000 Messpunkten für die Ortsdosisleistung* (ODL) and *ABI* (Alpha, Beta, Iod) *-Messnetz*.
The BfS management lies with the president and the vice-president. The institution itself is divided into four main areas and in a central department that is responsible for the administration: *Sicherheit in der Kerntechnik* (SK), *Sicherheit nuklearer Entsorgung* (SE), *Strahlenschutz und Gesundheit* (SG) og *Strahlenschutz und Umwelt* (SW). Connected with the organization, but not professionally subordinated are the institutions *der Reaktor-Sicherheitskommission* (RSK), *der Strahlenschutzkommission* (SSK) og *des Kerntechnischen Ausschusses* (KTA), cf. http://www.bfs.de/bfs/wir/fachbereiche.html

The reason for the demand was a report issued by the *German Reactor Safety Organisation* (GRS)[8] that was kept secret for one and a half year until a confidential summary made by the German *Federal Ministry for the Environment, Nature Conservation and Nuclear Safety* [9] was leaked to the German and Austrian press in February 2004 by *Friends of the Earth Germany* (BUND)[10].

Important in this context is the fact that 3 of the 5 nuclear power reactors which the president of the BfS wants to close down for safety reasons as quickly as possible have the same age as Barsebaeck 2 (and are newer than Oskarshamn 1 and 2), also are BWRs and just like the Barsebaeck nuclear power plant and Oskarshamn 1 and 2 are not designed to withstand an airplane crash, not even from a small aircraft. In this context it should be noted that in BWRs the storage pools are above the reactor itself, and are relatively high up in the reactor building. This means they are particularly vulnerable to interference from the outside. Furthermore, Storage pools are basically a further source of releases in the event of a serious plane crash. The older fuel there can also melt down.
The GRS report uses the following variables: The *mechanical impact* represented by three weight categories and two for the velocity of the aircraft, angle of impact, etc., the *thermal impact* represented by four groups of sequences of events in which there is damage to buildings of differing extents (from no entry of kerosene to maximum entry), three scenarios for the aircraft fuel, three representative scenarios for the different possibilities for fires, *spatial crash scenarios* for the reactor sites represented by a system of three categories of approach flight, an analysis of topographical features and surrounding buildings, etc. and *the vulnerability of the plants* represented by five groups of plant configurations, nine damage scenarios covering the spectrum of possible damage, precautionary internal and external protective measures, etc.
The three reference BWRs mentioned below (*see Table 1*) have approximately the same age as Barsebaeck 2 that was put into operation in 1977 and are newer than Oskarshamn 1 and 2 that was taken into operation in 1972 and 1972 respectively (Brunsbuettel was put into operation in 1976, Isar 1 in 1977 and Philippsburg 1 in 1979). The load cases apply to all aircraft types, i.e. large airplanes (e.g. Airbus 340, Boeing 747), intermediate-sized airplanes (e.g. Airbus 300) and small planes (e.g. Airbus 320) and velocities from 175 m/s to 100 m/s.
Four of the five BWR damage scenarios in the report even with small aircrafts at a low velocity include releases of radioactivity that cannot be controlled or only controlled with uncertainty and in one case there is a considerable release of radioactive substances.

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[8] **GRS** is a scientific-technical expert and research company. It provides interdisciplinary knowledge, advanced methods and qualified data for assessing and improving the safety of technical facilities and for further developing the protection of man and the environment from technical hazards and risks. GRS activities are mainly focused on the area of nuclear safety, where it is Germany's central expert institution. GRS undertakes intensive co-operation with various international partners and maintains close relations with foreign organisations. This involvement is manifested in many bilateral co-operation agreements and in the participation in numerous activities of the Organisation for Economic Co-operation and Development (OECD), the International Atomic Energy Agency (IAEA) and the European Union. Foremost of the international relations is the partnership with the French Institut de Radioprotection et de Sûreté Nucléaire (IRSN), which encompasses a broad range of common activities. RISKAUDIT, a joint subsidiary of GRS and IRSN, provides an interface to common customers. At the same time, it co-ordinates the activities of the European **T**echnical **S**afety **O**rganisations (TSOs) for issues related to the safety of nuclear power plants in Eastern Europe. See http://www.grs.de/en/about_grs/about_grs.html?pe_id=1 and http://www.grs.de/en/about_grs/profile.html
[9] The summary – *Schutz der deutschen Kernkraftwerke vor dem Hintergrund der terroristischen Anschläge in den USA vom 11. September 2001, Zusammenfassung der GRS-Studie durch das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU)* – can be found at http://www.bund.net/lab/reddot2/pdf/grs_gutachten.pdf and http://www.greenpeace.org/multimedia/download/1/423087/0/Summary_on_GRS_reactor_study_translation_eng.pdf
[10] *BUND veröffentlicht GRS-Gutachten zu Terrorgefahren für Atomkraftwerke*, Pressemitteilung vom 3. Februar 2004.

Table 1: Boiling Water Reactors. Reference plant Brunsbuettel (no explicit design against accidental airplane crash) also Isar 1 and Philippsburg 1[11].

Load Cases	Damage Scenarios	Expected Consequences
All types, all velocities	Extensive destruction of reactor building, early release of activity	Control of events is uncertain
All types, all velocities	Destruction of other buildings relevant for safety	Sequence of events is controllable
All types, all velocities	Aircraft engine penetrates wall of reactor building, fire spreads inside the building	Control of events is uncertain
All types, all velocities	Wreckage hits roof of reactor building, roof girder falls into the spent fuel element pool, fuel elements remain covered by water	Limited release from the fuel element storage pool
All types, all velocities	Wreckage hits roof of reactor building, roof girder falls into the spent fuel element pool, fuel elements are no longer covered by water, plus jet fuel fire	Considerable release from the fuel element storage pool

The types of aircrafts that the Barsebaeck nuclear power plant could probably not resist are the following:

Table 2: Data on a number of typical-type passenger planes compared to data on the Phantom fighter[12].

Size	Type of plane	Maximum take-off weight	Maximum fuel reserves
Small aircrafts	F-4E Phantom II	26,309 kg	6,000 l
	Boeing 737-600	65,090 kg	26,035 l
	Airbus A-320	77,000 kg	29,660 l
Medium-size aircrafts	Airbus A-300-603R	171,100 kg	68,700 l
Large aircrafts	Boeing 767-400 ER	204,120 kg	90,770 l
	Airbus A-340-600	365,000 kg	194,880 l
	Boeing 747-400	396,890 kg	216,840 l

Also **the Danish Emergency Management Agency** confirms the above-mentioned scenario in its *Memorandum of 21st of September 2001 on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebaeck nuclear power plant*. The Agency establishes that "basically, nuclear power plants are not constructed to withstand airplane crashes. The construction of a nuclear power plant takes into consideration a series of accidents that the plant is supposed to withstand. The possibility of an airplane crash is considered so low in this context that it is not part of the concepts of the construction".

However, some experts estimate that **not only an airplane crash in the reactor building, but also in the external electrical and cooling facilities could cause a meltdown in the reactor core.**
According to a study by a German scientist, Dr Helmut Hirsch, *Danger to German nuclear power plants from crashes by passenger aircraft*, Hannover, November 2001[13], the auxiliary buildings that could be damaged in a BWR-type nuclear power plant (like Barsebaeck) would be the following:

[11] *Zusammenfassung der GRS-Studie*. p. 9.
[12] P. 6.
[13] http://archive.greenpeace.org/nuclear/germannucplantsafety.pdf

(1) The switchgear building with the plant control room, and central electrical and electronic installations, (2) the reactor auxiliary building with water purification and ventilation facilities, (3) the turbine building with turbine and generator, (4) the transformer station with grid feed-in and transformer for own needs, (5) the emergency power building with emergency diesel generators and cold water control centre, (6) waste air chimney, (7) cooling towers (with re-cooling) and (8) constructions for removing and returning cooling water.

It is noteworthy, that the critical systems that provide cooling, electricity and storage of spent fuel are mostly in non-hardened buildings that could not withstand an aircraft impact. The study concludes that if damage is confined to a single one of the installations of importance where safety is involved, a situation with an enhanced risk would be created, but one that could probably be controlled.

However, "while it might seem more or less plausible that only limited damage would occur in the event of a small fighter plane crashing, **this cannot be assumed if a passenger plane crashes** (BBOFF's accentuation)[14]. More widespread destruction must be feared from the impacts of wreckage and fires. It can no longer be guaranteed that the cooling of the reactor would function, even if the integrity of the cooling system had not been impaired. If, for example, the electricity supply from the grid or the facility's own transformer and emergency supply system fail at the same time, no coolant pumps will be available (…) Destruction over a large area on the site can furthermore have the effect that personnel are no longer able to gain access and so intervene to make possible repairs, at least not within the necessary timeframe of only a few hours. In these cases a core meltdown will occur (…) If the meltdown is coupled with explosions, the containment will fail within about ten hours; otherwise it will fail as a result of excessive pressure in a matter of days. (With some old plants it can be expected to melt down in a few hours.) The radioactivity released is to some extent reduced because radionuclides condense inside the building. There is somewhat more time in which to take protective measures against the disaster. In this (…) scenario, too, however, **the radioactivity released is comparable to that at Chernobyl, with disastrous consequences over a large area**[15] (BBOFF's accentuation)".

The study also assesses than even if the reactor building remains by and large intact, there is a high probability that destruction on the site and tremors caused by the crash inside the reactor building itself could lead to a core meltdown.

However, event though there are two worst-case risk scenarios for a deliberate or an accidental airplane crash into the Barsebaeck nuclear power plant when the reactor is running the most critical remains the one, where **major damage is inflicted to the reactor building**, e.g. wall broken down, debris and possibly burning fuel affecting the interior.

The reactor building contains the reactor, part of the cooling circuit which goes to the turbine and the most important safety systems, most notably the emergency and secondary cooling systems and

[14]According to the report, the following points should be looked at when discussing the effects of a crash by a big passenger plane: (1) **The mechanical strain on the buildings affected** (the impact of the crash), (2) destruction by **flying debris** and (3) the **effects of fire** where the fuel burns. The impact of a crash depends on the mass and speed of the plane causing the impact, and on the area impacted and the extent to which concrete structures are broken down (the smaller the area, the more concentrated and so greater the effect). The greater mass of a passenger plane spreads the effect of its impact over a larger area. At the same time, the engines are compact "missiles", which can have a mass of several tons. Depending on the guidelines assumed, the speed of impact will probably be lower in the event of an accidental crash, since accidental crashes are first and foremost thought of as happening at take-off and landing. In the event of a deliberately engineered crash, which can mean a steep dive from a great height, greater speeds have to be assumed. E.g. the Markey report assesses that the planes used in the World Trade Center and the Pentagon attacks travelled at speeds of 533 km/h to 818 km/h when they struck.

[15]P. 8-9.

the core flooding system. If the outer reinforced concrete structure of the building is destroyed by a plane crash, **the inner containment cannot stand firm either**. The containment is designed to withstand effects from within (the build-up of pressure as a result of a pipeline bursting) and does not have any great ability to resist impacts from without. It has to be assumed that the reactor's cooling circuit will be damaged and that safety systems will also suffer major damage. If the pipelines of the cooling system, or the reactor vessel itself, incur great destruction, it would be immaterial if the emergency cooling system still functioned, since it would no longer be able to be effectively fed in.

Such a case will in a short time – inside an hour – lead to the meltdown of the reactor core. Radioactive substances will be released from the melted fuel and, since the containment and concrete shell have been destroyed, they can get into the open with practically no delay or retention inside the building. In all studies on risks such a scenario – a core meltdown with open containment – is regarded as the worst conceivable kind. It leads to especially large and especially swift releases of radioactivity. **The time available for taking protective measures against the disaster is very short**.

The study concludes that the amounts of radioactive substances released in this scenario "**may attain and indeed exceed those stated for the disaster with the reactor at Chernobyl**[16]".

As regards the effectiveness of countermeasures the study is very pessimistic. The basic problem is that while the chain reaction can be interrupted by swiftly shutting down a reactor, the development of heat caused by the intensive radioactivity of the fuel ("decay heat") cannot. During operation this radioactivity makes a contribution of about 7 % to the reactor's total output. It is responsible for the core melting within a short time if the cooling fails. Hence, *short-term countermeasures* aim at reducing the decay heat by shutting down the reactor in good time and thus slowing down the processes leading to core meltdown.

The study, however, considers these countermeasures **not very effective or their effect almost impossible to predict if there is major destruction of the reactor building with damage to the reactor vessel or storage pool and rapid loss of the entire coolant**[17]. In this case it is questionable whether clearance work which would enable countermeasures to cool the core to be taken could itself be undertaken in a heavily irradiated environment, even if days were available for the purpose.

As regards spent fuel, the study notes that storage pools are a further source of releases in the event of a serious plane crash, because the spent fuel there can also melt down. In boiling water reactors like the Barsebaeck nuclear power plant the storage pools are above the reactor itself, and relatively high up in the reactor building which means that they are particularly vulnerable to interference from outside. As mentioned in section II.D of this position paper, the quantity of spent fuel stored in the Barsebaeck nuclear power plant varies between 15 and 72 tons, the latter quantity almost equalling the amount of uranium in the reactor core.

As mentioned below in section II.D, WISE-Paris has estimated the release of caesium-137 to be up to a 100 % (from 50%) in case of an airplane crash[18]**. 15 years after the Chernobyl**

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[16]Ibid. p. 8.

[17]This estimate is very similar to the assessments in the Danish Emergency Management Agency's memorandum. The Agency concludes that " the longer time a reactor has been shut down before the accident, the less dangerous a possible release. However, if the time horizon for the shut down is hours only, the effect will be limited".

[18] "The potential for a zirconium "fire", following a loss of water, arises from the packing of fuel pools to high densities (Thompson, 2000a). A loss of water accident in the D cooling pond could lead, because of exothermic oxidation reactions of zirconium and other metals, to an accidental release up to 100% of the total caesium-137 contained in the

disaster caesium-137 was responsible for 80 % of the worldwide collective dose. If the assessment of WISE-Paris is correct, the release of caesium-137 from e.g. Barsebaeck 2 would be 2-4 times higher than the release from the Chernobyl reactor 4[19].

As regards the effectiveness of other countermeasures the study is equally pessimistic. It is concluded in the study that the options for increasing safety protection against crashes by medium to large passenger aircraft by technical retrofitting are extremely limited. While details can no doubt be improved, the risks to the plant will not be substantially reduced. E.g. **stationing military units** at nuclear power plants for the purpose of air defence, a measure implemented at the nuclear reprocessing plant in Cap de la Hague in France and in the Czech Republic, must be regarded as extremely problematic. Apart from the obvious danger of shooting down aircraft which have no interest in the plants – planes whose radio and navigation systems have failed, for example – new risks are created as a result. Ground-to-air missiles that miss their target could by mistake hit the power plant and cause damage. The air defence posts could themselves become the target of terrorist attacks. Terrorists could try to take them over so as to shoot at the nuclear plant. For this to be avoided the posts would have to be permanently protected by ground troops – which would be a big step towards militarization of the whole electricity supply system, something which cannot in any way be regarded as desirable[20].

In Germany, the nuclear regulatory authorities have experimented with the so-called **fog bells**[21], i.e. ignition of smoke grenades around the nuclear power plants, but have reached the conclusion that the only realistic option is a swift decommissioning of the most vulnerable reactors or at least the construction of massive concrete pillars located around the installations or an extra roof over the reactor buildings[22]. Another possibility that has been mentioned is the construction wind parks

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1,745 t of spent fuels stored (NRC, 2000)", Schneider, M (Dir.), POSSIBLE TOXIC EFFECTS FROM THE NUCLEAR REPROCESSING PLANTS AT SELLAFIELD AND CAP DE LA HAGUE, ANNEX 19, "Comparison of Caesium-137 Contained in Spent Fuels Stored at La Hague and Released During the Chernobyl Accident, p. 118, WISE-Paris, Report commissioned by STOA, European Parliament, 2001, http://www.wise-paris.org/english/reports/STOAFinalStudyEN.pdf

[19] A 5 years cycle for the fuel in the Barsebaeck 2 reactor core would indicate that the fuel burn-up should be between 40 and 50 GWd/t with a middle figure of 45 GWd/t. With a 45 GWd/t burn-up of the fuel, the Barseback inventory of caesium-137 should be approximately 1,4 kg per ton of spent fuel, i.e. **a total of around 105 kg** in the core, i.e. approximately **20 % more than in the Chernobyl reactor**.

[20] Hirsch p. 11-12.

[21] Jürgen Voges, *Der Königsweg zum Atomausstieg*, TAZ Nr. 7291, 23.2.2004, p. 7. The concept of **fog bell** (Nebelglocke) implies the ignition of smoke grenades when a suspicious aircraft enters the airspace around a nuclear power plant. In stead of the roof of the reactor building the terrorist pilot only sees a cloud of smoke which gives rise to the hope that the aircraft hits the ground in stead of the reactor roof or the pilot is deterred and flies away. The system has been tested by *die Kölner Gesellschaft für Anlagen- und Reaktorsicherheit* (GRS) at the request of the German Ministry of Environment.

The critics' objections against the system focus on (1) the time limits of the warnings in the limited German airspace do not allow for the nuclear plant to be covered up in time, (2) whether the smoke emissions function under adverse weather conditions as e.g. extreme coldness or storm, that (3) a well-educated terrorist pilot could turn away and attack again when the artificial clouds have dispersed and (4) whether the installation remains adequately fireproof when hundreds of smoke grenades are ignited.

Apart from that a well-educated terrorist could feed the navigation computer with the coordinates of the nuclear power plant. Mobile laptop GPS-systems, which the hijackers can bring on board on the aircraft already exist on the market. However, the fog bell system is popular with the nuclear industry because it is low-cost.

[22] Gerd Rosenkranz und Christoph Schult, *Kuppel im Qualm*, DER SPIEGEL 48/2003 - 24 November 2003. These security measures are expected to cost 100-200 million EUR per installation.

around the reactors. The towers of the wind stations are expected to make it very difficult for terrorist pilots to hit the installations[23].

B. Another worst-case scenario: A terrorist attack on the ground

Theoretically, a terrorist attack on the ground in the Barsebaeck nuclear power plant could arise from armed insurgents, from an external explosive device such as a truck or four-wheel drive vehicle bomb, or via one or more passive or more directly by one or more active insiders employed within the plant itself.

According to SKI that is the competent nuclear regulatory body in Sweden as regards security measures[24] the starting point in the process to develop regulations for physical protection is to assess the threat against Swedish nuclear power plants i.e. what today is known as a *design basis threat*, DBT. In co-operation with national intelligence and security authorities SKI has arrived to the conclusion that **the major threat is a terrorist act or a sabotage leading to a radiological accident**. This could lead to serious damage to the plant, to personnel, or to the loss of lives. Furthermore SKI has assessed that **an attack in which a threat of damage is made and in which the threat later can be realized is more likely than an attack solely intended to do damage to the reactor**. The basis for this philosophy is that if the aggressor has the qualifications to occupy a well-protected power plant and he also has the knowledge to endanger the safety of the reactor, then he probably also has goals e.g. political or economical, other than just to damage the reactor[25].

According to SKI, the overall purpose of the protection of a nuclear power plant is to deter and prevent a threat or an attack and in case of a realized threat or attack to neutralize it. This goal is achieved when the aggressor is unable to do damage which would lead to the fuel not being cooled. SKI's assessment is that if the reactor is protected against the assumed threat situations, there is a high probability that attacks likely to occur can be neutralized. On the whole, the protection can be said to consist of: (1) Multiple protective barriers, (2) system engineering measures, (3) administrative measures and (4) an armed outside response force.

In SKI's opinion **sabotage in the plant** during periods of normal operation will **not, in most cases, lead to more severe situations than those for which the plant is designed to handle safely**[26]. However, the inspectorate recognizes that a nuclear power plant is vulnerable to sabotage even during its shutdown period when the accessibility of the reactor building is greater compared to the periods of normal operation.

As mentioned above, SKI dismisses the idea of having armed guards at the facility to neutralize the aggressor, assuming "that the benefit of having such a force does not outweigh the

[23] Uffe Korsbech, *Terrorister og a-værker*, http://www.reo.dk/

[24] Stig Isaksson, *The concept of physical protection of nuclear facilities in Sweden*, Swedish Nuclear Power Inspectorate (SKI), SE-106 58 Stockholm, Sweden, as presented at the EUROSAFE forum November 4th and 5th 2002 in Berlin, http://www.eurosafe-forum.org/ipsn/pdf/euro2_5_10_phys_prot_sweden.pdf

[25] SKI has based the regulations for physical protection of nuclear power plants on the following **threat situation**: (a) The aggressor has knowledge of the design of the plant, its technical function and its surveillance routines. (b) The aggressor is armed and has explosives. The types of weapons and amounts of explosives are based on national experience. (c) The aggressors can be several people who force their way into the plant. (d) The forced entry will cause a verified alarm. (e) The aggressor will, some time after a verified alarm has sounded, occupy the plant's most important area of operation, the control room. (f) A hostage may be used. The hostage is assumed to perform ordered operations within his knowledge, but without access to hard-to-obtain information. (g) The aggressor may have help from an insider. (h) The aggressor is able to get control of the rest of the plant's vital areas after a defined time limit. The time limit is based on the time needed to get control of the areas outside the control room and the time needed to assure the operation of the reactor, to get personnel to the spot and to take over operation of the reactor from these areas. (i) Explosions outside vital areas may occur. (j) The plant personnel are unarmed, Isaksson, p. 2.

[26] Ibid. p. 2.

drawbacks" and that "having an armed plant security force in addition to the police would not be in compliance with the public spirit"[27]. Also, the Inspectorate considers the deterring effects of armed guards to be minor since the force at the plant would have to be quite limited. Consequently, the guards at the Swedish facilities are not armed and are rather considered as watchmen, having no obligation to neutralize an aggressor if such would endanger their lives. The responsibility to act as a response force and reoccupy the plant lies instead with the Swedish police.
Without further ado, SKI takes for granted that terrorists will be able to take over the reactor control room, realizing that **no protection system can assure that the reactor can be protected from a maximum attack**. Instead certain steps are taken to assure that the reactor will be in a safe mood when the personnel evacuate the room. Also, influence of the safety of the reactor must be made difficult by disconnecting parts of the control room. Other parts vital for the safe operation of the reactor are protected by redundant systems and by physical separation of the systems.
The above-mentioned provisions that were implemented in Sweden **in the late seventies** have not since been changed. However, more than two years after the September 11th attacks, the regulations are now being revised. That there has so far been no real sense of urgency in this respect is explained by SKI the following way: "What an acceptable physical protection system shall look like when it is implemented is dependent on many factors. To say "what is good to you is good for us" would be serious misjudgement. In fact important factors such as the actual threat situation in the country, or even in part of the country where the reactor is sited, the social order of the country and also type of reactor have to be taken into account**. Therefore the Swedish experience is, to make the physical protection system as effective as possible it should be based on specific national conditions** (BBOFF's accentuation)[28]".

As mentioned above new security regulations have not yet been implemented, but according to SKI, the events of September 11th will be taken into account in the revision process. The plan is to have the revised regulations in force sometime in 2004[29].

The assumption that nuclear power plants are impossible to protect from terrorist attacks on the ground, is confirmed by the American *Nuclear Regulatory Commission* (NRC). According to the NRC the performance of an operator of a nuclear power plant **is judged unsuccessful if an operator (i.e. a response force) is not able to prevent an aggressor from disabling and/or destroying all pieces of equipment/actions in a target set**. A report[30] published by Member of House of Representatives and The House Energy and Commerce Committee, Edward J. Markey, who analyzed more than 100 pages of correspondence from the NRC, establishes that security at US nuclear reactors **continues to be inadequate even after September 11th and that NRC had failed to adjust the security regulations to the evolving threat**. The report also concludes that security exercises at US nuclear reactor sites are inadequate and that sites **continues to fail the exercises 50 % of the times**[31].

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[27] Ibid. p. 2.
[28] Ibid. p. 6.
[29] Svenska Dagbladet, "*Skärpt såkerhet för kärnkraft*" d. 24/10-03.
[30] *Security Gap: A Hard Look at the Soft Spots in Our Civilian Nuclear Reactor Security*, (http://www.house.gov/markey/iss_nuclear_rep020325.pdf)
[31] Historically, the NCR has conducted force-on-force exercises known as *Operational Safeguards Response Evaluations* (OSRE) to assess the adequacy of the security at nuclear reactors. In 37 of 81 OSREs (46 % of the security tests) conducted between August 1991 and August 2001, the NCR identified weaknesses that allowed the attacking force to "reach a target set and simulate destruction of that equipment (…) i.e. the equipment necessary to be protected to prevent core damage" (Pages 27-29 in the NRC as quoted from p. 12 in the Markey report). The NRC identified serious weaknesses at 9 of 15 OSRE sites and required corrective action to be taken at 9 of 15 sites. As mentioned

Especially with respect to the Barsebaeck nuclear power plant, it has to be mentioned that SRSS (about this report, see section II.A) points out that the plant is especially vulnerable to terrorist attacks because of the large plate-glass windows along the wall to the control room facing land. Although it is likely that the glass in the windows can withstand even heavier blows, they increase the risk of sabotage. Furthermore, at number of additional rooms contain outside windows. Those most significant in this context are the windows located in the buildings containing the reserve power aggregates that face the sea because they do not offer the same level of protection normally found in American nuclear installations[32].

C. The safety level of the Barsebaeck nuclear power plant during normal operation

A serious accident at the Barsebaeck nuclear power plant does not have to be caused by a terrorist attack. Essential systems in nuclear facilities, including Barsebaeck, comprise a vast selection of among others valves, pumps, motors, power installations, feeding devices, shock absorbers, air ejectors, ventilation channels, cables, control panels, tanks, fire walls, diesel generators, sealings, drains, ventilators, hatches, passages, walls, fuses, condensers, transformers, bolts and weldings. All these systems, constructions and components are potential sources of malfunctions and interruptions of operation. The problems could be caused by many things: Designs, manufacturing, installation and construction defects, operation errors and lack of maintenance, explosions and fires, corrosion, vibrations, damage by water, heat, frigidity or radiation during normal operation or other sometimes unexpected physical phenomena caused by malfunctions, degradation of components due to old age and external incidents, e.g. the above-mentioned sabotage.

The assessment of the nuclear safety is further complicated by the variation of incidents that occur when a malfunction is combined with other malfunctions that create the possibility of accidents demanding emergency intervention by one or more of the facility's complicated safety systems. The success of such intervention depends on whether the designers of the facility have equipped it with sufficient safety measures. **More serious problems can emerge if unforeseen accidents occur, against which no precautionary measures have been implemented**.

All experience shows that serious accidents can have insignificant causes: A moment of inattention or thoughtlessness among the operation staff, a malfunction in an apparently insignificant component, a basic flaw in the facility's design that has been overlooked in spite of researches and studies. The history of nuclear power is filled with examples of accidents occurring in apparently "failsafe" systems.

An indication of the safety level of the Swedish nuclear power stations can be established from Sweden's worldwide position as regards the International Nuclear Event Scale – "INES" ("International Nuclear Event Scale"). This information system has existed since 1991. Every event is categorized in a seven-step scale. Level 7 is a "major accident" like the one in Chernobyl and level 5 is an "accident with an off site risk" like the one in Harrisburg. Since 1991 no "major accident" or "accident with an off site risk" have occurred at any nuclear power station in the world, but none the less a number of "anomalies" (level 1), "incidents" (level 2) and "serious incidents" (level 3). There is no clear reporting obligation for level 1 anomalies, consequently the figures are

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above, between August 1991 and August 2001 weaknesses were identified at 46 % of the sites tested. Furthermore, between August 2000 and August 2001, serious weaknesses were identified at 47 % of the sites tested and corrective action was required at 60 % of them. Most disturbing is that three plants tested shortly before 11th September 2001, Farley, Oyster Creek and Vermont Yankee, were the worst on record. In another assessment, **the NRC notes that between 15 to 20% of US nuclear plants would sustain safety critical levels of damage from vehicle bombs accessing close to the supervised boundary of the plant**.

[32] SRSS p. 3-38, 3-39 and 3-40.

not directly comparable. However, it can be established that eastern countries report regularly. Level 2 incidents must be reported within 24 hours and that is done relatively uniformly all over the world. At least 3 level 3 serious incidents have been registered 1991-2002, of which one has occurred in a Swedish nuclear facility. 46 level 2 incidents have been registered, **of which 7 have occurred at Swedish nuclear power plants**, **i.e. 15 % of all the nuclear incidents in the world[33]. This is a significant over-representation considering the fact that Sweden has only 11 reactors (12 before the decommissioning of Barsebaeck 1) and there were on the average approximately 420 reactors in the world during the period 1991-2002, i.e. the Swedish reactors comprised only 2,9 % of the total number of reactors in the world**.
These figures completely disprove the myth that the Swedish nuclear reactors are "the safest in the world" – a point of view that has had a bearing on the way the Barsebaeck nuclear power station is perceived by the public.
The preliminary reporting is made by the nuclear power plants themselves but the final estimate is made by the national nuclear inspectorates. In order to free the Swedish nuclear power plants from the suspicion of a low safety level, one has to assume that more or less all the other countries' nuclear inspectorates sweep the nuclear incidents under the carpet. For instance, variations in the judgment criteria cannot explain why USA has reported 4 incidents for almost 10 times more reactors than in Sweden.
A phenomenon that can hardly be interpreted as a coincidence or heterogeneous reporting is the division of serious incidents between the Swedish reactors. Almost all of the INES 2 incidents have occurred in the old reactors that were built in the sixties and in the beginning of the seventies. The Swedish journalist Fredrik Lundgren whose figures are the basis of this assessment draws the conclusion that the oldest reactors lie beneath international safety standards, but this is not the case with respect to the newest reactors. **The Swedish nuclear regulatory authority's (SKI) figures differ slightly from Lundberg's**[34]. For the same period SKI mentions a total of 30 INES level 1 anomalies at the Swedish nuclear power plants and 5 INES level 2 incidents. The sixth INES level 2 incident occurred at the nuclear research facility in Studsvik where also a serious INES level 3 incident has been reported (*see Table 3 and 4*).

Table 3: INES 2+ incidents at the Swedish nuclear power plants 1991-March 2002 according to Fredrik Lundberg and SKI respectively.

	Source		**Fredrik Lundberg**	**SKI[35]**
		In commercial operation	*INES 2+ incidents*	*INES 2+ incidents*
New reactors	Forsmark 1	1980	0	0
	Forsmark 2	1981	0	0
	Forsmark 3	1985	0	0
	Ringhals 3	1981	0	0
	Ringhals 4	1983	1	1
	Oskarshamn 3	1985	0	0

[33] These figures are from Fredrik Lundberg, *Världens dårligaste kärnkraft*, Ordfront 6/2002, http://www.ordfront.se/article.asp?Article_id=10946
[34] According to Fredrik Lundberg SKI listed an INES level 2 incident too much, before the regulatory authority published the figures itself.
[35] http://www.ski.se/extra/tools/parser/index.cgi?url=/html/parse/index.html&selected=5&mainurl=http://www.ski.se:80/extra/document/%3Fmodule_instance%3D1%26action%3Dshow_category%26id%3D62

	Total		**1**	**1**
Old reactors	Barsebaeck 2	1977	3	2
	Oskarshamn 1	1972	0	0
	Oskarshamn 2	1974	1	1
	Ringhals 2	1975	2	1
	Ringhals 1	1976	0	0
	Total		**6**	**4**
New and old reactors	**Total**		**7**	**5**

According to him, the INES reporting is not available from IAEA but has, however, in this case been made available by the SKI. According to Lundberg´s article, SKI has opposed international comparisons between PSA (= "Probabilistic Safety Analysis", see below) figures as well as INES events. The nuclear operators own association WANO makes comparative statistics, but they are not being published. After Lundberg's article was published SKI has made the Swedish INES figures available to the public on its website.

Table 4: Swedish INES incidents reported to IAEA. *Source: SKI*[36].

Year	**Date**	**Reactor**	**INES category**	**Description**
2002	***Summer***	Barsebaeck 2	Level 1	**Abnormal feed-water flow**
	2002-01-02	Studsvik AB	Level 3	High radiation levels measured on a package containing iridium-192
2001	*2001-07-26*	Barsebaeck 2	Level 1	Under-dimensioned rupture disc installed in the FILTRA-system
	2001-06-20	Ringhals 2	Level 1	Incorrect calculation of an algorithm in overload protection devices for local power distribution
2000	No incidents reported			
1999	*1999-05-25*	Barsebaeck 2	Level 2	Temporary lost of the seawater cooling systems
	1999-02-25	Oskarshamn 2	Level 0	Core instability occurred during maintenance performed in the switch yard
1998	No incidents reported			
1997	*1997-09-27*	Ringhals 4	Level 2	Closed valves in the containment spray pumps' suction lines during the non nuclear phase of the start up after refueling
	1997-08-17	Ringhals 2	Level 1	Automatic protection system disconnected during non-nuclear heat-up after refueling
	1997-05-16	Forsmark 2	Level 1	Degraded containment pressure suppression function during shutdown of reactor before outage period
1996	*1996-11-01*	Oskarshamn 2	Level 2	One of the emergency core cooling systems -the core spray system- was unavailable at Oskarshamn-2
	1996-08-13	Studsvik AB, Hot Cell	Level 1	Water Leak into a Hot Cell in Studsvik
	1996-07-18	Forsmark 1	Level 1	Erroneous line-up before start-up of vent pipe valves to the scrubber system
	1996-06-12	Barsebaeck 2	Level 1	Degraded pressure sub-pressure (PS) function
	1996-03-04.	Oskarshamn 1	Level 1	Failure of a containment isolation valve at a periodical test

36 http://www.ski.se/extra/tools/parser/index.cgi?url=/html/parse/index.html&selected=5&mainurl=http://www.ski.se:80/extra/document/%3Fmodule_instance%3D1%26action%3Dshow_category%26id%3D62

	1996-01-21	Oskarshamn 1	Level 1	A part of the residual heat removal system - the auxiliary condenser - temporarily not available
1995	*1995-11-15*	Ringhals 4	Level 1	Deviation from Technical Specifications
	1995-10-19	R2-0 Studsvik	Level 2	Overexposure of a worker at the research reactor R2-0 in Studsvik at Uppsala University's Neutron Research Facility
	1995-08-26	Oskarshamn 1	Level 1	Design deficiencies in diesel generators found during extensive testing
	1995-07-15	Forsmark 2	Level 1	A closed valve in the containment pressure relief line to the atmosphere and two closed valves in the venting line to the emergency filter
	1995-07-10	Barsebaeck	Level 1	Unintentional release to the sea of a minor amount of slightly contaminated water
	1995-05-28	Ringhals 2, 3, 4	Level 1	Routine surveillance reveals: steam generator safety valves open at higher pressure than specified at the Ringhals 2,3 and 4 PWRs
	1995-04-09	Ringhals 2	Level 0	Unsuccessful switch over from 400kV to 130kV
	1995-03-31	Oskarshamn 1	Level 0	Cracks in pump and valve casings
	1995-02-12.	Ringhals 3	Level 1	Not fully inserted controlling rods
	1995-01-01	Oskarshamn 1	Level 1	Design deficiencies identified; in the separation of electrical systems, avoidance of common cause failure in the reactor protection system and overpressure release in the auxiliary building
	1995-01-01	Oskarshamn 1	Level 0	Cracks in the reactor core shroud, in the lid of the shroud and in reactor vessel internals
1994	*1994-10-03*	Ringhals 2	Level 2	Steam generator safety valves were not functioning according to specifications
	1994-09-28	Barsebaeck 1	Level 1	Protection system not completely reestablished after refueling outage period
	1994-08-31	Barsebaeck 2	Level 1	Leaking isolation valve in the ECCS
	1994-08-26	Barsebaeck 1	Level 1	Missing lubrication grease to the ECC system's core spray pumps
	1994-08-22	Ringhals 4	Level 0	One control rod not fully inserted after scram
	1994-07-09	Ringhals 1	Level 0	Release of Iodine-131 from the turbine system
	1994-06-15	Forsmark 3	Level 1	Unintentional slow insertion of all the control rods
	1994-04-18	Ringhals 2	Level 1	Incorrect safe guard reporting
1993	*1993-10-12*	Barsebaeck 2	Level 1	Containment penetration test is not approved
	1993-05-18	Ringhals 2	Level 1	Circular crack in the penetration weld of the reactor vessel head
	1993-02-24	Oskarshamn 1	Level 1	Cracks in the pipe bands (elbows) in the residual heat removal system
	1993-03-02	Ringhals 1	Level 0	Minor leakage in a 25 mm pipe in the pressure relief system
	1993-02-28	Ringhals 1	Level 0	Minor leakage in a 32 mm valve bonnet seal
	1993-01-23	Ringhals 1	Level 0	Insufficient control rod function during hot start up test
1992	*1992-12-08*	Ringhals 2	Level 1	Incorrect connection of cables to relays in safety systems

	1992-08-17	Ringhals 1	Level 0	Cracks in feed water nozzles
	1992-07-28	Barsebaeck 2	Level 2	Clogged pump suction strainers in the wet-well pool
	1992-06-29	Ringhals 2	Level 0	Repair of reactor pressure vessel head penetration
1991	*1991-10-07*	Forsmark 2	Level 1	Closed manual service valves in the scram system
	1991-09-18	Ringhals 4	Level 1	Fuel assembly tilted during refueling
	1991-08-14	Oskarshamn 2	Level 1	Deviation from operating instructions
	1991-05-28	Ringhals 2	Level 1	Fuel assembly tilted over during core loading
	1991-02-21	Ringhals 3	Level 0	Discharge of radioactive gas in connection with dismantling of safety valves

One could argue that evaluated on the basis of the INES parameters alone, Barsebaeck 2 is statistically the most dangerous nuclear power reactor in Sweden. According to SKI's website, there were 6 INES level 1 anomalies and 2 INES level 2 incidents at Barsebaeck 2 during the period 1991-2002. For the same period SKI mentions a total of 30 INES level 1 anomalies at the Swedish nuclear power plants and 5 INES level 2 incidents. *This effectively means that 20 % of all INES level 1 anomalies and 40 % of all INES level 2 incidents at nuclear power plants in Sweden took place at Barsebaeck 2 during the period 1991-2002.*

Table 5: INES incidents registered by SKI, involving Barsebaeck 2[37].

Date	INES incident
Summer 2002	**Level 1**. Abnormal feedwater flow [38].
2001-07-26	**Level 1**. Underdimensioned rupture disc installed in the FILTRA-system.
1999-05-25	**Level 2**. Temporary lost of the seawater cooling systems.
1996-06-12	**Level 1**. Degraded pressure subpression (PS) function.
1995-07-10	**Level 1**. Unintentional release to the sea of a minor amount of slightly contaminated water.
1994-08-31	**Level 1**. Leaking isolation valve in the ECCS.
1993-10-12	**Level 1**. Containment penetration test is not approved.
1992-07-28	**Level 2**. Clogged pump suction strainers in the wet-well pool.

The most serious incident at Barsebaeck 2 was in June 1992 when a small cooling water leakage occurred before the start up. The emergency cooling systems automatically started but after 17 minutes they were blocked by loosened mineral wool. **By pure coincidence the reactors were only operating with two per cent of the full effect. At full effect the blocking would have happened after a few minutes and would have required very quick manual intervention in order to stop a drying up of the oven resulting in a subsequent meltdown**. The defect was

[37] http://www.ski.se/extra/tools/parser/index.cgi?url=/html/parse/index.html&selected=5&mainurl=http://www.ski.se:80/extra/document/%3Fmodule_instance%3D1%26action%3Dshow_category%26id%3D62
[38] Cf. *Kärnkraftverkens säkerhet och strålskydd*, p. 137-138, http://miljo.regeringen.se/propositionermm/sou/pdf/sou2003_100.pdf

discovered at the 5 oldest BWRs that in theory had not had a functioning emergency cooling system since Oskarshamn 1 started in 1971. SKI prohibited the operation of these reactors and they remained inactive for three and a half years, because other defects were discovered as well.

The causes of the many incidents are many and complex: In connection with a analysis of the **basic choice of the installation designs**, it was established in SRSS that it quickly seemed evident during discussions with staff at SKI and the energy company Sydkraft that the designs of the Barsebaeck nuclear power plant was not based on documented regulations and standards. Hence, yet another risk element was added to the plant, taking into consideration that basic flaws or omissions in the facility's design might exist[39]. SRSS concluded that the basis of the constructions of the facility, especially with respect to operation under emergency conditions, was diffusely documented and that it mostly was left up to the inventiveness of the constructing engineers to put the systems together. This puts "a large burden on the constructers who have been forced to interpret the general formulations regarding special practices for each type of equipment".

Even more dramatic are the conclusions from a comparison between the constructions and licensing practices in Sweden and USA: "Based on the results of the above-mentioned study it can be stated that in some respects the constructions in Barsebaeck 2 do not meet NCR's criteria. In other respects, as regards the constructions, there are no information or inadequate information available to determine whether NCR's criteria have been met. Although some parts of the constructions surpasses the requirements of the NCR's criteria, these constructions do not annul – neither in the legal nor in the technical sense – the need to meet all the safety standards. **Therefore it can be concluded that Barsebaeck 2 would not have received a license to operate in the United States, where the legal basis for licensing is in accordance with NRC's criteria** (BBOFF's accentuation)[40]".

SRSS identified certain potential sources of error in both Barsebaeck reactors that could be described as *"normal"*: (1) Fire in and beneath the control room panels, (2) malfunctions in the electrical cables, (3) malfunctions caused by slag in pipe lines, (4) projectiles originating from circulation pumps (detached pieces), (5) projectiles originating from turbines, (6) malfunction of power cables for control rods due to cooling of the pool, (7) malfunction of pump suction pipes for the core sprinkler systems due to hydro dynamic forces in the low pressure pool, (8) projectiles originating from diesel generators collide with other diesels, (9) fire in the fuel tank of the gas turbine, (10) asymmetric load on the tank and (11) load on the tank and internally due to hydro dynamic forces in the low pressure pool[41].

Another factor that should be mentioned is that even though Barsebaeck 2 started commercial operation in 1977 and even though the reactor was ordered later than both Forsmark 1 and 2, it has a

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[39] SRSS p. 3-42

[40] SRSS. p. 3-55. The question of the constructions of the Barsebaeck nuclear power plant was taken up some years later in a Danish-Swedish report – *"Report on the technical aspects of the security questions and common elements in the rescue preparedness in connection with the Barsebaeck nuclear power plant"*, An account given by a Swedish-Danish Committee on the security in the Barsebaeck nuclear power plant, DsI 1981:4 – Report no. 922, Copenhagen 1981. As regards the construction and the workmanship of the installations, the report states the following: "**SKI has explained that at the time for the construction of the Barsebaeck reactors SKI had no formal criteria for the whole reactor safety area** (BBOFF's accentuation) (…) SKI assesses that possible drawbacks deriving from the fact that SKI had no formal criteria have not influenced the safety status of the Barsebaeck nuclear power plant negatively. The committee has taken cognizance of SKI's estimate", p. 10.

[41] Ibid. p. 3-38, 3-39 and 3-40.

far more primitive electrical system with only 2 separate cable systems instead of the 4 that are installed in the more modern reactors. If the supply of electricity stops through one cable system, the safety of the reactor depends on only one. If that cable is cut, disaster is a reality[42]. Realizing this the plant management has adopted Barsebaeck 1's cable system into Barsebaeck 2 after its decommissioning in 2000.

With respect to a description of the safety conditions at Barsebaeck, it should be mentioned that **the plant is situated on layers of approximately 30 metres of clay**. The exact effects on this earth material in case of a meltdown of the reactor core is unknown, but the possibility of a penetration of the clay layers could be significant for the assessments of the effects of a meltdown[43].

Furthermore, it is possible to use indirect safety parameters by studying operation data that each year is being reported for nuclear power reactors all over the world, e.g. **(a)** the so-called **accessibility**, i.e. the part of the year where the reactor is in operation, **(b)** the **frequency of quick-stops** at the installations and **(c) discharge of radiation into the environment**.
Although none of these parameters say anything about the reactor in question the year in question, most safety experts claim that there is a connection between these operation data over a longer time perspective. Bad accessibility and many quick-stops indicate that the reactor is badly constructed, badly operated or more or less run-down. Older reactors have a worse basic construction and need a more active enhancement effort in order to sustain the same basic level than the newer ones – if this is possible at all. If maintenance is reduced, more INES incidents are to be expected, more production pauses, higher radiation doses into the environment and more quick-stops. **This picture is predominant at Swedish nuclear power plants and at the Barsebaeck nuclear power plant in particular**.

(a) A nuclear power reactor's **accessibility** can never be 100% because it has to be stopped for some weeks due to fuel switch. The break is also used for maintenance and modernization. The best reactors could have an accessibility of more than 90% year after year. The world average for all reactors is approximately 83%. The four newest Swedish reactors - Forsmark 1-3 and Oskarshamn 3 – have had a high constant accessibility, but this is not the case for the oldest reactors. The worst is Oskarshamn 1, Sweden's oldest nuclear reactor in operation. During the period 1992-2001 it was hardly in operation 48% of the time. Ringhals 1, the second oldest reactor, has the second lowest accessibility.
1991-1997 the accessibility at the Barsebaeck nuclear power plant was approximately 70%. During the eighties and as a recent as 1991 it had been more than 90 %. **From 2001 it has been rapidly declining and in 2003 it was 45,4 % - a little more than half the average for the Swedish nuclear reactors – because Barsebaeck 2 was out of operation for about 5 months due to extraordinary repairs. In 2003 Barsebaeck 2 had the lowest accessibility for any Swedish reactor and in 2002 the second lowest, but nevertheless the lowest for any reactor in operation that year** (c*f. Table 6*).

[42] Fredrik Lundberg, *Varför driver de Barsebäck ?*, http://www.glod.com/arkivet/textarkiv/Ovriga_medarbetare/fl_000601_karnkraft.html
[43] Ibid. p. 3-40 and 3-41.

Table 6: Accessibility % at Barsebaeck 2 and on the average for all Swedish nuclear reactors 2000-2003[44].

	2000	2001	2002	2003
Accessibility % Barsebaeck 2	87,3	88,4	77,2	45,4
Accessibility % on the average for all Swedish nuclear reactors	83,3	89,1	89,2	82,0

(b) As described in Table 7 the Swedish reactors have more quick-stops than foreign reactors. The world average has in recent years been approximately 0,4 per annum. While the new reactors do not differ much from the world average, the older have 4 times as many quick-stops. According to Fredrik Lundberg the picture is the same for Sweden over a longer timeline, whereas the world average has sunk considerably since 1990. **Barsebaeck 2 has had more than 3 times more quick-stops during the period 1997-2001 than the world average**.

Table 7: Quick-stops on the average per year for Swedish nuclear power reactors 1997-2001. *Source: Fredrik Lundberg, Världens dårligaste kärnkraft*, Ordfront 6/2002.

		In commercial operation	**Quick-stops on the average per year 1997-2001**
New reactors	Forsmark 1	1980	0,6
	Forsmark 2	1981	0,4
	Forsmark 3	1985	0,6
	Ringhals 3	1981	0,4
	Ringhals 4	1983	0,4
	Oskarshamn 3	1985	0,6
	Average		**0,5**
Old reactors	Barsebaeck 2	1977	1,4
	Oskarshamn 1	1972	3,4
	Oskarshamn 2	1974	1,8
	Ringhals 2	1975	1
	Ringhals 1	1976	0,8
	Average		**1,7**
World average			**0,4**

(c) With respect to **discharge of radiation into the environment** the picture is more complicated: Globally the most common nuclear reactors are pressurized water reactors (PRW), whereas the most common in Sweden are boiling water reactors (BWR), i.e. 7 of 11. The world's average 1998-2000 was 1,88 manSievert for BWRs. The Swedish BWRs' average was 0,89, less than half this figure, but if the BWRs are divided in old and new, the old perform considerable worse than the world's average. **Barsebaecks average is a little better than the world average for BWRs but more than 50% worse than the world average for newer BWRs** (*see Table 8*).

[44] Cf. Svensk Energi, *Elåret 2003*, p. 16, http://www.svenskenergi.se/energifakta/elaret_03/el%E5ret_2003.pdf

Table 8: Radiation doses (manSievert) from Swedish nuclear power reactors 1992-2001. *Source: Fredrik Lundberg, Världens dårligaste kärnkraft*, Ordfront 6/2002.

		In commercial operation	**Radiation doses (manSievert)**	**Comments**
Old BWRs	Barsebaeck 1 (1992-2000)	1975	1,7	*Old BWRs, higher radiation doses than world average*
	Barsebaeck 2	1977	1,6	
	Oskarshamn 1	1972	2,5	
	Oskarshamn 2	1974	2,0	
	Ringhals 1	1976	3,7	
	Average, old BWRs		**2,3**	
World average, BWRs 1998-2000			**1,88**	
New BWRs	Forsmark 1	1980	1,0	*New BWRs, lower radiation doses than world average*
	Forsmark 2	1981	1,3	
	Forsmark 3	1985	1,1	
	Oskarshamn 3	1985	0,7	
	Average, new BWRs		**1,0**	
PWRs	Ringhals 2	1975	0,9	*Ringhals 2 as world average, newer PWRs better*
	Ringhals 3	1981	0,7	
	Ringhals 4	1983	0,5	
World average, PWRs 1998-2000			**0,92**	

A classical problem as regards the calculation of the risk of a serious accident at a nuclear power station and the precautionary measures that can be implemented in order to prevent such an accident has been formulated in the so-called "*zero-infinity dilemma*". Simply put, this expression has derived from the fact that the product of two factors, when one factor is extremely big (bordering on infinity) and the other extremely small (bordering on zero) is an insoluble equation. With respect to the assessment of the risk connected with a nuclear power facility this "zero-infinity situation" emerges because the probability of a major accident normally is extremely small, whereas the effects of such an accident can be very large, i.e. infinity is approached from a relative position.

It is a fact that **the official safety analyses both as regards the Swedish nuclear power reactors in general and the Barsebaeck nuclear power plant in particular are characterized by a high degree of uncertainty**. In 1995 the IAEA (= "The International Atomic Energy Agency") established a maximum limit for the acceptable nuclear incident frequency of 1:10.000 for old reactors and a maximum limit of 1:100.000 for new reactors. In a report published the same year by the Barsebaeck nuclear power plant the nuclear incident frequency for the plant was stated as 1:256.410. In 1996 SKI and SSI claimed that the nuclear incident frequency for Swedish reactors was 1:100.000. In November 1997 the Oskarshamn nuclear power plant published a report on the nuclear incident frequency in the plant's reactor 2. The frequency was stated for three types of occurrences (HS1, HS2 and HS3 occurrences) as respectively 1:52.631, 1:2.380 and 1:5.000. It

appeared that it was a known fact that the results did not meet IAEA's safety requirements neither for the new nor for the old reactors. In June 1998 the **Barsebaeck nuclear power plant** published a report, stating that the nuclear incident frequency in the plant was higher than 1:10.000. The same year yet another Barsebaeck report was published, now claiming that the nuclear incident frequency for reactor 1 was 1:15.384 and that the nuclear incident frequency for reactor 2 was 1:12.500. On December 11th 1998 the Barsebaeck nuclear power plant published its final PSA-report, concluding that the nuclear incident frequency was 1:16.666 for some types of occurrences[45]. However, it can be objected to the PSA assessments that they have error margins in the order of factor 100. That means that an assessment that establishes the probability of a reactor core meltdown to be 1:10.000 reactor years in reality could be as low as 1:100[46].
The conflicting PSA assessments with respect to Barsebaeck have triggered critical questions in both the Danish[47] and the Swedish parliaments. E.g. four questions were asked in the Danish parliament in 1998 to the Danish Prime Minister and the Danish Minister of the Interior about this particular benchmark for the plant's safety level[48]. However, the conclusion of the Swedish Minister of Environmental Affairs who ultimately is politically responsible for the safety at the Swedish nuclear power plants was that "because the result of a PSA assessment does not provide any absolute and realistic standard for the total risk, it is the opinion of the Swedish nuclear regulatory authority (SKI), which is shared by regulatory authorities in other countries, that these results cannot in themselves be the basis of a decision on whether the reactors should continue their operation[49]".

As mentioned above, SRSS – the only international independent report analyzing the Barsebaeck nuclear power plant[50] - has estimated **that the risk of a core meltdown in one of the two Barsebaeck reactors on the basis of an expected lifetime of 40 years is up to 2 per cent. According to the report, the risk could be even higher**.

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[45] Cf. Fredrik Lundberg.
[46] E.g. see. http://www.riksdagen.se/debatt/fragor/fraga.asp?rm=9798&nr=966
[47] Question No. S 891 to the Prime Minister and No. 176, 177 and 230 to the Minister of the Interior from the Parliament's Environmental and Planning Committee, cf. http://www.ft.dk/?/Samling/19972/spor_sv/S891.htm, http://www.ft.dk/?/Samling/19972/udvbilag/MPU/Almdel_bilag388.htm and http://www.ft.dk/?/Samling/19972/udvbilag/MPU/Almdel_bilag447.htm
[48] One of the most interesting of these questions is probably question No. 176 that was put forward May 26th 1998: *"The Minister is asked to submit and comment on an article in the (Swedish) daily Dagens Nyheter April 28th 1998. It is said in the article that the probability of a serious accident at the oldest Swedish reactors at Oskarshamn and Barsebaeck, which are only furnished with two independent electricity systems, are now estimated to be 10-100 times bigger than previously assumed (from 1:1.000 to 1:10.000 reactor years)*". To this question the Minister of the Interior answered among others: "The article in question refers to a safety analysis that OKG, a private company controlled by the Sydkraft group and owner of the Oskarshamn nuclear power plant, has carried out of the Oskarshamn 2 reactor installation (…) According to SKI's press release, the result of the preliminary PSA analysis indicates a frequency of a reactor core meltdown of 1 occurrence per between 1.000 and 10.000 years and that the risk picture mainly is dominated by malfunctions in the electricity supply and the electricity system. IAEA, UN's international atomic energy agency in Wienna, recommends a PSA value for older nuclear reactors of 1:10.000 and 1:100.000 for newer reactors. SKI is in support of these recommendations and has established that the values for Oskarshamn 2 do not live up to these targets that Sydkraft itself has set for the installation (…) **It is not directly possible to implement the results of the analysis of Oskarshamn 2 to other installations, including the Barsebaeck nuclear power plant, but the Danish Emergency Management Agency agrees that it is natural to compare the assessment with Barsebaeck, because there is great similarity between the installations** (BBOFF's accentuation). However, Barsebaeck and Oskarshamn are not identical and the differences in systems and components could lead to significant differences in PSA results".
[49] Answer to question 1997/98:966, http://www.riksdagen.se/debatt/fragor/svar.asp?rm=9798&nr=966
[50] *Undersökning av svensk reaktorsäkerhet*, Riskbedömning for Barsebäck, Utförd av MHB Technical Associates Palo Alto, Kalifornien, Januari 1978, Ds I 1978:33, p. 1-14.

Particularly about the safety culture at the Barsebaeck nuclear power plant

In the most dangerous industry of all, in which most of the serious accidents have been caused by human errors[51], **the management and the employees at Barsebaeck 2 have publicly been corrected by SKI for lack of motivation in their work**[52]. However, the correction had no apparent effect and in 2003 SKI filed a criminal complaint against Barsebaeck Kraft AB. This was the first time officials at SKI have ever brought a criminal complaint against a nuclear operator. **The complaint has now resulted in a criminal case against the plant management**. The public prosecutor expects the trial to last at least a year. If the defendants are convicted they could be fined and sentenced to a term of imprisonment up to two years[53].

The series of incidents that lead to the criminal complaint and the criminal case has been described in Section 6.2 of the Nuclear Safety Inquiry's report *Kärnkraftverkens säkerhet och strålskydd*[54] from November 2003 that describes the safety culture at the Barsebaeck nuclear power plant the following way: "Barsebaeck 2 was restarted in March (2003) with new thermal mixers in the feedwater system and after being evaluated by the SKI. An inquiry of the incident was made. The results of subsequent inquiries and SKI's inspections showed deficiencies in work routines and methods inside and outside the reactor control room and in the handling of installation, construction, safety assessment and operation of the mixers that were damaged. **According to SKI this signifies major deficiencies in management of the plant. Hence, the nuclear power station has been put under special supervision from the SKI until further notice** (BBOFF's accentuation)".

According to an article in Nucleonics Week 34 - 03, 2003-8-21, *SKI files legal case against Barsebaeck*, Christer Viktorsson, director of SKI's Reactor Safety Office, has stated that the plant will be put under **special supervision for at least a year**. The plant was also under such supervision **between 1994 and 1997** because of a series of incidents that regulators concluded showed safety culture shortcomings.

The utility has also been forced to accept a number of organisational and administrative measures and e.g. make a plan in order to improve the safety culture before SKI approved a restart of the reactor in October 2003. SKI has even laid down a number of additional requirements for the operation on the facility after February 1st 2004, among others that

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[51] E.g SRSS described a series of possible accidents containing a potential risk during outage caused by human errors, resulting in loss of the reactor's primary system. Examples of such accidents are: (1) Errors during removal of circulation pumps that could cause loss of the primary system, (2) similar errors during removal of power devices for control rods or (3) erroneous handling of the valves during maintenance of the valves in the primary system.

At the Barsebaeck nuclear power plant these are potentially dangerous accidents because there is no possibility of spraying the core during the fuel refilling. Nor is the primary reactor containment intact during the outage before fuel refilling, because the containment top has been removed.

[52] In a newspaper article titled "*Sloppiness in Barsebaeck worries the authorities*" in Dagens Industri, September 1st 2001, Christer Viktorsson, the head of SKI's department for reactor safety is quoted for the following remark: "We were down (at Barsebaeck) in May, meeting the management. We felt that something had happened, that their attitude had changed". And the article continues: "Viktorsson thinks that the reason for the lack of motivation is that it is still uncertain what is going to happen with the plant. This is something that Barsebaeck's information director, Lars-Gunnar Fritz, agrees on. "The uncertainty is the problem. It doesn't help if you're good at your job. The politicians can still decide to close down the plant", Fritz says. An inspection of the nuclear power plant in July showed that a number of rupture disks had been wrongly installed for a year. This is now being investigated by SKI, but as early as May the inspectorate expressed its wish for the plant's management to initiate a safety measure program. This summer, SKI has plans to follow Barsebaeck's safety activities more closely". See http://www.skb.se/templates/Page.asp?id=2495http://www.skb.se/templates/Page.asp?id=2495

[53] *Platts: Barsebaeck-2 may have broken nuclear law*, Stockholm (Nuclear News Flashes)--23Oct2003.

[54] *Kärnkraftverkens säkerhet och strålskydd*, SOU 2003:100**,** Betänkande av Kärnsäkerhetsutredningen, Stockholm 2003, 240 p., http://miljo.regeringen.se/propositionermm/sou/pdf/sou2003_100.pdf

changes have to be made in the plant's work routines as regards supplier assessments and the handling of various tasks (BBOFF's accentuation) [55]".

The report comments on the significance of the incident the following way: "Because the accessibility of the safety measures were only marginally affected, SKI estimated the incident to be level 0 in the INES classification. **But because the utility continued operations even though the reactor functioned in an unexpected way, SKI upgraded the incident to level 1** (BBOFF's accentuation)", p. 138.

Even though the plant management is currently being prosecuted, it has not been suspended, i.e. it still manages the plant.

A complaint has been filed to the police against the SKI because of alleged negligence as regards the above-mentioned case. **The public prosecutor is currently looking into the matter**[56].

The recent incidents at the Barsebaeck nuclear power plant have had yet another ramification: In September 2003 **a crack causing a leakage in the suppression pool** was discovered. The leakage prevented a restart of the reactor that had been inoperative since July 17th. The leakage has existed for several years – ostensibly up to ten years and according to the plant's own press releases **leaking 9 litres water per hour**[57]. Operation was resumed December 11th 2003. According to a press release from the plant[58] the cause of the leakage was a leaky welding joint in the bottom of the suppression pool due to a bad welding made in 1989 between two plates, subsequently causing corrosion. The damage was found and repaired. Prior to the restarting of the reactor the Swedish government had hinted that it was willing to let it restart on dispensation, even though the crack was not found[59]. Barsebaeckkraft AB estimates that it has lost 700-800 million SEK during this extensive production pause including additional costs for repairs and examinations[60].

The many problems not least at the Barsebaeck nuclear power plant have had political ramifications, though. In its November 2003 report, the Nuclear Safety Inquiry Commission presented a proposal for the removal of certain provisions in order to enhance the motivation to

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55 Ibid. p. 137-38

56 According to an article in Sydsvenska Dagbladet from August 21st 2003 the chief prosecutor in Stockholm, Birgitta Cronier, has been assigned to investigate whether the SKI management is guilty of code violations or professional negligence while dealing with the above-mentioned incidents at Barsebaeck. The suspicions against SKI are based on the fact that SKI allowed the nuclear power plant to install a completely untested feedwater mixer in its cooling system. When the mixer was later switched SKI permitted the plant to install yet another untested mixer. Apart from that SKI hesitated in filing a criminal complaint against the plant management, although it was clear at an early stage that the mistakes that were made in connection with the suspension of operation very many and serious, http://se.news.yahoo.com/030821/58/19iv1.html

57 http://www.barsebackkraft.se/index.asp?ItemID=1291

58 http://www.barsebackkraft.se/index.asp?ItemID=1291

59 On November 11th Åsa Torstensson from the Swedish Centre Party asked the asked the Minister of Industry, Leif Pagrotsky (qustion 2003/04:246), about his position on an application on **dispensation with respect to a restart of the reactor**, because the leakage was under the threshold level. On November 19th 2003 the Minister of Environmental Affairs, Lena Sommestad, answered on behalf of the Minister of Industry, that "safety at the nuclear power plants is regulated by the Act (1984:3) on Nuclear Activities. om Kerneteknisk Virksomhed. The government has authorized SKI to supervise the compliance to this act. SKI monitors the incidents at Barsebaeck very closely and it is my estimate that the nuclear regulatory authority does a very competent and confidence inspiring job. Even internationally Sweden has been commended for the safety work and the subsequent repprting at two inquiry conferences under the Nuclear Safety Convention in 1999 and 2002. Therefore I am not worried about SKI's ability to perform these tasks in the future". See also http://www.svd.se/dynamiskt/inrikes/did_6496651.asp

60 Erik Magnussen, *Barsebäcks kärnkraftverk är i full gång igen,* Sydsvenskan, 2003-12-14.

report incidents at the nuclear power plants. **The proposal would imply that it would no longer be mandatory for SKI to report violations of the law committed by the staff at the nuclear power plants to the police**[61]. One could argue that this is a **”lex Barsebaeck”**.

II. Consequence scenarios for the worst possible accident at the Barsebaeck nuclear power plant

Regarding this subject, two things are crucial: How dangerous is the plant, i.e. what is the worst case scenario for a serious accident at Barsebaeck and which consequences could such an accident have ?

According the report *“Consequences in Sweden of a serious nuclear accident”* (for further information on this report, see section II.C below), whose assessments are the main basis of the Danish nuclear rescue preparedness, **the definition of the worst possible accident at the Barsebaeck nuclear power plant** is the following: ”Large floor rupture in the BWR (Barsebaeck) in combination with loss of all external power saturation, all reserve power saturation and with a malfunctioning pressure damper, which leads to an early container rupture[62]”. This scenario causes a so-called **rest risk release**, i.e. a “very substantial release of the whole inventory of noble gases and a tenth of the reactor’s content of iodine, caesium and tellurium is released. The more immovable substances are more contained”.

The impact of the rest risk release depends on at least five factors: (1) The **content** of radioactive substances in the reactor core, (2) the released **fraction** of the core inventory and the **form and composition** of the released material during the accident, (3) the **distribution** of radioactive substances into the environment, (4) the **concentration of radionuclides** in the environment and the **radioactive doses** for humans and (5) the **population density** in the contaminated territories.

Particularly with respect to (5) it is worth mentioning that **the Barsebaeck nuclear power plant is situated in the centre of the most densely populated area in Scandinavia, only 20 km east of the Danish capital Copenhagen and 15 km north of Malmoe**[63].

Ever since the Barsebaeck nuclear power plant was taken into commercial operation – Barsebaeck 1 in 1975 and Barsebaeck 2 in 1977 – a series of risk and consequence scenarios for the Swedish nuclear power plants have been analyzed in various scientific reports. Due to lack of space it is not possible to describe them all in this position paper[64]. Below (A-C) mainly those are described that

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[61] The proposed amendment to the Nuclear Technology Act § 29 and the Radiation Protection Act § 38 says verbatim: “With respect to the assessment whether the act is punishable it should be considered whether is has been remedied immediately after being discovered by those held responsible by this Act and the occurrence is reported to the regulatory authority”, cf. p. 31-32.

[62] Cf. Annex 1, *SKI – PM, Representative källtermer vid haverier i svenska reaktorer,* p. 4.

[63] **The location of dangerous activities** is explicitly mentioned in the Espoo-Convention as a factor that should be taken into consideration in an environmental impact assessment, cf. Appendix III (*“General criteria to assist in the determination of the environmental significance of activities not listed in Appendix I”*), subsection 1, item b, where it is stipulated that it is significant whether a given activity could be expected to have a negative impact across national borders “in locations where the characteristics of proposed development would be likely to have significant effects on the population”.

[64] As examples of reports that are **not** specifically mentioned are: *”Radioaktiv landforurening på dansk område efter et eventuelt stort havari på Barsebäckværket, Konsekvenser af en landforurening med radioaktive stoffer på Sjælland efter et hypotetisk kernenedsmeltningsuheld på Barsebäck”*, DELRAPPORT 1, Forsøgsanlæg Risø, november 1981,*”Radioaktiv landforurening på dansk område efter et eventuelt stort havari på Barsebäckværket, De økonomiske*

have played a role in the Danish green NGOs' scepticism towards the Barsebaeck nuclear power plant and those that are important for the Danish and Swedish regulatory authorities' perception of the effects of the worst possible accident at the plant.
Since 1986 the predominant benchmark for the consequences of the worst possible accident at a nuclear power plant has been the lessons learned from the Chernobyl disaster. Hence, it is only natural that BBOFF draws a comparison between the readioactive releases from the Chernobyl reactor the possible releases from the Barsebaeck nuclear power plant (D). Finally, we try to implement the lessons learned at Chernobyl in the Barsebaeck context (E).

A. "A study on Swedish reactor safety"

As early as the year after Barsebaeck 2 initiated its power production, a study on the risk and consequence scenarios for the Barsebäck nuclear power plant was published – *A study on Swedish reactor safety* – Risk assessment of Barsebaeck, carried out by MHB Technical Associates Palo Alto, Kalifornien, Januari 1978, Ds I 1978:33.
The report was commissioned by the Swedish Energy Commission's Working Group for Safety and the Environment. The Swedish study on reactor safety (SRSS) was carried out by MHB Technical Associates with Science Applications Incorporated (SAI) as junior consultants on behalf of the Energy Commission. The assessments of the consequence scenarios were made by Centre for Environmental Studies at the Princeton University. **First and foremost the report is interesting because it is the only one that is not made by Swedish or Danish authorities or the Barsebaeck nuclear power plant itself**.
The objective of the report was to give an account of the risks involved in the operation of Barsebaeck 1 and 2 compared to American Peach Bottom 2 reactors, including a study of possible errors and consequences deriving from these that could lead to large releases of radioactivity. The results of the report were presented in a way that made them comparable to the so-called WASH-1400 (*Reactor Safety Study – An Assessment of Accident Risks in U.S. Commercial Power Plants*, U.S. Nuclear Regulatory Commission, WASH-1400 (NUREG 75/104)), a.k.a. the "Rasmussen report". In 1965 where WASH-1400 was published, it was NRC's so far most extensive study on the safety problems of nuclear power. The basis of the report was a technical analysis of two American reactors, a BWR and a PWR. The report described five release scenarios for the BWRs and nine for the PWRs.

Among others, the main conclusions of the report were the following:

(1) The median risk of acute deaths in SRSS is higher than for WASH-1400 with a factor spanning from 2 to 25 as regards the probability and from 10 to 100 as regards the consequences.
(2) In a comparison of the risk of long-term cancer casualties SRSS indicates thousands more deaths than WASH-1400 except from the most serious nuclear accidents.

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virkninger af et stort Barsebäckuheld", DELRAPPORT 2, Søren Kjeldsen-Kragh og Poul Erik Stryg, Økonomisk Institut, Den kgl. Veterinær- og Landbohøjskole, november 1981, *"Radioaktiv landforurening på dansk område efter et eventuelt stort havari på Barsebäckværket"*, Redegørelse fra en arbejdsgruppe, november 1981, *"Rapport om sikkerhedstekniske spørgsmål og fælles elementer i beredskabsforholdene i forbindelse med Barsebäckværket"*, Afgivet af Svensk-Dansk Komité om sikkerheden på Barsebäckværket, DsI 1981:4 – Betænkning nr. 922, København 1981, and *"Samhällets åtgärder mot allvarliga olyckor"*, Betänkande av utredningen om kärnkraftsberedskapen, Statens offentliga utredningar 1989: 86, Stockholm 1989, 303 p.
Either these reports are considered to be outdated or they confirm the conclusions in the three reports that are described in this section of the position paper.

(3) A growing risk of long-term casualties could derive from thyroid cancer and cancer deaths from being exposed to ground contamination for a long time. This could cause an additional 5.000-34.000 deaths after an accident.
(4) **The dissemination of radioactive substances after an accident at the Barsebäck nuclear power plant could be so extensive that almost 20 European countries, including several eastern European countries and the (former) Soviet Union, would be contaminated**.
(5) **The international complications because of the ground contamination caused by an accident at the Barsebäck nuclear power plant could be one its most serious consequences**.
(6) **Under typical conditions the average size of the contaminated area after an accident would be 100.000 km2, i.e. more than twice the area of Denmark**.

There is a risk that not only the current population will be affected but also the future generations because of the long lifetime of the radioactive substances. Apart from that the consequences of a serious accident could result in an almost permanent prohibition of access to large areas (the so-called **exclusion zones**).
In a meltdown accident substantial amounts of radioactivity would leak into the groundwater. **In theory, just the strontium-90 contamination could cause more than 800 km3 water to reach its maximum threshold value. This compares to more than 1 % of the water in the Baltic Sea**.

B. "A Secretariat Report on society's measures against serious accidents"

Because of the Chernobyl catastrophe that caused damage in Sweden as well, on June 11th 1987 the Swedish Government authorized the head of the Swedish Ministry of Defence to form a committee that were to make an investigation on the Swedish nuclear and chemical preparedness plan[65]. The result was *A Secretariat Report on society's measures against serious accidents, the investigation (Ministry of Defence 1987: 01) of the nuclear preparedness* (369 pages). The report describes the consequences of a serious accident in a Swedish nuclear power plant[66]. **The report is probably the one thas has played the most important role in the Danish Barsebaeck resistance. For many years it was the backbone in OOA's and the Danish Greenpeace's Barsebaeck campaign**.
According to the report, the consequences of a serious nuclear reactor accident under unfavourable weather conditions, causing a release of radiation from the power plant, would be the following (*see Table 9*): **If the safety filter[67] functions properly:** Migration for ever of the population in the central warning zone (up to 5-10 kilometres from the reactor) within 24 hours. Evacuation for several years of the population in parts of the indication zone (up to 50 kilometres from the reactor, i.e. in case of an accident in the Barsebaeck nuclear power plant the whole Oeresund region) within a month. Evacuation of all pregnant women up to 100 kilometres in the direction of the wind (half

[65] In the Commission were county prefect Carl G. Persson and political spokespersons from the Swedish parliament Ingvar Björk, Beril Danielsson, Birgitta Hambraus, Per Olof Håkansson, Hans Lindblad and Britta Sundin. As experts were chosen member of the chancellery Ulf Bjurman, representative of the ministry Suzanne Frigren, general director Gunnar Bengtsson, secretary of the ministry, Agneta Björkenstam, office director Roland Nilsson and information director Gunilla Wünsche. The calculations on the risk scenario were made by SSI based on material from the Danish National Laboratory in Risø and the Swedish Defence Research Centre (FOA).
[66] The most significant parts of the report can be found at http://www.greenpeace.se/files/2000-2099/file_2097.pdf
[67] The filter installation is based on the concept of a radioactive release from the reactor being led through a building filled with stones and gravel, which – if it works – could prevent a large part of the radioactivity from being dispersed into the environment (apart from the airborne discharges). The filter system at the Barsebaeck nuclear power plant is situated in a separate building – approximately 50 m. from the Barsebaeck 2 reactor building – that is connected to the reactor building with pipes, cf. *Teknisk information om Barsebäck*, Ringhals Information 2004, p. 18.

of Zealand) within a month. Recommendations to stay indoors and eat iodine tablets up to 100 kilometres in the direction of the wind (half of Zealand) before the passing by of the radioactive clouds[68]. **If the safety filter does not work:** Evacuation of the entire population in a 60 kilometres zone from the power plant in the direction of the wind (the whole Oeresund region) in case of a risk of a radiation release. Vacation for ever within a few hours in a 60 kilometres zone from the power plant in the direction of the wind (the whole Oeresund region) in case of a radiation release and in a 100 kilometres zone (half of Zealand) within 24 hours. Vacation for several years in a 500 kilometres zone (the whole of Denmark) in the direction of the wind within a month. Evacuation of all pregnant women in a 500 kilometres zone from the power plant within 24 hours in the direction of the wind and in a 1000 kilometres zone (Northern Europe, a large part of Scandinavia) in the direction of the wind before the radioactive clouds pass by. Restrictions for among others grazing cattle in a 1000 kilometres zone from the power plant in the direction of the wind[69].

Table 9: The consequences of a serious nuclear reactor accident under unfavourable weather conditions causing a release of radiation into the environment.

Timeline	The safety filter functions properly	The safety filter does not work
The first 24 hours	Migration forever of the population in the central warning zone (up to 5-10 kilometres from the reactor).	Evacuation of the entire population in a 60 kilometres zone from the power plant in the direction of the wind in case of a risk of a radiation release. Vacation for ever within a few hours in a 60 kilometres zone from the power plant in the direction of the wind in case of a radiation release and in a 100 kilometres zone within 24 hours.
	Recommendations to stay indoors and eat iodine tablets up to 100 kilometres in the direction of the wind before the passing by of the radioactive clouds.	Evacuation of all pregnant women in a 500 kilometres zone from the power plant in the direction of the wind.
The first month	Evacuation of all pregnant women up to 100 kilometres in the direction of the wind.	Vacation for several years in a 500 kilometres zone in the direction of the wind. Evacuation of all pregnant women in a 1000 kilometres zone in the direction of the wind.

The rescue preparedness estimates of the 1987 Secretariat Report were later confirmed by a 1989 Report from the Swedish Ministry of Defence, *Society's measures against serious accidents*, the report on the investigation of the nuclear rescue preparedness, SOU 1989: 86, Stockholm 1989, (303 pages). The people behind the report who more or less were the same as those who were behind the Secretariat Report were assigned to draw the practical conclusions from both the Secretariat Report and another report from June 1988 containing preliminary conclusions to be considered for the 1989 Report and convert these considerations and conclusions into amendments. The report led to an amendment (*bill 1991/92:41 on society's measures against serious accidents*) in which the government proposed a series of changes in the rescue preparedness act.

[68] See the report p. 160-161.
[69] Ibid. p. 161-63.

Regarding the question of rest risk criteria the 1989 Report event represents an intensification compared with the Secretariat Report[70].

C. ”Consequences in Sweden of a serious nuclear accident”

The Danish Emergency Management Agency refers to this report from 1995 - *Consequences in Sweden of a serious nuclear accident*, An investigation carried out by the Swedish Radiation Protection Authority in consultation with the Swedish Nuclear Power Inspectorate, September 1995 (43 pages) - **as the one, whose estimates are primarily the basis of the Danish nuclear rescue preparedness**[71].

The report was made by a working group from SSI and SKI because the Swedish Energy Commission wanted an assessment of the effects of radioactive releases from a Swedish nuclear power plant in case of a serious accident. Part of the assignment was to discuss the different perspectives on the global risk scenarios and give an account of the estimates of earlier reports. It is noteworthy that the report states that its consequence scenarios for releases from serious reactor accidents **are representative of all the Swedish reactor types**, cf. p. 1 and 27, where, however, releases from the nuclear power plants in Ringhals and Forsmark are considered more dangerous as regards the so-called “rest risk releases”.

The assessments presented in the report are the following: In case the release-reducing measures function completely in a reactor with 1800 MW thermal effect, i.e. corresponding with a Barsebaeck reactor, the consequences of an accident will be limited (a so-called “realistic accident release”[72]). Depending on the direction of the wind some and perhaps up to 50 cancer deaths will occur in Europa (up to 1400 kilometres from the release source) within a period of 50 years. The scenarios for the Swedish nuclear power plants are almost the same, however, **a release from the Barsebaeck nuclear power plant is expected to have more serious consequences**. The cases of cancer will occur within a 70 kilometres zone from the reactor[73].

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[70] E.g. cf. the following excerpt from the report: “In the inquiry commission’s opinion the description in the earlier report of the nuclear activities and the risk of accidents gives a by and large correct picture of the threat that society faces. The same opinion is shared by most of the organizations and other authorities that have commented on our estimates. The description is sufficiently detailed to serve the purposes of the analysis as regards the commission’s reflections on among other things management, education, information, radiation protection, sanitation and questions about cooperation. It is the task of the security authorities to make precise assessments necessary to weigh the different precautionary measures against each other and evaluate the need for precautionary measures in different parts of the country.

In one particular respect, the commission intends to develop the argumentation of the earlier report. This applies to the *risks of sabotage and other terrorist acts* against nuclear power plants, transports or other nuclear activities and the importance these risks have for the threat scenario. The nuclear power plants have implemented different precautionary measures that aim at reducing the releases that could be the consequence of sabotage against vital parts of the facilities. **None the less the commission has reached the conclusion that the risk of terrorist acts and sabotage causing a radioactive release no longer have such “an extreme low probability” that it should be considered a rest risk and therefore – according to the parliament’s (earlier) decision – do not need to be taken into special consideration and cause further security-enhancing measures** (BBOFF’s accentuation)”, p. 61.

[71] Cf. the Danish Minister of Health and the Interior’s answer in the Parliament June 6th 2003 to questions No. S 3374 and S 3458.

[72] The expression used by SKI – ”realistic accident release” – includes diffuse leakages through the reactor container. The release occurs in two stages: First, the diffuse leakage the first few hours, then the release through the filter after 6 to 24 hours, p. 19. As regards **the Barsebaeck nuclear power plant** the following scenario applies: “Loss of external power saturation in combination with loss of all available reserve power saturation within 24 hours resulting in a meltdown and melting through the tank within an hour and after 6-17 hours releases trough the filter. Releases occur through the diffuse container leakage, corresponding with the density requirements in the technical regulations, and the filter, Annex 1, *SKI – PM, Representative källtermer vid haverier i svenska reaktorer*, p. 3.

[73] Ibid. p. 23.

If the release-reducing measures function, but it is necessary to release 0,1 % of the radioactive substances into the environment for safety reasons (a so-called “nominal accident release”[74]), 20-100 extra cancer deaths can be expected under normal weather conditions **for all the nuclear power plants**. Under rarely occurring very unfavourable weather conditions, this figure will rise to 200, **for the Barsebaeck nuclear power plant possibly 500**. No acute injuries are to be expected. If the release occurs in the grazing season, it is to be expected that the iodine coverage of the ground up to a distance of 70 kilometres from the source is such that the dairy cattle within an area of perhaps 5-10.000 km2 would have to be fed with substitute fodder the rest of the season, if the milk is to be used for consumption.
As regards a so-called **rest risk release** (see the defition above) the consequences are far more serious[75]. The scenario that leads to such an accident implies that the release will take place within an hour of the start of this sequence, which means that **no evacuation can take place near the reactor.** As regards the calculations on this type of release the total content of radioactive material in the reactor must be taken into consideration. **The report bases its calculations on the scenario below on a reactor with a thermal effect of 2000 MW[76]. The maximum doses are directly proportionate to the actual thermal effect.** The collective doses for the Barsebaeck and the Oscarshamn nuclear power plant take its starting point in 1800 MW and Ringhals and Forsmark in 3000 MW, i.e. the reactors in Ringhals and Forsmark have to be multiplied with a factor 1,5.
The report describes the result of a rest risk release the following way: “One cannot exclude that a number of deaths because of acute radiation sickness will occur among people within 5 kilometres from the release source. Large amounts of radioactive material will settle on the fields and make possible taking doses in through food consumption. In case of favourable wind conditions the number of cancer deaths up to 1400 kilometres from the source will amount to some hundreds in the course of 50 years. **Under more normal weather and wind conditions the numbers can rise to up to 2.000-8.000 and in the most unfavourable cases up to the double of this figure. The first 24 hours, the doses under the plume of smoke are such that a quick evacuation would be well founded at a distance of 100-150 kilometres from the release source. This cannot be arranged, though, because the time for warning is insufficient. The high ground dose the first month implies that a long-term evacuation from the area could be necessary up to a distance of 50 kilometres from the release source. Areas some hundred square kilometres in extension could be covered with so much radioactive caesium that they would be unemployable for several decades. Milk produced in large areas the first month after the accident would have to be discarded** (BBOFF’s accentuation)”, ibid. p. 2.

However, the report’s most serious assessment pertains to the release of caesium-137. After pointing out that the ground dose of territories covered with 10.000 kBq/m2 is still so high after 50 years that it is impossible to live there and that it is doubtful whether territories with a coverage of some thousands kBq/m2 can be utilized for a generation, it defines exclusion zones based on the 10.000 kBq/m2 contamination level within 20, 60 or 100 kilometres from the release source, depending on the weather conditions[77] (*see Table 10*), **thus confirming the worst-case scenarios of the 1987 Secretariat report and the 1989 Report.**

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[74] The ”**nominal accident release**” covers a situation where the release reducing measures fulfil the requirements, but do not reduce the release sufficiently. The scenario implies that the release of among other things iodine, caesium and tellurium goes up to 0,1 % of the content of an 1800 MW reactor (thermal effect) while the more stationary substances are more contained. Also in this situation, the release occurs in two stages, of which the first one corresponds with a diffuse leakage, p. 19.
[75] Ibid. p. 2.
[76] Ibid. p. 27.
[77] P. 32.

Table 10: Deposition Cs-137 a month after release. 2000 MW (thermal) reactor "rest risk release"[78].

	D-weather, no precipitation		**D-weather, precipitation**		**F-weather, precipitation**	
kBq/m2	***Area km2***	***Max. distance km***	***Area km2***	***Max. distance km***	***Area km2***	***Max. distance km***
> 100.000	-	-	5	5	15	10
> 10.000	2	3	200	40	150	30
> 1.000	50	20	2000	100	1000	60
> 100	2000	150	10000	200	6000	150

With respect to a **quick evacuation of the population in particular around the Barsebaeck nuclear power plant** it is stated in the report, **that the consequences of the radioactive releaes could be dramatic in Barsebaeck's case where substantial parts of the collective dose are received in areas with high radiation levels that have to be evacuated**[79]. For up to 95 % of the releases the fallout level is more or less the same for the nuclear power plants (Oskarshamn half of that though). Only in meteorologically extraordinary situations the consequences of an accident in the Barsebaeck nuclear power plant get considerably bigger than in the other plants. The tables 11 and 12 show the result of a probabilistic calculation of the probability level for the collective fallout (foodstuffs excluded). The assessments of Table 11 do not take into consideration that the population in the most affected areas has to be evacuated and that sanitation attempts will have to be made. Table 12 shows the result of a simplified calculation of the consequences of an evacuation.

Table 11: Probability levels (for Barsebaeck, Ringhals, Oskarshamn, Forsmark) for collective doses (manSv) after a rest risk accident, no counter-measures[80].

	10 %	*50%*	*90%*	*95%*	99%	99,9%
Barsebaeck	**10.000**	**30.000**	**130.000**	**160.000**	**560.000**	**1.300.000**
Ringhals	10.000	40.000	120.000	160.000	210.000	500.000
Oskarshamn	7.000	20.000	70.000	80.000	120.000	140.000
Forsmark	1.500	30.000	110.000	130.000	160.000	500.000

[78] Cf. the report's Table 8**,** p. 31. The weather types belong to the stability categories D and F according to the so-called Pasquill classification. D signifies a neutral atmosphere with more than 200 days and nights of good weather and approximately 500 hours of precipitation. F signifies a stabile atmosphere with less than 30 days and nights of godd weather and precipitation for less than 50 hours.

[79] P. 31.

[80] Table 6, p. 30.

Table 12: Probability levels for collective doses (manSv) after a rest risk accident after an evacuation of the population[81].

	10 %	*50%*	*90%*	*95%*	99%	99,9%
Barsebaeck	**10.000**	**26.000**	**100.000**	**130.000**	**160.000**	**210.000**
Ringhals	7.000	35.000	110.000	150.000	200.000	260.000
Oskarshamn	6.000	20.000	70.000	80.000	120.000	120.000
Forsmark	1.500	30.000	110.000	120.000	160.000	450.000

D. A comparison between the radioactive releases from the Chernobyl reactor and the possible releases from the Barsebaeck nuclear power plant

Since 1986 **the all-important standard for the worst possible accident at a nuclear power plant is the effects of the Chernobyl disaster**. Consequently, the Chernobyl-case is highly relevant to an environmental impact assessment of the Barsebaeck nuclear power plant. **In order to assess whether the long-term consequence scenario that Chernobyl represents can be applied in a Barsebaeck context it is necessary to determine to what extent the Chernobyl disaster is comparable to the worst case scenario for a serious nuclear accident at Barsebaeck**.

A comparison between the Chernobyl disaster and the worst-case scenario for a serious nuclear accident in the Barsebaeck nuclear power plant must be based on the quantities of radiation released from the Chernobyl accident and the possible releases from a serious nuclear accident in the Barsebaeck nuclear power plant. In this context it must be noted that the current official Danish/Swedish definitions of a worst-case scenario for an accident in a nuclear reactor are by no means exact. It is also a common trait that they are based on minimum, not maximum expectations. **Consequently, it is possible to conclude at least in principle that a very serious release of radioactive substances from a smaller reactor could equal or exceed a less serious release from a larger reactor – even in a worst-case scenario.**

However, although this is a complex situation in which approximately twenty radioactive substances are released into the environment – each of them with a different half-life – there is an indication that the more fuel a reactor contains, the bigger the release of radioactive substances will be in case of a serious accident. The gravity of a serious accident at the Barsebaeck 2 reactor derives from the released fraction of the core inventory. **The reactor core of Barsebaeck 2** contains 444 fuel assemblies. The fuel weight per assembly is 172 kgU/assembly **totalling a weight of 76.4 tons of heavy (uranium) metal (tHM)**.[82]

At the time of the accident there were approximately 200 tons of uranium in the Chernobyl reactor, but there is still some doubt as to how much radiation was unleashed into the atmosphere. Most estimates give the amount as between 3,8 % and 20 % causing the release 50 to 250 million Ci of radiation. The Ukrainian government agency Chernobyl Interinform contends that studies of the reactor over 15 years indicate that 95 per cent of the fuel still remains within the reactor[83]. The nuclear industry's organization *World Nuclear Organisation* (WNA) estimates that all of the xenon gas, about half of the iodine and caesium, and at least 5% of the remaining radioactive material in the Chernobyl-4 reactor core was released in the accident[84]. Nuclear Energy Agency's (NEA) report

[81] P. 31.
[82] http://www.barsebackkraft.se/index.asp?ItemID=1291
[83] Cf. http://www.chernobyl.info/en/Facts/Contamination/AmountRadiation
[84] Cf. http://www.world-nuclear.org/info/chernobyl/inf07.htm

from 2002, *CHERNOBYL, Assessment of Radiological and Health Impacts*[85], estimates that ”100% of the core inventory of the noble gases (xenon and krypton) was released, and between 10 and 20% of the more volatile elements of iodine, tellurium and caesium. The early estimate for fuel material released to the environment was 3 ± 1.5% (IA86). This estimate was later revised to 3.5 ± 0.5% (Be91). This corresponds to the emission of **6 ton of fragmented fuel**[86] (BBOFF's accentuation)”. According to the report this estimate is still valid (p. 35). Finally, the report ”Consequences in Sweden of a serious nuclear accident” talks about a release of all the noble gases, 50-60 % iodine-131, 30 % caesium-137 and 4 % strontium-90[87]. However, some estimates differ significantly from the above-mentioned[88].
Based on these figures, a release of 7,7 % the reactor fuel in Barsebaeck 2 will roughly speaking equal 3 % of the fuel in the Chernobyl reactor (6 tons of fragmented fuel) and a release of 12,8 % will equal 5 % of the fuel in the Chernobyl reactor (10 tons of fragmented fuel) – two of the most likely actual Chernobyl release scenarios. A release between 7,7 % and 51 % of the fuel will equal or exceed the release from the Chernobyl reactor and any release higher than 51 % from Barsebaeck 2 will exceed the release from the Chernobyl reactor.

The release of the fragmented fuel in general, however, is incidental to the release of caesium-137 - the most important isotope as regards the collective dose that was released in the Chernobyl accident. 15 years after the Chernobyl accident caesium-137 was responsible for 80 % of the collective dose worldwide. According to an assessment published by the *NEA Committee on Radiation Protection and Public Health* November 1995[89], **26,4 kg out of a total inventory of 87 kg caesium-137** was released, i.e. a release of 33 % of the core inventory. This was from a core melting, but other scenarios are possible – like the one where e.g. a large plane crashes on the reactor pool – leaving room for a fork of the release of perhaps between 25 % and 50 % of the caesium-137 reactor inventory[90]. This leads to the question, how much caesium-137 there would be in the Barsebaeck 2 reactor core. A 5 years cycle for the fuel in the reactor core would indicate that the fuel burn-up should be between 40 and 50 GWd/t[91] with a middle figure of 45 GWd/t. With a 45

[85] *CHERNOBYL, Assessment of Radiological and Health Impacts*, 2002 Update of *Chernobyl: Ten Years On*, NUCLEAR ENERGY AGENCY, ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) 2002, s. 157, http://www.nea.fr/html/rp/reports/2003/nea3508-chernobyl.pdf
[86] Ibid. p. 33.
[87] *Consequences in Sweden of a serious nuclear accident, 11 Bilaga 2. SSI-PM. Intraeffede reaktorolyckor*, p. 6.
[88] In early 2002 the Russian nuclear physicist Konstantin Checherov of the Kurchatov Institute in Moscow and his German colleague Sebastian Pflugbeil, Director of the Society for Radiation Protection in Berlin, claimed in a documentary broadcast on German national television, that most of the fuel had been released into the environment, with only an insignificant amount remaining in the reactor itself.
[89] *CHERNOBYL TEN YEARS ON, RADIOLOGICAL AND HEALTH IMPACT*, An Assessment by the NEA Committee on Radiation Protection and Public Health, November 1995, p. 18 and 20, http://www.nea.fr/html/rp/chernobyl/chernobyl-1995.pdf
[90] WISE-Paris has estimated the release of caesium-137 to be up to a 100% (from 50 %) in case of an airplane crash, but was heavily criticized for this: “The potential for a zirconium “fire”, following a loss of water, arises from the packing of fuel pools to high densities [Thompson, 2000a]. A loss of water accident in the D cooling pond could lead, because of exothermic oxidation reactions of zirconium and other metals, to an accidental release up to 100% of the total caesium-137 contained in the 1,745 t of spent fuels stored [NRC, 2000]”, Schneider, M. (Dir.), POSSIBLE TOXIC EFFECTS FROM THE NUCLEAR REPROCESSING PLANTS AT SELLAFIELD AND CAP DE LA HAGUE, ANNEX 19, “Comparison of Caesium-137 Contained in Spent Fuels Stored at La Hague and Released During the Chernobyl Accident”, s. 118. WISE-Paris, Report commissionned by STOA, European Parliament, 2001, .http://www.wise-paris.org/english/reports/STOAFinalStudyEN.pdf
[91] **The GWd/t**, the unit measuring the spent fuel burn-up, is an indicator of the average quantity of energy produced by the fuel in the core. A higher burn-up does mean that the same amount of fuel, e.g. one assembly, can deliver more energy, which in practice allows for the reactor to produce its full power during a longer time with the same set of fuel. Like any measure of energy (e.g. the kWh consumed by electric appliances), the energy delivered by one unit of fuel

GWd/t burn-up of the fuel, the Barseback inventory of caesium-137 should be approximately 1,4 kg per ton of spent fuel, i.e. **a total of around 105 kg in the core, i.e. approximately 20 % more than in the Chernobyl reactor**.
The Chernobyl release of caesium-137 equals a release of 25 % of the caesium-137 inventory in Barsebaeck 2. A worst-case scenario of this kind a regards a release of caesium-137 is supported by 1995 Report from SKI and SSI. **Based on just the release of caesium-137, it recommends exclusion zones up to 50 years within 20, 60 or 100 kilometres from the release source, depending on the weather conditions**[92].
Consequently, just for caesium-137 a Chernobyl type accident rest risk release at Barseback 2 with a core fusion and loss of confining barrier and with the same or even a smaller fraction release of caesium-137 could therefore be at least comparable to Chernobyl and possibly even worse.

An uncertainty factor in this context is the fact that these are not “official” figures, such as the ones that would derive from a safety analysis of the Barsebaeck nuclear power plant (e.g. one that would say: In case of a core fusion etc., there can be a release of xx % of the inventory, etc.). Exact figures cannot be extracted from an outside reference.

A second uncertainty factor in this context is the fact that the Ukrainian Chernobyl reactor is a RBMK, very different from the Swedish design, which makes a comparison between the orders of magnitude of the cores inventories distributions, i.e. the quantities of fission products and actinides produced by the fission reactions of one ton of uranium, extremely difficult.

A third uncertainty factor is the pattern of the release scenario itself. It has to be considered that Barsebaeck 2’s equivalence in terms of quantities released with Chernobyl does not necessarily imply an exact equivalence in terms of fall-out in the surrounding areas. This depends on such factors as the heat of the release of the radioactive substances - hence the height of the releases - and the wind and weather conditions. – hence the distance that the radionuclides can cover before they "fall” on the ground. The 30 kilometres exclusion zone around the Chernobyl reactor is actually very small compared to the large distances covered by some of the most important radionuclides (like iodine-131, or caesium-137, that could be found on land as far as in the UK). Only the heaviest radionuclides (like the plutonium isotopes) mainly fell that close to the plant. Therefore, in the case of an accident with a large release of the same order as in Chernobyl, but to a smaller height above the plant, **a 30 kilometres exclusion zone around the Barsebaeck nuclear power plant (like the one in Chernobyl) could actually be more contaminated than the exclusion zone around the Chernobyl nuclear power plant**.

A fourth uncertainty factor is the quantities of spent fuel stored in the Barsebaeck nuclear power plant. According to Sweden’s first national report under the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management, *Sweden’s first national report under the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management, Swedish implementation of the obligations of the Joint*

(measured in tons of material) is obtained by multiplying a power (GW) by a length-time (day). A burn-up of 50 GWd/t means that, when discharged, each ton of spent fuel has produced, on average, during more than a thousand days of stay in the core (4 to 5 years), the equivalent energy of 50 GW for one single day.
[92] *Consequences in Sweden of a serious nuclear accident*, p. 31-32.

Convention, Ds 2003:20, 180 pages[93], each nuclear power plant in Sweden has a fuel pool, close to the reactor vessel, in which spent fuel is stored temporarily for at least nine months. Then it is being transported to Central Interim Storage for Spent Fuel (CLAB), situated at the Oskarshamn nuclear power plant, where it will be stored for at least another 30 years before being encapsulated and deposited in a repository. The fuel pools in the Swedish nuclear power plants constitute integrated parts of the reactor facilities, and are for the purpose of the Joint Convention not considered to be separate spent fuel management facilities. The pools also have space for the plundered reactor core, fresh fuel, scrap and boxes.

According to the Barsebaeck plant's own website[94], approximately a sixth of the fuel in the reactor, i.e. **15 tons**, is changed every year. The lifetime of the reactor fuel is approximately 5 years. The change takes place every summer when the reactor is briefly shut down for a so-called revision.

According to the above-mentioned report, Barsebaeck 2 has a fuel pool capacity of 644 fuel assembly positions. **An inventory status revealed that 405 spent fuel assemblies, totalling a weight of 72 tons, were stored in Barsebaeck 2 as of December 31st 2001**, this amount being surpassed only by Oskarshamn 1 (120 tons) and Ringhals 2 (84 tons), *see Table 13*.

Table 13: Spent nuclear fuel stored 2001-12-31 at Swedish nuclear power plants[95].

Fuel pool at NPP	**Fuel pool capacity (No of fuel assembly positions)**	**Spent nuclear fuel stored 2001-12-31**	
		No of assemblies	*Tons*
Barsebaeck 2	644	405	72
Oskarshamn 1	894	706	120
Oskarshamn 2	935	369	65
Oskarshamn 3	918	188	38
Forsmark 1	612	263	47
Forsmark 2	491	351	65
Forsmark 3	1 040	284	51
Ringhals 1	644	268	46
Ringhals 2	260	200	84
Ringhals 3	212	167	72
Ringhals 4	190	163	71

There is an overall consensus that the spent fuel is not less dangerous than the fuel in the reactor core and in some respects even more dangerous[96]. Since the concentration of caesium-137 builds up almost linearly with burn-up, there is on the average about twice as much of this substance in a ton of spent fuel as in a ton of fuel in the reactor core. *And furthermore:* Uranium fuelled commercial size nuclear reactor (1000 MW electrical effect) produces roughly 200 kg of

93 http://www.ski.se/dynamaster/file_archive/030423/3ac68b07a100a3ab0d4c74e968a02cba/SKI%5fK%e4rnavfallskonventionsrapport.pdf

94 http://www.barsebackkraft.se/index.asp?ItemID=1291

95 Table D.32.2.1 *Interim storage at the nuclear power plants*, p. 30. The figures from Forsmark 1,2 and 3 are from 2002-10-1.

96 An American study, Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson and Frank N. von Hippel, *Reducing the hazards from stored spent power-reactor fuel in the United States*, Jan 31, 2003 (http://www.inesap.org/pdf/supplement14.pdf - published in *Science & Global Security*), describes in detail the hazards of high-density storage of spent fuel in pools. The study points out that spent fuel recently discharged from a reactor could heat up relatively rapidly to temperatures at which the zircaloy fuel cladding could catch fire and the fuel's volatile fission products, including 30-year half-life 137Cs would be released.

plutonium per year. Initially, plutonium-239, the most important fissile isotope of plutonium with a half-life of 24.000 years, has been produced in a sizable quantity to fabricate weapons of mass destruction. Plutonium-239 is a well-known carcinogenic (cancer-causing) substance, but reactor grade plutonium, which consists of a combination of various isotopes of plutonium, is **eight to ten times more toxic by weight than pure plutonium-239. One gram of reactor grade plutonium oxide corresponds with the cumulated annual limit of inhalation for as many as 40 million people**[97]**.** Most of the radioactive substances in spent fuel degrade after some hundreds years, but some of the most dangerous substances will exist up to a 100.000 years[98].

If one equals the spent fuel to the reactor fuel at least 15 tons of fuel will have to be put into the equation as regards the release scenarios. This means that a release of 6,4 % of the fuel in Barsebaeck 2 would equal 3 % of the fuel in the Chernobyl reactor and that a release of 10,7 % would equal 5 % of the fuel in the Chernobyl reactor. A release between 6,4 % and 42,8 % of the fuel would equal or exceed the release from the Chernobyl reactor and any release higher than 42,8 % from Barsebaeck 2 would exceed the release from the Chernobyl reactor.

If the 72 tons of spent fuel from the December 2001 inventory status are thrown into the equation, the following result will emerge: A release of 4 % of the fuel in Barsebaeck 2 would equal 3 % of the fuel in the Chernobyl reactor and that a release of 6,6 % would equal 5 % of the fuel in the Chernobyl reactor. A release between 4 % and 26,6 % of the fuel would equal or exceed the release from the Chernobyl reactor and any release higher than 26,6 % from Barsebaeck 2 would exceed the release from the Chernobyl reactor.

In all circumstances and especially regarding the release of caesium-137 it is possible to draw the conclusion that the worst-case scenario for a serious accident in the Barsebaeck 2 reactor could be comparable to the Chernobyl disaster.

E. The lessons learned from Chernobyl in a Barsebaeck context

A quick glance at the research concerning Chernobyl shows that there is far from consensus in the scientific community on what conclusions to draw from the consequences of the disaster as regards health and environmental issues – not least because these consequences are far from over and still continue to develop in unpredictable ways. The scientific data, as well as all the other information, indicate that the problems will continue affecting people living in the contaminated areas for a long time to come, but considering that there are still conflicting opinions as to what extent and for how long, BBOFF has chosen mainly to use the least controversial source on what conclusions to draw from the accident **– the UN website**[99] www.chernobyl.info

The website gives the impression that the socio-economic consequences from the Chernobyl disaster for the two most affected countries, Chernobyl's home country, Ukraine, and its

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97 http://pub97.ezboard.com/fnuclearspacefrm25.showMessage?topicID=74.topic

98 According to the Swedish nuclear scientist Mats Törnqvist, it will take 4,5 billion years before the radiation from spent fuel degrades to the level of fresh nuclear fuel. Freshly made fuel has the level 83,6 GBq before it is put in the reactor and spent fuel the level 2.300 GBq after 100.000 years, http://www.skb.se/templates/Page.asp?id=2803 and http://www.skb.se/templates/Page.asp?id=2778

99 Behind the homepage are (*international partners)* the Swiss Agency for Development and Cooperation (SDC), the UN Office for the Coordination of Humanitarian Affairs (UN OCHA), OCHA International Cooperation on Chernobyl, United Nations Development Program (UNDP), (*regional partners*) the Ukraine Ministry of Emergencies and Affairs of Population Protection from the Consequences of the Chernobyl Catastrophe, the UNDP Country Office in Minsk, Belarus, the Ukraine Ministry of Emergencies and Affairs of Population Protection from the Consequences of the Chernobyl Catastrophe and the UNDP Country Office in Kiev, Ukraine.

neighbouring country, Belarus, are beyond discussion[100]. Striking is also the fact that **any new estimate of the consequences of the Chernobyl disaster seems to be more pessimistic than the previous**. It is evident when one deals with the Chernobyl problem complex that the short-term rescue preparedness measures that have been implemented in order to remedy the consequences of the disaster, in a long-term perspective become secondary compared with the enormous effect this disaster has on the foundations of society itself which it will take many generations to overcome to the extent that it is possible at all.

According to the UN website[101] international estimates suggest that a total of between 125 000 and 146 000 km2 in Belarus, Russia and Ukraine are contaminated with caesium-137 at levels exceeding 1 curie (Ci) or 3,7 x 1010 becquerel (Bq) per square kilometre. **That is an area 3 times larger than Denmark**. At the time of the accident, about 7 million people lived in the contaminated territories, including 3 million children. About 350.400 people were resettled or left these areas. However, about 5.5 million people, including more than a million children, continue to live in the contaminated zones. It is not contested that 31 workers died shortly after the disaster. About 800.000 people were involved in the sanitation work up to 1989. 300.000 are estimated to have received radiation doses totalling more than 0,5 Sv. The number of casualties remains controversial. According to figures issued by government agencies in the three former Soviet republics affected, about 25.000 of the 800.000 liquidators have so far died as a result of their exposure to radiation. According to the Liquidators' Committee, the total number of deaths is 100.000. There is a consensus that at least 1800 children and adolescents in the most severely contaminated areas of Belarus have contracted cancer of the thyroid because of the reactor disaster. It is feared that the number of thyroid cancer cases among people who were children and adolescents when the accident happened will reach 8000 in the coming decades. This figure is given in the report published by an expert delegation of the United Nations Development Programme (UNDP) and the United Nations Children's Fund (UNICEF) in January 2002. World Health Organization (WHO) projections, however, put the figure at 50.000. The German specialist in radiation medicine and Chernobyl expert, Professor Edmund Lengfelder of the Otto Hug Strahleninstitut in Munich, which has been running a thyroid centre in Belarus since 1991, warns of up to 100.000 additional cases of thyroid cancer in all age groups.

All people within a radius of 30 kilometres around the Chernobyl reactor - 130.000 men, women and children - were evacuated from their homes. The area has since been declared an **exclusion zone**, where no one is allowed to live. **An exclusion within a radius of 30 kilometres around the Barsebaeck nuclear power plant would in Sweden include Malmoe, Lund, Landskrona,**

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[100] Cf. http://www.chernobyl.info/en/Facts/Countries, http://www.chernobyl.info/en/Facts/Countries/SituationUkraine, http://www.chernobyl.info/files/doc/TabengKiew.pdf, http://www.chernobyl.info/files/doc/InterviewKiewEng.pdf, http://www.chernobyl.info/en/Facts/Countries/SituationBelarus, http://www.chernobyl.info/files/doc/TabE_Minsk.pdf, http://www.chernobyl.info/files/doc/InterMinskE.pdf and http://www.chernobyl.info/en/Facts/Countries/SituationRussia

[101] http://www.chernobyl.info/en/Facts/HealthLongterm/Overview, http://www.chernobyl.info/en/Facts/HealthLongterm/CancersInGeneral, http://www.chernobyl.info/en/Facts/HealthLongterm/Overview, http://www.chernobyl.info/en/Facts/HealthLongterm/ThyroidCancerChildrenAdolescents, http://www.chernobyl.info/en/Facts/HealthLongterm/LeukaemiaChildrenAdults, http://www.chernobyl.info/en/Facts/HealthLongterm/CancerInAdults, http://www.chernobyl.info/en/Facts/HealthLongterm/OtherDiseasesChildrenAdults, http://www.chernobyl.info/en/Facts/HealthLongterm/ComplicationsPregnancy, http://www.chernobyl.info/en/Facts/HealthLongterm/GeneticDefects and http://www.chernobyl.info/en/Facts/HealthLongterm/PsychologicalConsequences

Esloev, **Staffanstorp and at least twenty villages and in Denmark all of Amager, Copenhagen City, Frederiksberg, Vesterbro, Noerrebro, Oesterbro, Vanloese, Broenshoej, Valby, Vigerslev, Hvidovre, Avedoere Holme, Broendbyoester, Roedovre, Utterslev, Nordhavn, Bispebjerg, Hellerup, Husum, Moerkhoej, Gladsaxe, Soeborg, Buddinge, Bagsvaerd, Vangede, Gentofte, Charlottenlund, Skovshoved, Jaegersborg, Ordrup, Lyngby, Sorgenfri, Virum, Klampenborg, Taarbaek, Raadvad, Soelleroed, Holte, Gl. Holte, Oeveroed, Naerum, Troeroed, Skodsborg, Vedbaek, Sandbjerg, Isteroed, Ravnsbjerg, Hoesterkoeb, Braadebaek, Hoersholm, Usseroed, Valleroed, Rungsted and Kokkedal.** In this context it is worth noting that the 1995 report from SSI and SKI (see section II.C) has confirmed worst-case scenarios implicating exclusion zones of **20, 50, 60 and 100 kilometres** from the release source, depending on the weather conditions.

Consequently, it can be concluded that the concept of the 30 kilometres zone is conservative compared to some of the Swedish authorities' own scenarios. This exclusion zone is actually very small compared to the large distances covered by some of the most important radionuclides from the Chernobyl accident. Therefore, in the case of an accident with a large release of the same order as in Chernobyl, but to a smaller height above the plant, **a 30 kilometres exclusion zone around the Barsebaeck nuclear power plant could actually be more contaminated than the exclusion zone around the Chernobyl nuclear power plant**.

Just like the exclusion zone around the Chernobyl nuclear power plant is a historical fact, it is a fact that the three countries on which the disaster has inflicted the greatest losses – Ukraine, Belarus and Russia – have lost approximately 440 billion USD because of the accident - in Danish currency **2889 billion DKK**[102]. This cost is spread over time: It started on the day of the accident and amounts to that total now, but the concerned states are not done with it. The affected populations still suffer from the consequences, hence the cost is still there and it will go on for decades. An indication that the total financial loss is larger than the above-mentioned is also the fact that damages in other countries are not included. So far, this amount is **more than twice the total Danish GNP for 2002**[103].

On one hand the expenses originate from *direct losses* - the value of the proportion of the Republic's national reserves lost, dormant and operating value of farms, objects of social

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[102] The costs are divided the following way: **Ukraine:** According to information from the Ukrainian government agency Chernobyl Interinform, government spending on alleviating the effects of the accident has been **USD 6.5 billion since 1991**. Currently, **5-7 per cent of the national budget** is consumed by dealing with the consequences. **By 2015, Ukrainian experts estimate that the disaster will have cost the economy a total of USD 201 billion**, cf. http://www.chernobyl.info/en/Facts/Countries/SituationUkraine **Belarus:** The official Chernobyl Committee in Minsk, which is responsible for dealing with the consequences of the disaster, estimates the total damage for the Republic at **USD 235 billion.** This is equivalent to 32 times the total national budget, at the 1985 level. Currently 10 per cent of the budget is consumed by managing the consequences of Chernobyl, cf. http://www.chernobyl.info/en/Facts/Countries/SituationBelarus **Russia:** Costs incurred by the Russian state as a result of the nuclear disaster totalled about **USD 3.8 billion** between 1992 and 1998. Of this sum, USD 3 billion was paid in compensation to the helpers and victims, cf. http://www.chernobyl.info/en/Facts/Countries/SituationRussia

A series of other European countries also suffered economic losses but these losses are not included here. E.g. it could be mentioned that with respect to **Sweden** a report from 1995 - *Radioactive substances destroy agriculture in Skåne* - sums up the economic loss for the Swedish state because of the Chernobyl accident within the resort of the Department of Agriculture (Jordbruksverket) alone to **680 million SEK**. The expenditure primarily covers discarded reindeer meat, i.e. the meat value, slaughtering costs, loss of extra charges and costs for tests, control, caesium analysis and cold storage (including costs for dealing with the meat during waiting until the result of the analysis. In the budget year 1986/87 expenditure was 321 million SEK, 1987/88 68 million SEK, 1988/89 54 million SEK, 1989/90 42 million SEK, 1990/91 70 million SEK, 1991/92 55 million, 1992/93 38 million SEK and 1993/94 30 million SEK.

[103] The GNP for Denmark 2002, main account (prices of the year, million DKK) after account and time: **1.365.214**, http://www.statistikbanken.dk/statbank5a/default.asp?w=800

infrastructure, housing and natural resources – and on the other hand they come from *indirect losses*: Losses through economic and social factors (general and living conditions, population's health) that affect or halted production; reduced productivity, raised costs and the complexity of supplying other objects of government, cooperative or private property; and losses caused by the migration of the population out of the affected areas. Additional costs are spending to deal with the consequences of the disaster and to achieve normal functioning of various branches of the economy in the contaminated territories, including the creation of danger-free conditions for the population to live and work. They also include expenditure to compensate for the consequences of negative factors, value of additional resources necessary to compensate for losses and loss of profit, expenditure on decontamination work and organising the monitoring of the radioactive situation.

Contrary to the Chernobyl nuclear power plant that is situated in a thinly populated agricultural area, the Barsebaeck nuclear power plant is situated in the most densely populated area in Scandinavia, less than 30 kilometres from the largest city in Denmark and the third largest city in Sweden. According to the Danish Statistical Agency 661.034 people lived in the Danish capital (Copenhagen, Frederiksberg and Gentofte) 2003. **Therefore it is likely that far more than the 350.000 people who were evacuated or resettled after the Chernobyl disaster would have to be evacuated or resettled in Denmark in case of the worst possible accident in the Barsebaeck nuclear power plant. It is also likely that the Danish economic losses would be much higher than the 2889 billion DKK the Chernobyl disaster so far has cost the three former Soviet republics. The metropolitan area is the economically most productive area in Denmark. 2001 the GNP per capita in Copenhagen and Frederiksberg was 397.000 DKK compared with an average for the whole country of 247.000 DKK per capita, i.e. almost 16 times higher than the year 2000 GNP per capita in Ukraine and 8 times higher than the year 2000 GNP per capita in Belarus**[104].

It is worth noting that the above-mentioned assessments of the losses due to the worst possible accident at the Barsebaeck nuclear power plant are **moderate compared to American estimates of the economic consequences of a serious accident in a US nuclear power plant**. These assessments estimate that damages could be **between approximately 40% and 180%** more than what have been registered following the Chernobyl disaster.
In the wake of the 1979 Three Mile Island accident, the government-owned/contractor operated (GOCO) facility **Sandia National Laboratory** (www.sandia.gov) prepared a report on behalf of the NRC - *Calculation of Reactor Accident Consequences (CRAC-2) for U.S. Nuclear Power Plants (Health Effects and Costs)* (Washington, DC: Nuclear Regulatory Commission, 1982). This 1982 study estimated that damages from a severe nuclear accident could run as high as 314 billion USD – or more than 590,4 billion in 2000 USD, i.e. **approximately 4014 billion DKK**. Since that study, the NRC has developed "more realistic" modelling improvements to the agency's *probabilistic risk assessment*. A review of their 1982 study "**found that property damages would be twice as much as those calculated in 1982, solely on the basis of the modelling improvements made**[105]".

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[104] About the GNP per capita in Copenhagen, Frederiksberg and the whole country, see http://www.statistikbanken.dk/statbank5a/default.asp?w=800 and http://www.statistikbanken.dk/statbank5a/default.asp?w=800 About the GNP per capita in Ukraine and Belarus, see http://www.leksikon.org/art.php?n=3064&t=257 and http://www.leksikon.org/art.php?n=2916&t=257

[105] Keith O. Fultz, *A Perspective on Liability Protection for a Nuclear Plant Accident,* Government Accounting Office, GAO/RCED87-124, June 1987, s. 40, http://www.citizen.org/documents/Anderson-wenonah.PDF, http://www.texas.sierraclub.org/rad_waste/nuke_subsidies.html and http://www.safeenergy.org/PriceAndersonFactSheet.pdf

The so far highest economic loss assessments were published in 1989 by the *German Reactor Safety Organisation* (GRS)[106] for the worst possible accident at a German nuclear power station and confirmed by the German *Federal Ministry for the Environment, Nature Conservation and Nuclear Safety* (BMU) in 1999. **GRS and BMU estimate that the financial losses are approximately 14 times higher than the figures currently known with respect to the Chernobyl disaster** (*cf. Table 14*). **This assessment is probably the one most suitable as a model for describing the financial consequences of the worst possible accident at the Barsebaeck nuclear power plant, the population concentrations and the economic activity level near the plant taken into consideration**.

Table 14: Estimates of financial losses originating from Chernobyl and the worst possible accidents at nuclear power stations in USA and Germany (billion DKK).

Country	Accident location	Year	Sources	Loss estimate billion DKK
Ukraine, Belarus, Russia	Chernobyl	1986-2001	Government declarations from Ukraine[107], Belarus[108] and Russia[109]	2889
USA	US nuclear power station	1982	NRC, Sandia National Laboratory	4014
USA	US nuclear power station	1987	NRC, Government Accounting Office	8000
Germany	Gerrman nuclear power station	1989 and 1999	Gesellschaft für Reaktorsicherheit[110], Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit[111]	40790

As regards the **civil liabilities** connected with a serious accident in a nuclear power plant that concerns an international third party, there are two levels of liability: **For the operator and for the state**. According to the *Annex to Sweden's second national report under the Convention on Nuclear Safety, Ds 2001:41*[112], the national legislation in Sweden, which implements the obligations under

[106] For further information on GRS, see note 8.

[107] *Official statement by the Ministry of Emergencies of the Ukraine on important issues concerning the nuclear accident at Chernobyl*, cf. http://www.chernobyl.info/files/doc/InterviewKiewEng.pdf

[108] *Official statement by the Chernobyl Committee of the Republic of Belarus on important issues concerning the nuclear accident at Chernobyl*, cf. http://www.chernobyl.info/files/doc/InterMinskE.pdf

[109] *Ministry of the Russian Federation for Civil Defense Affairs, Emergencies and Elimination of Consequences of Natural Disasters (EMERCOM of Russia): Chernobyl Accident, Results and Problems in Eliminating the Consequences in Russia 1986 - 2001*, Moscow, 2001, p. 3, http://www.chernobyl.info/en/Facts/Countries/SituationRussia

[110] Gesellschaft für Reaktorsicherheit (GRS), *Deutsche Risikostudie Kernkraftwerke Phase B*, Köln Juni 1989 and Deutsche Sektion der Internationalen Ärzte für die Verhütung des Atomkrieges/Ärzte in sozialer Verantwortung e.V. (IPPNW), *Gesundheitsschutz und Risikovorsorge, Verfassung und Atomgesetz zwingen zur Stilllegung der deutschen Atomkraftwerke*, 2. überarbeitete Auflage, November 2001, p. 3 and 4, http://www.atom-recht.de/IPPNW-Atomrechts-Studie.rtf

[111] BMU 1999: *Untersuchungen der Rahmenbedingungen des nationalen und internationalen Rechts für die Energiekonsensgespräche*, Bonn, 12. Aug. 1999. Geschäftszeichen: RS I 1 - 40105/1.3 and IPPNW, *Gesundheitsschutz und Risikovorsorge*, p. 6.

[112] http://www.ski.se/extra/tools/parser/index.cgi?url=/html/parse/index.html&selected=5&mainurl=/extra/document/%3Fmodule_instance=1%26action_show_category.1.%3D1

the Paris Convention and the Brussels Supplementary Convention[113] on the **practical provisions for insurance of nuclear power plants**, is the Act on Nuclear Liability. This Act provides that the operator of a nuclear installation, which is the source of a nuclear incident, is liable to provide compensation to those who have suffered personal injury or damage to property as a result. The liability of the operator is strict and exclusive. The liability amount has been raised progressively since the Act was first passed in 1968. The current limit, which came into effect on April 1st 2001, is 300 million Special Drawing Rights (SDR) which correspond to approximately **2,67 billion DKK** (3,3 billion SEK).

The Act provides for compensation over and above that available under the terms of the Paris Convention and the Brussels Supplementary Convention. If there is a nuclear incident for which the operator of a nuclear installation located in Sweden is liable, and the amounts available under the two Conventions are insufficient to allow compensation in full, the state will compensate the victims from a maximum sum of **4,86 billion DKK** (6 billion SEK) per incident. This extra tier of compensation is available only in relation to nuclear damage suffered in **Sweden, Denmark, Finland, Norway**, or in the territory of **any other Party to the Brussels Supplementary Convention** (and only to the extent that this Party provides similar additional compensation for damage suffered in Sweden).

Recently, **the European Commission** has given the green light for **extending international cover for nuclear risks**[114]. The Protocol to the Paris Convention therefore extends the concept of nuclear damage to **cover damage to the environment, non-material damage and the cost of safeguard measures**. The amount of liability that a nuclear operator must bear will be increased from 15 million special issue rights (approximately 21 million EUR on 1 January 2002) to a minimum of **5,2 billion DKK** (700 million EUR). Operators will be required to be insured or have a financial guarantee equivalent to this amount. At the same time, the amounts of supplementary compensation provided for in the Brussels Convention will be increased up to a compensation ceiling of **11,1 billion DKK** (1.500 million EUR).

Like the Paris Convention the Swedish Nuclear Liability Act provides that the operator of a nuclear installation is liable to pay damage even if there has been no fault or negligence on his part. **However, the operator is not liable for nuclear damage caused by a nuclear incident directly due to an act of war, armed conflict, civil war or insurrection or caused by a grave natural disaster of an exceptional character**[115]. This would probably mean that **the operator of Barsebaeck 2 would not be liable for nuclear damage in Denmark caused by a terrorist attack on the plant**. If the operator is not liable for nuclear damage in Denmark, **neither is the Swedish state**[116].

Just as striking as the fact that neither the operator of the Barsebaeck nuclear power plant, nor the Swedish state are liable for nuclear damage deriving from a terrorist attack on the plant, is the fact **that nuclear damage in Denmark corresponding with the Chernobyl scenario will practically**

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[113] The most important international treaty on liability and nuclear power that has been ratified by Sweden and Denmark is the *Convention on Third Party Liability in the Field of Nuclear Energy* a.k.a. **The Paris Convention** that was adopted in Paris July 29th 1960, amended January 28th 1964 and entered into force April 1st 1968, http://www.nuclearfiles.org/redocuments/1960/600729-liability.html

The Paris Convention was amended by the *Convention Supplementary to the Paris Convention on Third Party Liability in the Field of Nuclear Energy* (as amended) that was adopted in Brussels January 31st 1963, January 28th 1964 and November 16th 1982, http://www.nuclearfiles.org/redocuments/1963/630131-liability-suppl.html

[114] **IP/03/1000,** Brussels, 11 July 2003, *Nuclear energy: the Commission approves the strengthening of international cover for nuclear risk*, http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/03/1000|0|RAPID&lg=EN&display

[115] Swedish Nuclear Liability Act, Section 11, Subsection a and b, http://www.nea.fr/html/law/nlb/NLB-02-SUP.pdf

[116] Ibid. Section 28, Subsection a. However, claims for compensation can be brought against the individuals who have caused the damage, i.e. the terrorists, Section 14, paragraph b.

not be compensated. Although the owners of Barsebaeck are the Swedish state itself, the largest energy company in Sweden (Vattenfall AB), the largest energy company in Southern Sweden (Sydkraft AB) that for its part is owned by the world's largest private energy company (E.ON.) and the Norwegian state, nuclear damage in Denmark as described above will only be compensated in the order of a quarter of a per cent (a calculated 0,26 %) under the current Swedish legislation, presupposing that there are no claims in Sweden. If the new Protocol from the European Commission is adopted in Sweden, the compensation will go up to approximately half a per cent (a calculated 0,56 %), again presupposing that there are no claims in Sweden.

The compensation provided for in the Swedish Act on Nuclear Liability is only 12% of the compensation that the victims of a serious accident in a US nuclear power plant are entitled to get according to the so-called Price-Anderson Act[117]. If the new Protocol of the European Commission is implemented in Sweden this figure will rise to 26%.

III. Reasonable alternatives to Barsebaeck's electricity production

Pursuant to Article 5 (1) in the EIA-Directive," where an environmental assessment is required under Article 3(1), an environmental report shall be prepared in which the likely significant effects on the environment of implementing the plan or programme, and **reasonable alternatives taking into account the objectives and the geographical scope of the plan or programme, are**

[117] **The Price-Anderson Act** (Section 170 of the Atomic Energy Act of 1954, 42 U.S.C. 2210 as reauthorized in the Energy Policy Act of 2003 - H.R. 2983) provides indemnity protection to the US nuclear industry in the case of a nuclear accident and establishes a no-fault insurance regime for compensation of public damages. Originally intended as a short-term measure to spur nuclear investment, the Act has been in effect for forty-six years and has undergone several modifications. The Act provides two levels of financial protection: *primary* and *secondary*. The **primary level of protection** under the Act requires that all reactor operators carry approximately **1,36 billion DKK** (200 million USD) in liability insurance per reactor. This primary insurance limit was last raised with the1988 Amendments to the Act and has not been increased to account for inflation since that time. Primary insurance is provided by the American Nuclear Insurers (ANI) a joint underwriting association of insurance companies. The Act also requires nuclear operators to participate in a **secondary retrospective assessment program** to meet public damages above the 200 million USD primary insurance limit. Any damages above a reactor's 200 million USD primary insurance coverage are to be assessed equally against all operating reactors, up to a current limit of approximately **570 million DKK** (83,9 million USD), per accident (a 5% surcharge may also be imposed to pay legal costs). These assessments, called "retrospective premiums," would be paid out at a rate of approximately 68 million DKK (10 million USD) per reactor, per year, until the cap is met. Retrospective premiums are adjusted for inflation every five years. The Act currently covers 106 reactors (103 of which are currently operating). As a result, the Price-Anderson Act would provide approximately **62 billion DKK** (9,09 billion USD) in compensation in the event of a nuclear accident. Payment of any damages above this combined primary and secondary cap would require congressional action. Under the Act, only reactor owners and operators are liable for damages in the event of an accident; companies that designed reactors or provided reactor parts or construction services are exempt from liability under the Act.
As in the case of the Ringhals Company Group and the Swedish state as regards Barsebaeck, it is generally considered unlikely that the Price-Anderson Act would provide adequate public compensation in the event of a major accident at an American nuclear reactor, http://www.texas.sierraclub.org/rad_waste/nuke_subsidies.html, http://www.house.gov/commerce_democrats/press/energybillsummary.htm and http://www.safeenergy.org/PriceAndersonFactSheet.pdf

identified, described and evaluated (BBOFF's accentuation). The information to be given for this purpose is referred to in Annex I[118]".
This provision is similar to Article 5 (a) in the Espoo-Convention that stipulates a transboundary consultation process concerning " possible alternatives to the proposed activity, **including the no-action alternative** (BBOFF's accentuation)".

The objective of the Barsebaeck nuclear power plant is to produce electricity. 2000-2003 Barsebaeck 2's electricity output was **2,2 - 4,4 TW/h per annum**, covering up to 30% of the electricity consumption in Southern Sweden. However, the electricity production at the plant has been decreasing because of a growing number of extraordinary suspensions of operation. In 2002 the output was 3,9 TW/h, which represents a decrease compared to 2000 where the total was approximately 2,9 TW/h[119]. In 2003 the accessibility was less than 45,4 % - the lowest that year for any nuclear reactor in Sweden – and the output was only 2,2 TW/h. **In 2000 and 2003 Barsebaeck 2 had the lowest output of the 11 Swedish nuclear reactors, in 2001 and 2002 the next lowest (but in 2002 the lowest among the reactors in operation)**[120]. According to the plant's managing director, Leif Öst, the production target of 2004 is 4 TW/h[121]. Barsebaeck 2 had its so far best year in 1991, where production was 4,6 TW/h[122].
In 2003 Barsebaeck 2's electricity output was 1,7**%** of the total Swedish electricity production, in 2000 2%, in 2001 2,8% and in 2002 2,7% (*cf. Table 15*).

Table 15: Electricity production in Sweden and at the Barsebaeck nuclear power plant 2000-2003 (TW/h) and Barsebaeck 2's share of the total Swedish electricity production[123].

	2000	**2001**	**2002**	**2003**
Electricity production Sweden	141,9	157,7	143,3	132,5
Electricity production Barsebaeck 2	2,9	4,4	3,9	2,2
Barsebaeck 2's share of the total Swedish electricity production	2%	2,8%	2,7%	1,7%

The question in this context is, whether Barsebaeck could be replaced by other electricity sources that are not connected with the risk factors described in section I in this position paper or the potential consequence scenarios described in section II or by other measures that render Barsebaeck 2's electricity output superfluous.

That replacement for Barsebaeck's electricity output can be found or that this output can be rendered superfluous is a vital part of the political basis for the decommissioning of the plant as it is formulated in a March 2003 agreement between the Social Democrats, the Centre Party and the Leftist Party. According to this agreement **the question of decommissioning of Barsebaeck 2**

[118] The issues dealt with in Annex I (b), are "the relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme".
[119] Cf. Svensk Energi, *Elåret 2003*, p. 16, http://www.svenskenergi.se/energifakta/elaret_03/el%E5ret_2003.pdf and *Annual Report 20002, The Ringhals Group*, p. 19, http://www.barsebackkraft.se/files/Ringhals%20Eng%20slutversion_1.pdf
[120] Ibid. p. 16.
[121] *Barsebäcks kärnkraftverk är i full gång igen*, Sydsvenskan, 14. December 2003.
[122] Press release Barsebaeck Kraft AB 2004-5-24, *Barsebäck 2 i drift efter snabbt bränslebyte*.
[123] *Elåret 2003*, p. 16 and 21.

should be dealt with in the negotiations with the nuclear industry on the decommissioning of the other reactors and the energy policy in its entirety and if a negotiation solution on the decommissioning of Barsebaeck 2 cannot be reached, “the government has an ambition of closing down the reactor with authorization from the Act on Nuclear Decommissioning (from 1997) after sufficient measures have been implemented”[124]. The measures presuppose that a decommissioning of Barsebaeck 2 **does not have a negative effect on the effect balance, the price of electricity, the industry’s access to electricity and the climate and the environment**. The parties behind the energy agreement estimated March 2003 that the preparations for a decommission of Barsebaeck 2 would not be completed before end of April 2004.

However, critics of the agreement, among them *Folkkampanjen mot Kärnkraft-Kärnvapen* (the Swedish Anti-Nuclear Movement), have pointed out that **these conditions have been met a long time ago**[125]. In connection with **the effect balance**: When the 1997 law was passed the effect reserve of the Scandinavian market was 24 GW. In Northern Europe the effect surplus was 95 GW, i.e. 10 times the whole Swedish nuclear program. Since 1997 the Swedish state has accepted that the Swedish energy companies have shut down reserve power totalling net 1200 MW – just as much as the two Barsebaeck reactors together. Furthermore, the 5 oldest reactors were inactive autumn/winter 92/93 without causing a lack of effect. During one cold autumn week 1993 7 out of 12 reactors were unexpectedly closed down without any consequences for the electricity consumers. In connection with **the price of electricity**: A decommissioning of Barsebaeck 2 only affects the price of electricity with a few oerer/kWh or less than an oere. With respect to **the industry’s access to electricity**: The Swedish industry’s access to electricity is reduced when the electricity is used for heating up private houses. Since 1997 approximately 150.000 electrical heating pumps have been installed in Sweden – in cold weather an increase of the strain on the effect balance of 1200 MW. Electrical heating comprises mainly of electricity from nuclear power, more than 40 TW/h/year. As regards **the climate and the environment**: The climate and the environment are improved if nuclear power is abolished together with electrical heating. Any decrease of consumption of electricity has a positive effect on the environment.

Similar to the FMKK, **the Danish Energy Authority**[126] estimated in 2001, that a shutdown of Barsebaeck 2 would not in itself ”threaten the supply at the Nordic electricity market as such[127]”.
The Danish Energy Authority estimated, that approximately **2500 MW** conventional fossil fuelled productive capacity (i.e. double the FMKK estimate) had been closed down in Sweden in recent years, of which most ”had been put in mothballs”, i.e. that the installations had been taken out of

[124] Press release from Naeringsdepartementet 18 March 2002, http://www.regeringen.se/galactica/service=irnews/owner=sys/action=obj_show?c_obj_id=49909 and http://www.naring.regeringen.se/fragor/energi/energiprop2003/fragor_svar.htm

[125] Jorma Kahanpää**,** *Remissvar Barsebaeck-2.N2002/10308/ESB, N2002/10323/ESB* (http://www.folkkampanjen.se/dok1/jk20030108.pdf)

[126] **The Danish Energy Authority** was established in 1976, and as of 27 November 2001 is an Authority under *the Ministry of Economic and Business Affairs*. The Danish Energy Authority carries out tasks, nationally and internationally, in relation to the production, supply and consumption of energy. This means that the Authority is responsible for the whole chain of tasks linked to the production of energy and its transportation through pipelines to the stage, where oil, natural gas, heat, electricity, etc. are utilized for energy services by the consumer. By establishing the correct framework and instruments in the field of energy, it is the task of the Danish Energy Authority to ensure security of supply and the responsible development of energy in Denmark from the perspectives of the economy, the environment and security. It is the task of the Danish Energy Authority to advise the minister, to assist other authorities, to administer Danish energy legislation and to conduct analyses and assessments of the development in the field of energy, nationally and internationally, cf. http://www.ens.dk/sw1220.asp

[127] *Miljø- og energiministerens besvarelse af spørgsmål nr. 152 stillet af Folketingets Miljø- og Planlægningsudvalg (Alm. del - bilag 567) d. 5/2 2001,* http://www.folketinget.dk/Samling/20001/udvbilag/MPU/Almdel_bilag712.htm

operation but not scrapped. Hence, they could be put back in operation in weeks or a few months. The Danish Energy Authority established that ”10 Danish units totalling approximately 2250 MW – mainly fossil fuelled – have been scrapped 1998-2000. Of these approximately 900 MW have been scrapped physically or are in the process of been scrapped physically. The rest ”have been put in mothballs”. Two additional installations totalling a productive capacity of 400 MW are shut down because of the putting into operation unit 2 of the Avedoere power plant in autumn 2001. Finally, two units at the Amager power plant whose environmental permits expire in 2004 have to be mentioned. **In round figures 5000 MW conventional productive capacity have been closed down in recent years in Sweden and Denmark by market mechanisms** (BBOFF's accentuation)”.
Particularly the basis of the Swedish government's decision with respect to the assessment of **the effect balance** that is based on independent consultants' reports is criticised by the Danish Energy Authority: ”It should also be mentioned that the Swedish Energy Agency estimates the installed effect of the hydroelectric power to be 16 200 MW, **i.e. approximately 2000 MW more hydroelectric power than (…) estimated in the consultants' reports** (BBOFF's accentuation). The consultants' assessments are based on surveys from Svenska Kraftnät that correct for hydrological conditions and local grid limitations. Furthermore, the existence of approximately **1300 MW in the form of gas turbines in the system, mainly located in Middle and Southern Sweden, should be mentioned** (BBOFF's accentuation). Those are normally not considered a part of the Swedish effect balance because they are used as an “emergency reserve”. Apart from that about **500 MW gas turbines were recently taken out of operation** (BBOFF's accentuation). Finally, approximately 2,3 TW/h electricity is used in large heating pumps as of today. **This consumption might be eliminated and the spare capacity considered an effect reserve (in the order of 500 MW)** (BBOFF's accentuation)”[128].

In 2000 the Danish authorities' reservations about the basis for the Swedish government's decision were shared by a report from **the Swedish Energy Agency**[129]. The Swedish government had asked the agency to examine if it was possible to reorient the Swedish energy system in such a way that 3 extra TW/h could be produced per year as compensation for Barsebaeck 2. **The agency reported to the Swedish government that there was nothing to prevent a decommissioning of Barsebaeck 2**. However, the shutdown of the reactor and the general reorientation of the Swedish energy system were a central prerequisite if Sweden were to reach its environmental goals. The Swedish Energy Agency also pointed out that the electricity supply should not necessarily be a exclusive national matter because cross-border trade should be as natural as inland trade. Inevitably, new power stations would be built where it was most profitable. Their location would not be determined by political demands for self-sufficiency. The market mechanisms press the prices down and the electricity markets are de-monopolized and merging. For this reason alone the Swedish Energy

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[128] *Redegørelse om den svenske regerings skrivelse af 28. september 2000 vedrørende den fortsatte omstilling af Sveriges energisystemer*, http://www.folketinget.dk/Samling/20001/udvbilag/MPU/Almdel_bilag712.htm

[129] **The Swedish Energy Agency**, which was formed in 1998, works towards transforming the Swedish energy system into an ecological and economically sustainable system through guiding state capital towards the area of energy. This is done in collaboration with trade and industry, energy companies, municipalities and the research community. The Swedish Energy Agency has a traditional council authority. Its directors are selected by the Swedish government, cf. http://www.stem.se/WEB/STEMEx01Eng.nsf/PageGenerator01?OpenAgent&MenuSelect=7164E78CC77169B8C1256DE500361A83&WT=About%20us and http://www.stem.se/WEB/STEMEx01Eng.nsf/PageGenerator01?OpenAgent&MenuSelect=E52EB1256CF22285C1256E4E0046EA7B&WT=About%20us.Our%20organisation

Agency concluded that the preconditions for the energy reorientation program that were introduced in 1997 were met, particularly in light of the increasing importance of the climate issue[130].

Another indication that Barsebaeck 2 could be taken off the grid in the short term is the fact that the Swedish electricity consumption decreased 3,4 TW/h from 2002 to 2003[131], corresponding with more than 150% of the electricity output at the Barsebaeck nuclear power plant in 2003.

Recently, surveys made by the Swedish authorities have established that the electricity output of the Barsebaeck nuclear power station can be dispensed with. As mentioned above, the Swedish Parliament laid down various guidelines for the energy policy in Sweden in spring 1997. Among other things, this implied that the energy supply should be reoriented by virtue of a more efficient energy exploitation and en energy system based on long-term and primarily domestic and renewable energy sources. Apart from the energy policy guidelines for the whole country, measures were adopted in order to develop electricity and heating supply in Southern Sweden, more specifically the country's most southern municipalities. The Swedish Parliament earmarked 400 million SEK for these measures. In order to achieve its goal the government set up a commission in June 1997 - *Delegationen for energiförsöjning i Sydsverige (DESS)*[132]. DESS, an authority under the Ministry of Industry, formally stopped its activities December 31st 2002. **Among other things the commission's work was supposed to constitute the basis of possible measures regarding a decision on the decommissioning of Barsebaeck 2**[133].
In its final report - *Slutrapport för DESS verksamhet 1997-2002*[134] - the commission drew an optimistic picture of the energy situation in Southern Sweden and established that – even if the Barsebaeck nuclear power plant was shut down – there would be good possibilities to increase the electric and heating production in the region.

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[130] *Energimyndigheten vill stänga Barsebäck 2* (ERA 000807), http://www.era.se/nyh/nyh00/0807bar.html, Ingeniøren, *Barsebäck 2 bliver overflødig*, http://cph.ing.dk/arkiv/3200/barseb.html and Ingeniøren, *Ingen strømmangel i Sverige*, http://cph.ing.dk/arkiv/2499/barseb2.html

[131] According to *Elåret 2003*, p. 11, consumption fell from 149,5 TW/h in 2002 to 146,1 TW/h in 2003.

[132] The commission comprised 12 representatives from industry, research communities and politics and had to its disposition a secretariat with four employees. DESS was assigned three main tasks: (1) To examine the energy situation in Southern Sweden, (2) to make decisions in the energy field and (3) to take its own initiatives in the energy sector. The commission was in a position to support research as well as education, information, projects, surveys, planning and investments. Measures aiming at energy consumption reduction were considered just as important as measures aiming at energy production increase. The chairman of the commission was Göte Bernhardsson, county mayor of Västra Götaland's county. The other members were Uno Aldegren (s), Helsingborg, the chairman of the region council, Björn Anderberg (m), Helsingborg, architect, Helene Andersson (c), Varberg, bank official, Carl Bennet, Göteborg, managing director of Elanders AB, Marie Granlund (s), Malmö, member of the Swedish Parliamant, Gunilla Jönson, Mölnlycke, rector of Lund's Technical University, Birgitta Palmberger, Stockholm, head of department in the Swedish Energy Agency, Roland Palmqvist (s), Kävlinge, chairman of the municipality council, Kerstin Paulsson, Lund, Netsoft Lund AB, Sören Romberg, Ronneby, economist and Lennart Värmby (v), Växjö, ombudsman. Cf. *En uthållig energiförsörjning*, Regeringens proposition 1996/97:84, http://rixlex.riksdagen.se/htbin/thw?%24%7BHTML%7D=PROP_LST&%24%7BOOHTML%7D=PROP_DOK&%24%7BSNHTML%7D=PROP_ERR&%24%7BMAXPAGE%7D=26&%24%7BCCL%7D=define+reverse&%24%7BTRIPSHOW%7D=format%3DTHW&%24%7BBASE%7D=PROPARKIV9697&%24%7BFREETEXT%7D=&PRUB=&DOK=&PNR=84&ORG=, DESS slutrapporten p. 3 and *Förordning (1998:62) med instruktion för Delegationen för energiförsörjning i Sydsverige*, http://rixlex.riksdagen.se/htbin/thw?%24%7BOOHTML%7D=SFST_DOK&%24%7BSNHTML%7D=SFSR_ERR&%24%7BBASE%7D=SFST&BET=1998%3A62&%24%7BTRIPSHOW%7D=format%3DTHW

[133] Cf. http://www.dess.nu/om.htm

[134] http://www.sparkraft.nu/infobase/infobasedl.asp?filerefid=5454&meid=12600

The report demonstrates a potential for making the regional industry more efficient corresponding with **1,9 TW/h per annum**. In a study of the electricity consumption at 11 companies in Oskarshamn, carried out by energy researchers from Linkoeping University and the South Eastern Energy Office but financed by DESS, it was established that the companies with a reasonable effort could **cut their electricity consumption in half and reduce their total energy consumption approximately 40%**. This stipulation was confirmed by an analysis of more than hundred industries and real estates carried out by DESS and the regional energy offices[135]. The report also establishes that it is possible to produce electricity at combined power and heating stations already in existence. If the boiler installations are rebuilt there is a productive potential of **0,6–1,3 TW/h electricity per annum**.

Building wind parks is expected to contribute additionally about **1,5 TW/h per annum** [136]. The result of an energy conservation campaign titled "*switch off the electricity*" was estimated to constitute **0,5 TW/h pro year**[137].

Together these measures makes up for as a minimum the production target for the Barsebaeck nuclear plant for 2004 and lie 50-100% above the plant's electricity output in recent years.

There is yet another indication that Barsebaeck's electricity can be dispensed with: In a report by Svensk Fjärrvärme AB, *Fjärrvärme och kraftvärme i framtiden*[138], from February 2004, it is established that the electricity output of the Swedish combined power and heating stations is expected to increase from approximately 5 TW/h today to **11 TW/h** in the year 2010. This increase corresponds with 5% of the total Swedish electricity production. With the expected development of district heating from 50 TW/h today to 60 TW/h in 2010, combined district heating and electric power generation could increase to approximately 27 TW/h electricity output or with a larger gas contribution to 41 TW/h. **The high numbers comprise one third of the present Swedish hydroelectric and nuclear power production**[139].

The expected increase in district heating up to the year 2010 is estimated to reduce the Swedish releases of carbon dioxide about 3 million tonnes, **equalling the Swedish Parliament's climate target for all of Sweden**. Furthermore, the discharges from the carbon fuelled power stations outside Sweden will decrease with additionally 2 million tonnes through reduction of electric heating due to growth in district heating.

To this could be added that new combined heat and electric power generation replaces carbon fuelled electric power generation in the European electricity system. Thus, the expected

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[135] Cf. *"Enorm potential för elsparande i industrin"*, 11/9 2002-9-11, http://www.sparkraft.nu

[136] *"Det framtida energiläget för södra Sverige ser bra ut"*, http://www.sparkraft.nu/index.asp

[137] The objective of the campaign "*switch off the electricity*" was an attempt to make the Southern Swedes to alter their behaviour with respect to energy consumption by virtue of many small and simple energy conservation advices. An examination of the effects of campaign shows that approximately half of everybody between 15 and 60 years of age has manifested some form of energy conserving behaviour. Because of these good results, it is suggested in DESS's final report that the campaign is extended to all of Sweden. Furthermore, DESS have granted 97 million SEK in investment support to 33 projects, which have resulted in energy production and energy conservation totalling **0,48 TW/h per year**. About 40 research and development projects have received a support of approximately 220 million SEK, cf. *"Det framtida energiläget för södra Sverige ser bra ut"*.

[138] http://www.fjarrvarme.org/download/1589/kraftvärme.pdf

[139] Cf. the report's p. 5. The basis of the reports and the forecasts is mainly contributions from all the trade association *Svensk Fjärrvärme's* member companies, where they themselves evaluate how much district heating they expect to sell in 2010 based on the conditions known in 2003 as regards market, taxes, tax proposals, etc. The forecasts for combined district heating and electric power generation presuppose total investments in the years 2002-2010 of approximately 42 billion SEK, i.e. 5,3 billion SEK per year. It is also expected that the exploitation of firewood, natural gas and waste energy will increase up to.

development of combined heat and electric power generation contributes with an additional **5 million tonnes** reduction of carbon dioxide discharges up to the year 2010. **Altogether the European discharges of carbon dioxide will be reduced 10 million tonnes according to this prediction – i.e. 4 times the Swedish climate targets**[140].

IV. Conclusion

Above, we have briefly tried to analyze some of the various subjects that in our opinion should be a part of an environmental impact assessment of the Barsebaeck nuclear power plant. Apart from that, they should in our opinion influence the decision on whether the plant should have its environmental permit renewed.

As regards an evaluation of the **risk scenarios** that could lead to a serious accident at the plant, it can be established that with respect to the physical protection against **a terrorist attack in the form of an airplane crash** both the plant management and the nuclear regulatory authorities are in an impossible position as regard the implementation of precautionary measures in order to enhance the security level. This is because the options concerning the protection against crashes from small, middle-sized or large passenger aircrafts are limited. Although some details probably could be improved the total risk would not be reduced. The only way to ensure that the Barsebaeck nuclear plant cannot be threatened by deliberate or accidental airplane crashes is to **decommission the plant**. This conclusion has been reached in Germany where the president of the German radiation protection agency has recommended that five of the oldest nuclear reactors should be closed for security reasons. Three of these have the same age as Barsebaeck 2, are also boiling water reactors and – just like Barsebaeck – are not designed to withstand an airplane crash, not even by a smaller aircraft.

With respect to precautionary measures against a **terrorist attack on the ground**, it can be established that they at this point in time are insufficient both at the Barsebaeck nuclear power plant and all other Swedish nuclear power plants at that there probably not is any prospect of them getting significantly better. The assumption that nuclear power plants are impossible to protect against terrorist attacks from the air and the ground are backed up by estimates made by the US *Nuclear Regulatory Commission* (NRC). **That the Swedish nuclear regulatory authority shares this assumption lies implicitly in the fact that they have chosen not to publish the analyses of the physical protection of the Swedish nuclear power plants**. However, it has to be recognized that the Swedish security authorities are facing an insoluble problem, because no nuclear power plant in the world can be defended by armed and well-organized terrorists who are willing to sacrifice their lives. The only way to ensure, that the Barsebaeck nuclear power plant cannot be threatened by terrorists is to **decommission the plant**.

According to an assessment of **the safety level of the Swedish nuclear power stations during normal operation** based on the International Nuclear Event Scale – INES – the Swedish nuclear power plants perform rather poorly. **Furthermore, one could argue that evaluated on the basis of the INES parameters alone, Barsebaeck 2 is statistically the most dangerous nuclear power reactor in Sweden.** *20 % of all INES level 1 anomalies and 40 % of all INES level 2 incidents at nuclear power plants in Sweden took place at Barsebaeck 2 during the period 1991-2002.* In

[140] The forecast presupposes a reorientation of energy taxes and other basic rules for the heating market as they emerge in 2003. The report assesses that the development of district heating can be impeded mainly by a price regulation or an energy taxation system that discriminates resource efficient systems such as district heating.

addition to the plant's old age one of the main reasons could be the **basic choice of reactor design** that is such in nature that Barsebaeck 2 according to an independent, international report **would not have been granted an operation permit in the USA**. Other indirect parameters for the level of safety during normal operation – including **PSA-analyses, accessibility, the frequency of quick-stops** and **discharge of radiation into the environment** – give the impression of a nuclear power plant that is old, outdated and worn-down.

However, there are indications that the safety culture at the plant is the single largest safety risk during normal operation. In this context it should be remembered that the accidents at Chernobyl and Three Mile Island were caused by human errors. Apart from the fact that the management and the employees at Barsebaeck 2 have publicly been corrected by SKI for lack of motivation in their work, SKI has filed a criminal complaint against Barsebaeck Kraft AB. The complaint has now resulted in a criminal case against the plant management. In addition, the plant has been put under special supervision for at least a year by the nuclear regulatory authority. The plant was also under such supervision between 1994 and 1997.

In BBOFF's opinion, the doubts that for some time have been raised about the safety culture at Barsebaeck– whether they are based on hard facts or not – are yet another serious reason to recommend that an environmental permit is not given to the plant.

With respect to an assessment of the **effects of a serious accident at the Barsebaeck nuclear power plant** is worth mentioning that **the plant is situated at the centre of the most densely populated area in Scandinavia, only 20 km east of the Danish capital Copenhagen and 15 km north of Malmoe. It could be argued that this is the worst location of any nuclear power station in the world**.

An analysis of Barsebaeck 2's reactor inventory – particularly with respect to its content of **caesium-137** – indicates a possibility of **release scenarios just as serious or more serious than the releases from Chernobyl**. This assumption is confirmed by reports from the Swedish nuclear regulatory authorities.

All people within a radius of 30 km around the Chernobyl reactor have been evacuated from their homes. This area has been declared an **exclusion zone** and no people live there anymore. **An exclusion zone within a radius of 30 km from Barsebaeck would include in Sweden Malmoe, Lund, Landskrona, Esloev, Staffanstorp and at least more than twenty villages and in Denmark all of Amager, Copenhagen K, Frederiksberg, Vesterbro, Noerrebro, Oesterbro, Vanloese, Broenshoej, Valby, Vigerslev, Hvidovre, Avedoere Holme, Broendbyoester, Roedovre, Utterslev, Nordhavn, Bispebjerg, Hellerup, Husum, Moerkhoej, Gladsaxe, Soeborg, Buddinge, Bagsvaerd, Vangede, Gentofte, Charlottenlund, Skovshoved, Jaegersborg, Ordrup, Lyngby, Sorgenfri, Virum, Klampenborg, Taarbaek, Raadvad, Soelleroed, Holte, Gl. Holte, Oeveroed, Naerum, Troeroed, Skodsborg, Vedbaek, Sandbjerg, Isteroed, Ravnsbjerg, Hoesterkoeb, Braadebaek, Hoersholm, Usseroed, Valleroed, Rungsted and Kokkedal**. The reports from the Swedish nuclear regulatory authorities that are the basis of the Danish nuclear rescue preparedness include consequence scenarios implying **exclusion zones within a distance of 20, 50, 60 and 100 kilometres from the radiation release source dependent of the weather conditions**.

Hence, it can be concluded that the concept of a 30 km exclusion zone is moderate compared to some of Swedish authorities' own scenarios. In the case of an accident with a large release of the same order as in Chernobyl, but to a smaller height above the plant, **a 30 kilometres exclusion zone around the Barsebaeck nuclear power plant could actually be more contaminated than the exclusion zone around the Chernobyl nuclear power plant**.

Contrary to the Chernobyl nuclear power plant that is situated in a thinly populated agricultural area, the Barsebaeck nuclear power plant is situated in the most densely populated area in Scandinavia, less than 30 kilometres from the largest city in Denmark and the third largest city in Sweden. According to the Danish Statistical Agency 661.034 people lived in the Danish capital (Copenhagen, Frederiksberg and Gentofte) in 2003. **Therefore it is likely that far more than the 350.000 people who were evacuated or resettled after the Chernobyl disaster would have to be evacuated or resettled in Denmark in case of the worst possible accident at the Barsebaeck nuclear power station. It is also likely that the Danish economic losses would be much higher than the 2889 billion DKK the Chernobyl disaster so far has cost the three former Soviet republics that have sustained the heaviest losses. The metropolitan area is the economically most productive area in Denmark. In 2001 the GNP per capita in Copenhagen and Frederiksberg was almost 16 times higher than the year 2000 GNP per capita in Ukraine and 8 times higher than the year 2000 GNP per capita in Belarus**.

It is worth noting that the above-mentioned estimates of the possible economic losses caused by a serious accident at the Barsebaeck nuclear power plant are moderate **compared to official American assessments of the financial losses deriving from a serious nuclear accident at an U.S. nuclear power station**. These estimates put the losses in the order of **between 40% and 180%** above the losses that have so far been registered from the Chernobyl accident. **The German authorities estimate that the financial losses from the worst possible accident at a German nuclear power station are approximately 14 times higher than the figures currently known with respect to the Chernobyl disaster**.
The financial losses in Denmark originating from the worst possible accident at the Barsebaeck nuclear power plant will either not be compensated or compensated in the order of a quarter or half of a per cent of the actual losses by the operator and the Swedish state.

Additionally contravening a recommendation of an environmental permit for the Barsebaeck nuclear power plant is the fact that there are several environmentally friendly alternatives to its activities. The conditions which the Swedish Parliament has set for decommissioning the Barsebaeck nuclear power plant – namely that a shutdown of the plant **has no negative consequences for the effect balance, the electricity price, the industry's access to electricity or the climate or the environment –** have been met long ago. Most recently, surveys and analyses made by **the Swedish and Danish authorities** have established that **Barsebaeck's electricity production can be dispensed with**.

On the basis of the information presented in this position paper BBOFF recommends that the Barsebaeck nuclear power plant should not be given an environmental permit. In stead the Danish and the Swedish government should intensify their efforts to shut down the plant as quickly as possible.

- *Niels Henrik Hooge 2004-6-11 –*

Thanks to Jorma Kahanpää from the Swedish anti-nuclear movement (FMKK) and Allan Andersen from the Danish Society for the Conservation of Nature for their contributions to this position paper.

Annex 1

What is Barsebaecksoffensiv ?

Barsebaecksoffensiv (BBOFF) is a loosely organized network consisting of activists, green NGO's and political parties in Denmark, Sweden and Germany.

GREEN NGOs:

The Danish Ecological Council (www.ecocouncil.dk), contact person: Christian Ege Jørgensen, tel. +45 33 18 19 33, E-mail: christian@ecocouncil.dk

NOAH – Friends of the Earth Denmark (www.noah.dk), contact person: Kim Ejlertsen, tel. +45 35 36 12 12, E-mail: kim@noah.dk

The Danish Society for the Conservation of Nature (www.dn.dk), contact person: Allan Andersen, tel. +45 39 17 40 35, E-mail: aa@dn.dk

The Danish Organisation for Renewable Energy (www.orgve.dk), contact person: Ann Vikkelsø, tel. +45 35 37 36 36 and +45 28 88 02 51, E-mail: annv@ove.org

Eco-net (www.eco-net.dk), contact person: Lars Myrthu-Nielsen, tel. +45 62 24 43 24, E-mail: eco-net@eco-net.dk

Nature and Youth (www.natur-og-ungdom.dk), contact person: Søren Mejnert, tel. +45 86 22 58 99 and +45 28 72 95 21, E-mail: smeinert@wanadoo.dk

Copenhagen's Environmental and Energy Office (www.kmek.dk), contact person: Ann Vikkelsø, tel. +45 35 37 36 36 and +45 28 88 02 51, E-mail: kmek@sek.dk

POLITICAL PARTIES:

Enhedslisten, the Danish Red-Green Alliance (www.enhedslisten.dk), contact person: Rikke Fog-Møller, tel. +45 33 37 50 61, E-mail: elrifm@ft.dk and rikkefo@worldonline.dk

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