Risk and consequence scenarios for the worst possible accident in the Barsebäck nuclear power plant

Barsebäcksoffensiv's (BBOFF's) paper 31th of August 2003 (draft version) on the Danish Emergency Management Agency's answers in the Danish Parliament to questions no. S 3374, S 3375, S 3376 and S 3377 about the Danish nuclear rescue preparedness, including a comparison between the Chernobyl disaster and the consequences of the worst possible accident in the Barsebäck nuclear power plant

Background of the paper: *End of May 2003 Keld Albrechtsen from Enhedslisten and Pernille Blach Hansen from the Social Democrats put forward four questions to the Danish Minister of the Interior, Lars Løkke Rasmussen, which he answered in writing after consultations with the Danish Emergency Management Agency. The agency is responsible for the management of the consequences in Denmark of an accident in the Barsebäck nuclear power plant. The questions were triggered by an article in the daily MetroXpress Monday the 20th of May that described, how the consequences of a terrorist attack against the Barsebäck nuclear power plant was downplayed by the Danish authorities after the attack against World Trade Centre September 11th 2001. According to the article, the Swedish Ministry of Defence had established in 1987 that the population would have to be evacuated at a distance of 60 kilometres in the direction of the wind, if radiation was released from the Barsebäck nuclear power plant. This scenario was contrary to a memorandum that the Danish Emergency Management Agency published after the attack against the World Trade Centre. In the article, one of the directors of The Swedish Nuclear Power Inspectorate (SKI), Christer Viktorsson, said that in his opinion the serious Swedish accident assessments from 1987 were still in play.*
The article caused the two politicians to pose the critical questions. However, the Minister of the Interior did not doubt the Danish risk and consequence scenarios, demand further investigations or question the Danish Emergency Management Agency's handling of the nuclear rescue preparedness.

In this paper BBOFF has tried to answer the following questions: Which scenario applies today as regards the worst possible accident in the Barsebäck nuclear power plant ? Is the worst possible accident in the Barsebäck nuclear power plant comparable to the Chernobyl disaster ? What are the consequences of the Chernobyl disaster ? If the worst possible accident in the Barsebäck nuclear power plant is comparable to the Chernobyl disaster, how can the lessons learned from Chernobyl be applied in a Danish context ? Is it possible to make a preliminary estimate of the losses that such a disaster would inflict on the environment, public health and the economy in Denmark ? How safe are the Swedish nuclear power plants ? How safe is the Barsebäck reactor 2 ? What is the likelihood that the reactor will be decommissioned and if so, when ? What is the role of the Danish Emergency Management Agency in the ongoing efforts to close down the Barsebäck nuclear power plant ? Does the agency have a political function ? Does the Danish nuclear rescue preparedness live op to the international principles for radiation protection, as the Danish Emergency Management Agency claims, or are new political initiatives necessary ? And finally: Who are liable in case of the worst possible accident in the Barsebäck nuclear power plant and how much are they going to pay ?

In order to be able to answer these questions, BBOFF presents the findings below of some of the reports that describe the consequences of a serious accident in a nuclear power plant and also the two contrasting scenarios that caused the questions to be asked to the Danish Minister of the Interior: On one hand, the Swedish disaster scenarios of the 1987 Secretariat Report from the Swedish Ministry of Defence and a 1989 Report from the Swedish Ministry of Defence, and on the other hand the scenario of the Danish Emergency Management Agency which the agency claims is based on a report from 1995 – *Consequences in Sweden of a serious nuclear accident* – published by SKI and the Swedish Radiation Protection Authority (SSI). After that follows a description of the consequences of the Chernobyl disaster, as they are perceived according to the international consensus. The main source in this context is the information presented on the website, established by the UN on this topic 2002, a January 2002 UNDP and UNICEF report, a 2002 report from Nuclear Energy Agency (NEA), an April 2003 report from Institute de Radioprotection et Sûreté Nucléaire (IRSN), a 2002 official declaration from the government of Ukraine and a 2002 official declaration from the government of Belarus.
Furthermore, a brief estimate of the safety level of the Swedish nuclear power plants, emphasizing the accident frequency and Sweden's position in the international information system on nuclear accidents – "INES" – and an estimate of the safety level at the Barsebäck nuclear power plant. Finally follows a comment on the Swedish government's nuclear energy policy and an estimate of the possible time horizon for the decommissioning of the Barsebäck nuclear power plant.

Contents

Annex 3: The Danish Emergency Management Agency's memorandum 21st of September 2001 on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebäck nuclear power plant.
Annex 4: Glossary

SUMMARY

The organizing of the Danish nuclear emergency response plan is based on risk and consequence scenarios founded on a certain perception of the hazards of nuclear power. Apart from protecting people against the consequences of a nuclear accident, the rescue preparedness plan has a vital influence on the public's perception of nuclear power. In this context it is worth noting that the influence of the Danish Emergency Management Agency transcends just handling the emergency measures against the consequences of a serious nuclear accident, because the long-term consequences for the environment, public health and the economy in Denmark cannot be remedied by emergency measures alone.

For many years the Danish Emergency Management Agency was criticised by the now abolished *Information on Nuclear Power* (OOA – The Danish WISE) for downplaying the consequences of the worst possible accident in the Barsebäck nuclear power plant. OOA argued that NGO's that were critical or at least neutral towards nuclear power should have an input in the risk assessments that were the basis of the Danish nuclear emergency response plan.

End of May 2003 the problem came on the agenda again, when Keld Albrechtsen from Enhedslisten and Pernille Blach Hansen from the Social Democrats put forward four questions about the Danish nuclear rescue preparedness plan to the Danish Minister of the Interior, Lars Løkke Rasmussen. The questions were triggered by a newspaper article, that described how the consequences of a terrorist attack against the Barsebäck nuclear power plant was downplayed by the Danish authorities when they made a risk assessment after the attack against World Trade Centre September 11th 2001. In its memorandum the Danish Emergency Management Agency used a worst-case scenario for a serious nuclear accident, i.e. a major accident categorized as a level 7 on the International Nuclear Event Scale ("INES"), and claimed that acute casualties would not occur even in this situation, but that a number of children would suffer thyroid gland cancer and that a part of the population would be afflicted by belated damage in the form of leukaemia and other cancer types, hereditary diseases and foetus damage. The worst consequences would consist of an increase of cancer cases over a generation. However, the increase would be so limited compared to the total number of cancer cases in society that it probably could not be registered statistically. The socio-economic consequences of a nuclear disaster were not mentioned, nor the consequences for the environment.

The conclusion of the memorandum was that most of the negative consequences of the worst possible accident in the Barsebäck nuclear power plant could be avoided if people stayed indoors and some types of food were to be restricted.

The memorandum was in conflict with the assessments of the Swedish Ministry of Defence, whose scenarios were recently confirmed by Christer Viktorsson, one of the directors of SKI.

Because of the Tjernobyl catastrophe that caused damage in Sweden as well, 11th of June 1987 the Swedish Government authorized the head of the Swedish Ministry of Defence to form a committee that were to make a report on the Swedish nuclear and chemical nuclear rescue preparedness. In the committee 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, ministry secretary Agneta Björkenstam, office director Roland Nilsson and information director Gunilla Wünsche. The result was *A secretariat report on society's measures against serious accidents, the investigation (Ministry of Defence 1987: 01) of the nuclear rescue preparedness.* The report describes the consequences of a serious accident in a Swedish nuclear power plant. The calculations on the following risk scenario were made by SSI based on material from the Danish National Laboratory in Risø and the Swedish Defence Research Centre (FOA).
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 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 Øresund 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 Øresund region) in case of a radiation release and in a 100 kilometres zone (half of Seeland) within 24 hours. Evacuation of all pregnant women in a 500 kilometres zone from the power plant within 24 hours 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.
In the Danish Emergency Management Agency's memorandum it was assumed that the safety filter did not work, because it described a worst-case scenario.

The examples, how the Danish Emergency Management Agency estimates the worst possible consequences of a serious accident in the Barsebäck nuclear power plant, analyzed in this paper, show that the consequences are still being downplayed. If one compares the competing risk and consequence scenarios for the Swedish nuclear power plants the way they are described in the agency's answers to the two politicians and the September 26th 2001 memo, it is evident that they are a far cry from the scenarios described in the 1987 Secretariat Report and the 1989 Report. **Nor are the agency's scenarios similar to those described in the 1995 report "Consequences in Sweden of a serious nuclear accident" which the agency refers to as its main source.** Especially as regards this last report it is worth noting how it assesses 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, 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, thus **confirming the worst-case scenarios of the 1987 Secretariat report and the 1989 Report.**

Especially regarding the Danish Emergency Management Agency's September 2001 memo, in which the agency describes a scenario where a fully tanked passenger or military airplane crashes into the Barsebäck nuclear power plant when the reactor is still running, it is evident **that there is no similarity between the memo and the 1987 Secretariat Report, the 1989 Report or the 1995 Report**. In the answers to the two members of parliament the agency claims that the consequence scenarios that constitute the basis of the Danish rescue preparedness planning are "in accordance with international practices for radiation protection" – i.e. the lessons learned from the Chernobyl disaster – and in the September 2001 memo the agency refers to Chernobyl, when it describes the consequences of the worst possible accident in the Barsebäck nuclear power plant. Since 1995 a number of reports from international organizations have presented information that throws new light on the consequences of the Chernobyl disaster, but the Danish Emergency Management Agency has chosen to ignore the last eight years of research in this field.

Initially, a comparison between the Chernobyl disaster and the worst-case scenario for a serious nuclear accident in the Barsebäck 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 Barsebäck 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. For instance, the 1995 report which the Danish Emergency Management Agency refers to, when it defends the Danish nuclear rescue preparedness plan, defines a rest risk release as "very substantial releases (in which apart) from the whole inventory of noble gasses more than a tenth of the reactor inventory of iodine, cesium and tellur is released. The heavier substances are expected to be more contained". **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 Barsebäck 2 reactor derives from the released fraction of the core inventory. **The reactor core of Barsebäck 2** contains **a weight of 76.4 tons of uranium**. 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. **Based on these figures, a release of 7,7 % the reactor fuel in Barsebäck 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 Barsebäck 2 will exceed the release from the Chernobyl reactor.**

In this context it is worth noting that the scenario for the rest risk release described in the 1995 Report from SKI and SSI, which the Danish Emergency Management Agency claims that the Danish nuclear rescue preparedness plan is based on, is comparable to the above-mentioned actual Chernobyl release scenarios.

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 estimate by the UNSCEAR committee, **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, while the Barseback inventory of caesium-137 should be approximately **a total of 105 kg** in the core, i.e. **more than in the Chernobyl reactor**.

The Chernobyl release of caesium-137 equals a release of 25 % of the caesium-137 inventory in Barsebäck 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.**

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 Barsebäck nuclear power plant. Exact figures cannot be extracted from an outside reference. **A second uncertainty factor** is the fact that the Ukrainian Chernobyl reactor is a RBMK, very different from the Swedish design. **A third uncertainty factor** is the pattern of the release scenario itself. **A fourth uncertainty factor is the quantities of spent fuel stored in the Barsebäck nuclear power plant**. Approximately a sixth of the fuel in the reactor, i.e. **15 tons**, is changed every year. However, an inventory status December 31st 2001 revealed that 405 spent fuel assemblies totalling a weight of **72 tons** were stored in Barsebäck 2. 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.
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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 2 reactor could be comparable to the Chernobyl disaster.

All new information on the Chernobyl disaster indicates that the consequences of a serious nuclear accident are far more serious than the Danish Emergency Management Agency presupposes in its calculations of the consequences of the worst possible accident in the Barsebäck nuclear power plant. All people within a radius of 30 kilometres around the Chernobyl reactor were evacuated from their homes. The area has since been declared an **exclusion zone**, where no one is allowed to live. **An exclusion zone within a radius of 30 kilometres around the Barsebäck nuclear power plant would in Sweden include Malmö, Lund, Landskrona, Eslöv, Staffanstorp and at least twenty villages and in Denmark all of Amager, Copenhagen City, Frederiksberg, Vesterbro, Nørrebro, Østerbro, Vanløse, Brønshøj, Valby, Vigerslev, Hvidovre, Avedøre Holme, Brøndbyøster, Rødovre, Utterslev, Nordhavn, Bispebjerg, Hellerup, Husum, Mørkhøj, Gladsaxe, Søborg, Buddinge, Bagsværd, Vangede, Gentofte, Charlottenlund, Skovshoved, Jægersborg, Ordrup, Lyngby, Sorgenfri, Virum, Klampenborg, Tårbæk, Rådvad, Søllerød, Holte, Gl. Holte, Øverød, Nærum, Trørød, Skodsborg, Vedbæk, Sandbjerg, Isterød, Ravnsbjerg, Høsterkøb, Brådebæk, Hørsholm, Usserød, Vallerød, Rungsted and Kokkedal.** In this context it is worth noting that the 1987 Secretariat Report consequence scenario, one of the directors of SKI recently confirmed, has an **exclusion zone 100 kilometres in the direction of the wind**, and that the 1995 Report from SSI and SKI 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 Barsebäck 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**. 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. So far, this amount is **more than twice the total Danish BNP for 2002**. Contrary to the Chernobyl nuclear power plant that is situated in a thinly populated agricultural area, the Barsebäck 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. The Danish capital is inhabited with more than 660.000 people. 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 Barsebäck 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 BNP 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 2000 BNP per capita in Ukraine and 8 times higher than the 2000 BNP per capita in Belarus.

The security level of the Swedish nuclear power plants has a central position in the risk scenarios. **All the probability calculations that for 50 years have been the basis of the 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**. In this context the Barsebäck nuclear power plant has a special position. The plant is situated less than 20 kilometres from Kastrup airport. When the fully tanked airplanes take off from Kastrup they are less than five minutes of flight time from the plant. If terrorists hi-jack an airplane in Kastrup in order to attack the Barsebäck nuclear power plant, counter measures cannot be implemented before the disaster is a reality.

A serious accident in the Barsebäck nuclear power plant does not have to be caused by a terrorist attack, though. It is a fact that the official Swedish safety evaluations are characterized by a high degree of uncertainty. **That the safety level in the Swedish nuclear power plants is lower than what the public perception indicates can be established from Sweden's worldwide position as regards the International Nuclear Event Scale – "INES".** This information system has existed since 1991. According to one source, 7 level 2 incidents have taken place in Swedish nuclear power plants out of a total figure of 46 during the period 1991-2002, i.e. 15 % of all the nuclear incidents in the world. This is a significant over-representation considering the fact that Sweden has only 11 reactors (12 before Barsebäck 1 was decommissioned) and that on the average there were approximately 420 reactors in the world during the period 1991-2002. According to SKI's website, there were 5 INES 1 anomalies and 2 INES 2 incidents in

Barsebäck 2 1991-2002. **Statistically, that makes Barsebäck 2 the most dangerous nuclear power reactor in Sweden.** For the same period SKI mentions a total of 29 INES 1 anomalies in the Swedish nuclear power plants and 5 INES 2 incidents. The sixth INES 2 incident occurred in the nuclear research facility in Studsvik where also a serious INES level 3 incident has been reported.

In general, two main factors determine the estimates that the competing risk and consequence scenarios put forward: On one hand the conclusions that are drawn from the Chernobyl disaster and on the other hand political demand. That these two factors are not always compatible with each other can be registered in the fluctuations in the Swedish authorities´ scenarios for the consequences of a serious accident in a nuclear power plant: While the international research agencies paint a still more bleak picture of the consequences of the Chernobyl disaster, some of the Swedish authorities' scenarios for the consequences of a serious nuclear accident gets more optimistic. **A likely explanation for this is the fact that the Swedish population is currently the one most friendly towards nuclear power in Europe.** Consequently, not only the technical responsibilities of the Danish Emergency Management Agency, but also its political role has increased, considering the fact that there is no longer any political pressure in Sweden to decommission the Barsebäck nuclear power plant.

A highly relevant aspect of the decommissioning issue is the Swedish state majority ownership control of 8 of the 11 nuclear reactors in Sweden. Vattenfall AB - the fifth largest energy company in Europe with a turnover of more than 100 billion SEK in 2002 - is in possession of the majority ownership of both the Forsmark and the Ringhals Company Group that includes the Barsebäck and Ringhals nuclear power plants. **Vattenfall AB is owned 100 % by the Swedish state, i.e. the Ministry of Industry, Employment and Communications (Näringsdepartementet).**
Hence, when it comes to the question of phasing out nuclear power, the Swedish government not only has to negotiate a voluntary agreement with itself about 8 out of 11 of the nuclear reactors in Sweden, but it also has to ask itself whether the conditions for decommissioning Barsebäck 2, of which it exercises full ownership control, have been met.
So far, the Swedish government has promised five times to decommission Barsebäck 2 and each time broken its promises. **Considering that it is still uncertain when Barsebäck 2 will be shut down and one could argue that the likelihood that the reactor will be decommissioned is dwindling as time passes by, because of the growing popular support for nuclear power in Sweden, the Danish government should increase its pressure on the Swedish government and at the same time play with open cards as regards the evacuation plans for the many people who will be affected by the worst possible accident in the plant.**
It is only natural that economic estimates of the consequences of the various scenarios should be integrated into this political and administrative transparency strategy.

Consequently the Danish government should

- *initiate an independent investigation of the Danish nuclear rescue preparedness– preferably with the involvement of one or more independent international research agencies.*

- *initiate an independent investigation of what the consequences of the worst possible accident in the Barsebäck nuclear power plant would be for the environment, public health and the economy in Denmark.*

This investigation should be based on the newest international findings in this field and should try to reach a clarification of

- the short-term and long-term effects of such an accident on the *environment* and *public health*, including its influence on the frequency of thyroid cancer, leukaemia, other cancer diseases and diseases in general among children and adults, its influence on pregnancy and on the new generations and not least its psychological effects.

- *the risk dimension*, including the extent of the service duty for the personnel expected to carry out the sanitation in Denmark after the worst possible accident in the Barsebäck nuclear power plant. To throw light on this problem is highly relevant considering that the number of casualties among the 800.000 mitigators of the consequences of the accident in the Chernobyl nuclear power plant is estimated to be between 25.000 and 100.000 and considering that 92 % of the 336.000 mitigators in Ukraine have officially been recognized sick.

- the *direct losses* from the accident - expenditure on decontamination work in the affected territories, emergency aid and medical help to the affected population, research of the environment, public health and production of non-contaminated foodstuffs, organizing the monitoring of the radioactive situation, radiation-ecological improvements of residential areas and radioactive waste management, resettlements of the most affected parts of the population and improvements in their living conditions – and the *indirect losses* - long-term production loss caused by loss of arable land and forests, shutting down of agricultural production facilities and industrial facilities and loss of profit opportunities.

In this context is has to be taken into consideration that the economic damage done to the Danish society if literally hundreds of thousands of citizens will have to give up their residences, while at the same time hundreds of thousands of jobs are lost, will not be compensated in full by Vattenfall AB and Sydkraft AB that own the Barsebäck nuclear power plant, or by the Swedish state. It is also worth noting that **according to the Swedish nuclear liability act, the operator might be exonerated wholly or partially if a person suffering damage has contributed hereto due to gross negligence on his part**. This could pertain to the Danish Emergency Management Agency, if a Swedish court deems the Danish nuclear rescue preparedness insufficient. People in Denmark who suffer personal injury because they were not evacuated in time would have to bring actions against the Danish Ministry of the Interior instead.
Just as striking as the fact that neither the operator of the Barsebäck 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 one described in section I.F (the Chernobyl scenario) will practically not be compensated**. As part of the privileges that the Swedish government has granted the nuclear industry, the maximum limit of the insurance policies of the Swedish energy companies is 2,67 billion DKK (3,3 billion SEK). The Swedish state itself will cover nuclear damage that the operator does not compensate due to the above-mentioned ceiling, though not more than with 4,86 billion DKK (6 billion SEK). **Although the owners of Barsebäck 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 magnitude 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.

- *Consequently, the Danish government and the Danish parliament should as quickly as possible negotiate a liability agreement with the Swedish government that compensates for nuclear damage in Denmark in a realistic way and at the same time increase the pressure that is put on the Swedish government to decommission Barsebäck's reactor 2*

I. The competing risk and consequence scenarios

Before the competing risk and consequence scenarios as regards the worst possible accident in the Barsebäck nuclear power plant are described, it would be relevant to throw a quick glance at some of the scenarios that have been predominant since the rise of nuclear power fifty years ago. A common feature of these scenarios is that they apart from being technical and scientific estimates of specific chains of incidents are also political documents, because they form the conditions for the weighing of the risks that determines the public perception of the pros and cons of nuclear power. Whether they want it or not the responsible authorities, i.e. those who make the estimates and those who plan the corresponding emergency measures are players in a political game where the stakes are high. Consequently, one has to take into consideration the possibility that especially *because* they have a crucial part in forming the political options in this field, *they themselves are submitted to political pressure*. Without considering this fact it would be impossible to understand the apparent historical discontinuity and the leaps in judgment that seem to take place within short time-spans and without any apparent reason in the course of the development of the risk and consequence scenarios.

A. 50 years' risk and consequence scenarios

During the fifty years of existence of nuclear power at number of studies have been carried out on the hazards of nuclear power. In the fifties and sixties the studies were mainly American, but when the first nuclear power plants were built in Sweden in the seventies, the Swedish authorities began to make their own research. A brief historical account is given below of the most important studies, emphasizing the Swedish perspective[1].

Parker and Healy's study from 1955 were among the first great American studies on the consequences of a serious nuclear accident. The report concludes that a release of fission products could kill 200-500 persons assuming a population density of 80-200 per km2. Beyond this 3.000-5.000 could be submitted to radiation exposure on dangerous levels, even though an evacuation quickly took place.

WASH-740 that was published by the American Nuclear Regulatory Commission (NRC) was the first major study on a serious nuclear accident and was more or less the basis of all estimates of reactor safety up till the mid-seventies. **The report concluded that up to 50 % of all the fission products in the reactor inventory would be released into the environment in a worst-case scenario.** Even the most long-lived and insoluble products were thought to have the same ability to be released into the environment. The report pointed out that if the release was hot the fission products would fly high up into the atmosphere and no evacuation would be necessary. If on the other hand the fission products were spread around in air temperature, half a million people would have to be evacuated and close to four million people would have to be submitted to various kinds of restrictions. The report also contained an estimate for the costs for society that would be the consequence of a serious nuclear accident. The costs were from long-term evacuation of the population and restrictions on agriculture. **In a worst-case scenario the restrictions on agriculture would include an area of 400.000 km2 – an area approximately 9 times larger than Denmark – and the costs would amount to a total of 9 billion USD.** Typical of this and all the earlier studies was the fact that the scenarios only took into account acute radiation damage and ignored the long-term consequences, e.g. cancer diseases. Even the consequences of high concentrations of radioactive iodine in the air were ignored. WASH-740 concludes that the acceptable radiation dose in an emergency situation was 20.000 mGy. Today, SSI prescribes consumption of iodine in case of a 100mGy radiation level.

The next major study on reactor safety was *WASH-1400*, a.k.a. *"the Rasmussen report"*. The report was published 1965 by NRC and was the basis of the Swedish risk assessments in the late seventies. The foundation of the report was a technical analysis of two American reactors, a boiling water reactor (BWR) and a pressure water reactor (PWR). The report described five radiation release scenarios for the boiling water reactor and nine for the pressure water reactor.

---

[1] The account is mainly based on *Consequences in Sweden of a serious nuclear accident*, a study carried out by SSI and SKI, September 1995, p. 5-10.

The first large study in Sweden was the so-called *närforläggningsutredningen* (SOU, 1974) that was published 1974. The report deals with the security issues of nuclear power plants situated in densely populated areas. The study was made because the Stockholm Electricity Company 1968 had applied for a license to build a nuclear power plant few kilometres from the centre of Stockholm. The study of the Värtan project led to a decision to look into the possibilities of generally localizing nuclear power plants in densely populated areas. **The study concluded that it was economically sound to build nuclear power plants in the three most densely populated areas in Sweden.** It also concluded that it was a good idea to localize them in the population centres for environmental reasons, because it would reduce the air pollution from energy production. The risk of accidents was discussed but the probability that they would occur was considered to be so low that it was acceptable compared with other risks in society. If an accident occurred, there would be no casualties further away than 3 kilometres from the reactor.

1977 the *Energy and Environmental Committee* published a report *"Energy, health, environment"* (SOU, 1977) proposing that the collective dose from nuclear power production should not exceed 0,01 manSv per MW-year electrical effect. In case of a serious radiation release life-threatening doses could emerge in the surroundings of the nuclear power plant and the consequences would be strongly dependent of weather conditions.

March 28th 1979 the first serious accident occurred in a nuclear power reactor when a meltdown took place in block no. 2 in the nuclear power plant **Three Mile Island** outside Harrisburg in the USA. The reactor had been running for exactly a year. **The accident was the first milestone in the change in the global perception of the hazards of nuclear power. In Sweden, the accident led to a referendum on whether to abolish nuclear power.** The Swedish government appointed a reactor safety commission in order to find out, which safety-enhancing measures could be implemented in the Swedish nuclear power plants. November 1979 the commission presented its report. It established that the Swedish reactors were not less safe than the American reactors. On the contrary, some of them were even safer. The report also discussed a series of precautionary improvements. The most radical was the idea about the release-limiting precautions. By connecting an escape-valve with the reactor container and let the releases pass through a safety filter chamber, it is possible to reduce the pressure and a rupture of the containment can be avoided in a case of a meltdown. A large part of the radioactive substances will remain in the filter. **The government adopted the proposal and decided that the Barsebäck nuclear power plant should install a safety filter no later than 1985. The other nuclear power plants were obliged to install their filters in the late eighties.**

December 1989 SSI published the study *"A more efficient emergency response system"* (SSI, 1979) that described the consequences of nuclear reactor accidents in Sweden. The agency made an assessment of the consequences of a release of radioactive noble gasses, radioactive iodine and a worst-case scenario, where a large part of the fission products would be released. SSI concluded that the risk of acute radiation damage was the highest if the release took place under rainy conditions. **In this case acute radiation sickness and casualties could occur among unprotected persons up to a distance of 20 kilometres from the reactor. Under dry weather conditions the risk of inhaling radioactive substances would be higher than the short-term risk from the substances on the ground. Up to a distance of 20 kilometres unprotected persons could be inflicted with damage to their lungs. Damage to children's thyroid glands could occur within a distance of 20-30 kilometres of the reactor and in extreme cases within 50 kilometres. The number of cancer deaths was estimated to lie between 3.000 and 150.000, depending on the direction of the wind and the weather conditions. The scenario was based on the assumption that all radioactive noble gases, 90 % of the radioactive iodine, 50 % of the radioactive caesium and between 3 and 30 % of the other radioactive substances would be released.** This scenario more or less corresponds with the releases from the Chernobyl reactor.

Because of Danish concerns about the two reactors in the Barsebäck nuclear power plant the Danish and Swedish governments appointed *a Danish-Swedish committee* in order to assess the consequences in Denmark of a possible serious accident in the plant. The Barsebäck committee commissioned consequence assessments both from Danish and Swedish experts. In Denmark, the assessments of the consequences of the releases were based on the WASH-1400 BWR-2 and BWR-3 designations. In Sweden assessments were made both for serious nuclear accidents with and without filtrated pressure relief. The safety filter system was being projected in the Barsebäck nuclear power plant at that particular point in time.

After **the Chernobyl disaster** April 1986, the **other milestone** in the global public perception of the hazards of nuclear power, the Swedish government appointed an *emergency planning commission* in order to investigate how the nuclear emergency response system could be improved. The commissions report *"Society's measures against serious accidents"*, SOU 1989:86 and the Secretariat Report it is based on are described in more detail under section I.B and I.C.

The report led to a bill, *Bill 1991/92.41 on society's measures against serious accidents,* in which the government proposes changes in the rescue service, for instance to impose on the municipalities to organize warning systems and bring about information to the population and to impose on the counties to take responsibility for the sanitation after a release of radioactive substances from a nuclear facility. Also the number of measure stations in connection with warnings of increased radiation levels was to be increased as well as the resource allocation for more advanced measuring systems.

Because of the parliament's decision to abolish nuclear power in Sweden SKI and SSI were commissioned by the government in 1989 to make safety and radiation protection assessments relevant for a decision on **which reactors to decommission first**. However, according to SKI and SSI no particular nuclear power plant could be separated from the others as regards a serious nuclear accident where the release-reducing precautions functioned properly (SKI-SSI, 1990). Only as a consequence of a rest risk accident would a large release under unfavourable weather conditions result in acute deaths. The radioactive ground coverage from a rest risk accident could be so big that an evacuation of the population in the areas with the highest doses could be necessary. **SKI and SSI concluded that the consequences of such a disaster would be worse from an accident in the Barsebäck nuclear power plant than in the other nuclear power plants because of Barsebäck's close vicinity to Malmö and Copenhagen**. It was pointed out that reactors abroad were more accident-prone than the Swedish and that the need for an emergency organization would exist even if the Swedish nuclear power plants were decommissioned.

September 1995 SSI and SKI published the report *"Consequences in Sweden of a serious nuclear accident"* commissioned by the Swedish Energy Commission who wanted to know the consequences of radiation releases from a Swedish nuclear reactor in case of a serious accident. Part of the assignment was a discussion of the different views on global risk scenarios and to give an account of earlier studies. The report's conclusions are described below in section I.D.

The same year the Swedish Ministry of Defence published the study *"Radioactive substances destroy agriculture in Skåne"* (SOU 1995:22) as part of a report under *the threat and risk investigation*. As a consequence of the Chernobyl disaster that caused large areas in Northern Sweden to be contaminated and cost the Swedish Department of Agriculture (Jordbruksverket) at least 680 million SEK (see section I.E) a scenario is described in the study, where radioactive fallout from a serious accident in a nuclear power plant 700 kilometres south-east of Sweden contaminates parts of Skåne where the background radiation doubles or triples. Some farmers are evacuated with their families, the dairy cattle are isolated and all dairy production in Skåne is suspended. A year later the sale of food from Skåne has fallen considerably: Milk 45 %, meat 15 %, eggs 10 %, corn 10 % and vegetables 30 %. Precautionary measures were proposed, e.g. that the authorities should continue developing methods for collection and reporting of data from radiation measurements. As regards sanitation after the fallout, resources should be spent on a relatively strong national emergency organization. The counties should improve the sanitation measures so that a detailed plan could be initiated on a short notice, if deemed necessary. It was proposed that the Department of Agriculture in consultation with other proper authorities should be assigned to study the question of damages so that the Department relatively quickly could provide the government with a basis for a decision on a statutory instrument for compensation to the injured parties.

B. The difference between the Danish Emergency Management Agency's memorandum and the 1987 Secretariat Report

The Danish estimates: Triggered by the terrible happenings in New York the 11th of September, 21st of September 2001 the Danish Emergency Management Agency published a memorandum on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebäck nuclear power plant. The memo described a scenario where a fully tanked passenger or military airplane crashes into the Barsebäck nuclear power plant when the reactor is still running, causing a meltdown of the reactor fuel and simultaneously a heavy fire following the ignition of the airplane fuel causing radioactive substances from the reactor to fly high up into the atmosphere and to be spread out over a vast area. The memo also touched on the organizing of the Danish nuclear rescue preparedness. In its memorandum the Danish Emergency Management Agency used a worst-case scenario for a serious nuclear accident, i.e. a major accident categorized as a level 7 on the International Nuclear Event Scale ("INES" – about this concept, see chapter II), and claimed that acute casualties would not occur even in this situation, but that a number of children would suffer thyroid gland cancer and that a part of the population would be afflicted by belated damage in the form of leukaemia and other cancer types, hereditary diseases and foetus damage. The worst consequences would consist of an increase of cancer cases over a generation. However, the increase would be so limited compared to the total number of cancer cases in society that it probably could not be registered statistically. The socio-economic consequences of a nuclear disaster were not mentioned, nor the consequences for the environment. As regards the description of the long-term effects, the memo took its starting point in a report published by the Danish Department of the Environment in 1982 – before the Chernobyl disaster: *"Radioactive ground-contamination in Denmark after a possible serious nuclear accident in the Barsebäck nuclear power plant"*.

The conclusion of the memorandum was that most of the negative consequences of the worst possible accident in the Barsebäck nuclear power plant could be avoided if people stayed indoors and some types of food were to be restricted.

The Danish nuclear rescue preparedness plan is based on the scenarios presented in this memorandum[2]. The memo recommends evacuation of people living close to a nuclear power plant that has had a serious accident – normally within an emergency zone in a distance of 10-15 kilometres from the plant. As regards evacuation of people who live further away it states the following: "Evacuation of people further away is more doubtful because it cannot be determined in advance which areas will be affected. Furthermore, evacuation of larger groups of the population are time and resource consuming measures that are inconvenient and of radical nature for the affected people and for society. Also, there is a risk that the evacuation will not be completed before the passing of the radioactive clouds. Evacuation before the passing of the radioactive clouds will normally not be appropriate under Danish conditions but cannot be excluded in residential areas in the vicinity of the Risø National Laboratory (p. 24)".

The Swedish estimates: *The following is the scenario that one of the directors of SKI, Christer Viktorsson, recently confirmed in a statement to the daily MetroXpress.* Because of the Chernobyl catastrophe that caused damage in Sweden as well, 11th of June 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[3]. 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[4].

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: **If the safety filter 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 Barsebäck nuclear power plant the whole Øresund region) within a month. Evacuation of all pregnant women up to 100 kilometres in the direction of the wind (half of Seeland) within a month. Recommendations to stay indoors and eat iodine tablets up to 100 kilometres in the direction of the wind (half of Seeland) before the passing by of the radioactive clouds[5]. **If the safety filter does not work:** Evacuation of the entire

---

2 The rules governing the nuclear rescue preparedness have been laid down by the Minister of the Interior according to § 5 subsection 2 in the Preparedness Act. This includes "the organization of the rescue preparedness in the event of any accident in nuclear plants including the distribution of tasks and the cooperation between the national rescue preparedness and the municipal rescue preparedness, respectively, and the activities of the rescue preparedness compared with the activities of other authorities within the preparedness structure".

3 In the committee 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 mnistry 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).

4 The most significant parts of the report can be found in http://www.greenpeace.se/files/2000-2099/file_2097.pdf

5 See the report p. 160-161.

population in a 60 kilometres zone from the power plant in the direction of the wind (the whole Øresund 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 Øresund region) in case of a radiation release and in a 100 kilometres zone (half of Seeland) within 24 hours. Evacuation of all pregnant women in a 500 kilometres zone from the power plant within 24 hours 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[6].
In the Danish Emergency Management Agency's memorandum it was assumed that the safety filter did not work, because it described a worst-case scenario.
As regards the consequences for the rescue preparedness, the Secretariat Report does not distinguish between an accident in the Barsebäck nuclear power plant and the other Swedish nuclear power plants. For instance, the so-called indication zone (up to 50 kilometres from the nuclear power plant) is the same for the Barsebäck nuclear power plant as for the other nuclear power plants (see the report's p. 92-93).

B. A report from 1989 backs up the Secretariat Report

The rescue preparedness estimates of the 1987 Secretariat Report are dealt with again in 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. Both reports were examined by various organizations and authorities and the examinations were integrated into the report. As part of the basis for the 1989 report were also considerations from some working groups that were appointed in 1988 and dealt with topics such as information, education and exercise, health care, cooperation, research and harmonization of activities in peace and war. 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, among others that the municipalities should plan warning systems and dispersion of information to the population, that the county councils should be responsible for sanitation after a release of radioactive substances and that the number of measuring stations should be increased, including an increase in the resource allocation for more advanced measuring systems.
The 1989 Report backs up the estimates of the Secretariat Report as regards a serious accident in a Swedish nuclear power plant and even discusses, whether the estimates of the Secretariat Report in certain respects are not pessimistic enough. It concludes that although the release-minimizing measures have reduced the risk of release of radioactive substances into the environment, it can still not be excluded that a large-scale release could occur in case of a serious accident, especially if the safety filter does not work.
On p. 57-58 in the report, the following is stated: (4.1.3. *Lessons learned from the nuclear accident in Chernobyl*) "**According to both SKI and SSI, the consequences of the accident in Chernobyl more or less confirm the earlier assessments of the effects of serious nuclear accidents** (BBOFF's accentuation). However, the destroyed Soviet reactor was a graphite moderated channel-boiler reactor that differs from the Swedish light-water reactors on crucial

[6] Ibid. p. 161-63.

points. It is not the opinion of SKI – and the Energy Council has made the same estimate – that the accident in Chernobyl technically speaking changes the risk scenarios for the Swedish reactors. **However, the accident throws light on the consequences in general of very serious nuclear accidents** (BBOFF's accentuation). After the implementation of the release-reducing measures in the Swedish nuclear facilities, **an accident causing a release of the same type and size as the one in Chernobyl belongs to the rest risk category as regards the Swedish facilities.**

The investigative commission emphasized in its earlier report that the assessment of the risks of accidents also applies to the Swedish reactors (BBOFF's accentuation). (…) Since this report the Soviet authorities have presented new information on the Chernobyl fallout. It confirms earlier information on the fallout in the 30 kilometres zone near the reactor. **However, it seems that another area – bigger than the first one – has been heavily contaminated. This area is situated approximately 200 kilometres northeast of the reactor. The Soviet authorities contemplate extensive protective measures in this area. Before the accident a total of 270.000 people lived in this area, where especially comprehensive protective measures could be implemented** (BBOFF's accentuation).

4.1.4 *SSI's assessments*

In connection with this investigation SSI has carried out schematic calculations of the correlation between the distance from the release source and the maximum radiation dose, a person can be exposed to the first 24 hours after the passing by of the radioactive clouds. The assessments that are described in section 5.2 in the Secretariat Report on society's measures against serious accidents (see section I.B) are based on calculations from the Risø National Laboratory and the Swedish Defence Research Centre.

The information presented in the previous section on another large contaminated area in the Soviet Union after the Chernobyl accident does not change the basis for the threat scenarios. **According to SSI, this information is a concrete example of the risk of heavy radioactive contamination over great distances that was described in the Secretariat Report** (BBOFF's accentuation)".

Regarding the question of rest risk criteria the 1989 Report represents an intensification compared with the Secretariat Report, what the following quote is an example of: "In the investigative 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.

On the service duty: The 1989 Report concludes that the situation after a serious nuclear accident will be such that it would be necessary to mobilize all the resources of society. Consequently, it wants to authorize the authority that is responsible for the rescue preparedness to collect the necessary resources through service duty and intervention in others' rights (p. 243-45). As regards these proposals the committee member Birgitta Hambraeus gave the following dissenting opinion ("Do not extend the service duty and the availability act", p. 286-87): "I do not think that the service duty or the availability act should be extended to the long-lasting sanitation work after a nuclear accident.

The Chernobyl accident is not over, neither here in Sweden nor in the Soviet Union. The sanitation work still continues in Ukraine.

In its latest meeting, the commission was informed that an area 200 kilometres from Chernobyl had a radiation contamination level just as high as the contamination level near the reactor.

According to information from SSI 30.000 people worked from the beginning under high radiation levels. Among other things they buried the reactor, helped stop contamination of water resources, removed masses of earth, sandblasted streets and houses, etc. At this particular point in time approximately 6.000 people are involved in this kind of activities.

The commission proposes that the service duty should be extended to include sanitation work (p. 244). For several years the authorities should be able to order various people to work in a dangerous environment in which one is unaware of how much radiation exposure one gets.

The commission also wants an amendment of the availability act (p. 283) so that society can control the machines, buildings, etc. that are needed, whether the owners accept it or not.

I oppose this proposition. Instead, the commission should have proposed that the government should investigate if enough people are willing to volunteer and enough owners of the necessary equipment for sanitation are willing to place it at the disposal of society.

In order to give a realistic picture of what this work implicates, the lessons learned from the sanitation work after the Chernobyl accident should be taken into consideration. **At lot of things indicate that all of the resources of Sweden would not be enough** (BBOFF's accentuation)".

D. " Consequences in Sweden of a serious nuclear accident"

In two of the answers to Keld Albrechtsen and Pernille Blach Hansen the Danish Emergency Management Agency refers to a Swedish 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, and **mentions it as the one, whose estimates it is that primarily are the basis of the Danish nuclear rescue preparedness.** The agency rejects the 1987 Secretariat Report arguing that its assessments are based on a bigger reactor than Barsebäck 2 and therefore "over-estimates the possible consequences in Denmark of the worst possible accident" and refers instead to the 1995 report that "to a higher degree takes into account the consequences of the Chernobyl disaster". In the answer to Pernille Blach Hansen the following is stated: "In the (1995) report there is no distinction between an evacuation before and after a possible passing by of radioactive clouds. The Danish Emergency Management Agency has compared the analyses of the report with the Barsebäck situation and it is the opinion of the Agency that even in the case of the worst possible accident in the Barsebäck nuclear power plant, it will not be necessary to carry into effect an evacuation *before* a possible radioactive cloud passage over Denmark. However, it has to be expected that the protective measure "go inside" will be brought about.

The primary reason that there will be no need for an evacuation is that Barsebäck reactor 2 has only 600 MW electrical effect compared to other Swedish reactors that are 1000 MW and that Danish houses generally offer a better protection against radiation that the Swedish wooden houses. Furthermore, the international standard only prescribes evacuation before the passing by of the radioactive clouds in the immediate vicinity of the nuclear power plant, i.e. within the limitations of the inner emergency zone 10-15 kilometres from the plant. These guidelines are also followed in Sweden. SSI has informed The Danish Emergency Management Agency that there are no plans to evacuate Malmø and Lund before a possible radioactive cloud passage over these cities, even though they are situated closer to the nuclear power plant than Copenhagen itself (BBOFF's accentuation)".

In this section of the paper BBOFF will discuss whether SKI's and SSI's report from 1995 confirms the Danish Emergency Management Agency's three main assertions: That there is no cause for evacuation, because Barsebäck 2 has a smaller effect than the other Swedish nuclear power plants, that Danish houses in general give a better protection against radiation than the Swedish wooden houses and that the Swedish authorities do not have any plans for the evacuations of Malmø and Lund before a possible passing by of radioactive clouds, although they are closer to the Barsebäck nuclear power plant than Copenhagen. **In this context it is worth noting that neither the 1987 Secretariat Report nor the 1989 Report distinguishes between the Barsebäck nuclear power plant and the other Swedish nuclear power plants, consider the building material of the Swedish houses important or reject the necessity of evacuating Malmø and Lund before the radioactive clouds pass by.**

The report *Consequences in Sweden of a serious nuclear accident* 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 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 notable that the authors of the report – contrary to the Danish Emergency Management Agency – generally do not regard a serious accident in the Barsebäck nuclear power plant less dangerous than releases from the other Swedish nuclear power plants – in certain respects they consider the Barsebäck nuclear power plant more dangerous – and that the report states that its consequence scenarios for releases from serious reactor accidents **are representative of all the Swedish reactor types**, see p. 1 and 27. 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 Barsebäck reactor, the consequences of an accident will be limited (a so-called "realistic accident release"[7]). 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**

[7] 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 Barsebäck 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.

the Barsebäck nuclear power plant is expected to have more serious consequences. The cases of cancer will occur within a 70 kilometres zone from the reactor[8].

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”[9]), 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 Barsebäck 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**, i.e. the “very unlikely, but theoretically possible case, where the release reducing precautions cannot be utilized, the consequences are significantly more substantial[10]”. In this very substantial release 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 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[11]. The maximum doses are directly proportionate to the actual thermal effect.** The collective doses for the Barsebäck 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**

---

[8] Ibid. p. 23.

[9] 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.

[10] As regards **the Barsebäck nuclear power plant** this scenario is described as follows: ”Large floor rupture in the BWR (Barsebäck) 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, Annex 1, *SKI – PM, Representative källtermer vid haverier i svenska reaktorer*, p. 4.

[11] Ibid. p. 27.

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 [12], thus confirming the worst-case scenarios of the 1987 Secretariat report and the 1989 Report.

As regards **a quick evacuation of the population in particular around the Barsebäck nuclear power plant** it is stated in the report (p. 30-31): "According to the table (The result of a probabilistic calculation of the probability level for the collective fallout (foodstuffs excluded): Table 6. *Probability levels (for Barsebäck, Ringhals, Oskarshamn, Forsmark) for collective doses (manSv) after a rest risk accident, no counter-measures.* Indications for Barsebäck: 10 %: *10.000*, 50%: *30.000*, 90%: *130.000*, 95%: *160.000*, 99%: *560.000*, 99,9%: *1.300.000*) up to the 95 % level the fallout 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 Barsebäck nuclear power plant get considerably bigger than in the other plants. The assessment does not take into consideration that the population in the most affected areas have to be evacuated and that sanitation attempts will have to be made. A simplified calculation of the consequences of an evacuation leads to the result of table 7 (Table 7. *Probability levels for collective doses (manSv) after a rest risk accident after an evacuation of the population.* Barsebäck: 10%: *10.000*, 50%: *26.000*: 90%: *100.000*, 95%: *130.000*, 99%: *160.000*, 99,9%: *210.000*) **The consequences are dramatic in Barsebäck's case where substantial parts of the collective dose are received in areas with high radiation levels that have to be evacuated** (BBOFF's accentuation)".
The conclusion of the above-mentioned is that **the report does not confirm the answers of the Danish Emergency Management Agency to Keld Albrechtsen and Pernille Blach Hansen.** The report states emphatically that **the consequences of an accident in the Barsebäck nuclear power plant are bigger than in the other Swedish nuclear power plants** in case of the so-called "realistic" and "nominal" accidents. Only in a case of a rest risk accident the consequences in Ringhals and Forsmark are worse. **Nevertheless, the areas surrounding the Barsebäck nuclear power plant will have to be evacuated as quickly as possible.** The report does not confirm that building materials are significant for radiation protection. That an evacuation of Malmø and Lund before the release is not recommended is only because **the release happens so quickly that there is simply not time to carry it out.**

E. A comparison between Chernobyl and the Barsebäck nuclear power plant

In its answers to the two members of parliament the Danish Emergency Management Agency thrice refers to "the international practices for radiation protection" and at the same time claims that its consequence scenarios and the rescue preparedness measures as regards the worst possible accident in the Barsebäck nuclear power plant are in accordance with these practices. In section I.F BBOFF will try to take a closer look at what lies in the concept "international practices for radiation protection".

[12] **Table 8, Deposition Cs-137 a month after release. 2000 MW (thermal) reactor "rest risk ‚release"**, p. 31-32.

First, however, it is necessary to establish that since 1986 **the all-important standard for the worst possible accident in a nuclear power plant are the consequences of the Chernobyl disaster**. Consequently, the international practices for radiation protection are based on the lessons learned from Chernobyl. Nevertheless, the continuously growing complex of problems emanating from this accident is far from constituting an exact science. 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**[13] www.chernobyl.info

A quick glance at the website and some of the most important reports in this field 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. **On the other hand, the socio-economic consequences from the Chernobyl disaster for the two most affected countries, Ukraine and Belarus, are beyond discussion.** 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.

Partly in order to determine whether the rescue preparedness measures that the Danish Emergency Management Agency claims are sufficient to remedy the short-term consequences of the worst possible accident in the Barsebäck nuclear power plant are in accordance with "international principles for radiation protection" and partly in order to determine, whether the long-term scenario they reflect is realistic, it is necessary to determine **to what extent the Chernobyl disaster is comparable to the worst case scenario for a serious nuclear accident in the Barsebäck nuclear power plant**.

A comparison between the Chernobyl disaster and the worst-case scenario for a serious nuclear accident in the Barsebäck 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 Barsebäck 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. For instance, the 1995 report which the Danish Emergency Management Agency

---

[13] 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. The website reflects the need for objective, neutral information on the accident in Chernobyl and its consequences. It describes its legitimacy the following way: " Although a great deal of information about Chernobyl is available, on the Internet and elsewhere, each source represents its own interests, which are not always immediately apparent. In addition, there is no website that provides a general, coherent and up-to-date overview of the subject. This situation has created uncertainty about many issues, both internationally and among the local population (…) In certain cases it is unclear where genuine gaps in our knowledge exist and where information has simply not been processed or has not been made public", http://www.chernobyl.info/en/Strategy/Leitbild".

refers to, when it defends the Danish nuclear rescue preparedness plan, defines a rest risk release as "very substantial releases (in which apart) from the whole inventory of noble gasses more than a tenth of the reactor inventory of iodine, cesium and tellur is released. The heavier substances are expected to be more contained[14]". **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 Barsebäck 2 reactor derives from the released fraction of the core inventory. **The reactor core of Barsebäck 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)**.[15]
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[16]. 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[17]. Nuclear Energy Agency's (NEA) report from 2002, *CHERNOBYL, Assessment of Radiological and Health Impacts*[18], 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**[19] (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[20]. However, some estimates differ significantly from the above-mentioned[21].
Based on these figures, a release of 7,7 % the reactor fuel in Barsebäck 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

---

14 P. 27.
15 http://www.barsebackkraft.se/index.asp?ItemID=1291
16 Jf. http://www.chernobyl.info/en/Facts/Contamination/AmountRadiation
17 Jf. http://www.world-nuclear.org/info/chernobyl/inf07.htm
18 *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
19 Ibid. p. 33.
20 *Consequences in Sweden of a serious nuclear accident, 11 Bilaga 2. SSI-PM. Inträffede reaktorolyckor*, p. 6.
21 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.

release higher than 51 % from Barsebäck 2 will exceed the release from the Chernobyl reactor.
In this context it is worth noting that the scenario for the rest risk release described in the 1995 Report from SKI and SSI, which the Danish Emergency Management Agency claims that the Danish nuclear rescue preparedness plan is based on, is comparable to the above-mentioned actual Chernobyl release scenarios.

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[22], **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[23]. This leads to the question, how much caesium-137 there would be in the Barsebäck 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[24] 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. **more than in the Chernobyl reactor**.
The Chernobyl release of caesium-137 equals a release of 25 % of the caesium-137 inventory in Barsebäck 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[25].**
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.

---

[22] *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

[23] 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

[24] **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 (measured in tons of material) is obtained by multiplying a power (GW) by a lengthtime (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.

[25] *Consequences in Sweden of a serious nuclear accident*, p. 31-32.

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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 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, *Swedish implementation of the obligations of the Joint Convention*, Ds 2003:20, 180 pages[26], 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 Barsebäck plant's own website[27], 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, (Table D.32.2.1 *Interim storage at the nuclear power plants*, p. 30) Barsebäck 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**

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

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

Barsebäck 2 as of December 31st 2001, this amount being surpassed only by Oskarshamn 1 (120 tons) and Ringhals 2 (84 tons)[28].

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[29]. 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 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**[30]**.** 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[31].

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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 2 reactor could be comparable to the Chernobyl disaster.

---

28 The table gives the following inventory list for the Swedish nuclear power plants (**Spent nuclear fuel stored 2001-12-31:** *No of fuel assembly positions, no of assemblies, tons*): **Barsebäck 2**: 644 405 72, Oskarshamn 1: 894 706 120, Oskarshamn 2: 935 369 65, Oskarshamn 3: 918 188 38, Forsmark 1: 1) 612 263 47, Forsmark 2: 1) 491 351 65, Forsmark 3: 1) 1 040 284 51, Ringhals 1: 644 268 46, Ringhals 2: 260 200 84, Ringhals 3: 212 167 72, Ringhals 4: 190 163 71. Notes 1) Data from 2002-10-01.

29 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.

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

31 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

F. Chernobyl and the consequences of the Chernobyl disaster

The Chernobyl nuclear power plant, its location and surroundings: The Chernobyl nuclear power plant lies in Northern Ukraine, only 7 kilometres from the Belarus border, in an area of wet woodlands near the river Pripyat that runs into the Dnjepr. The town of Pripyat that was built particularly for the workers of the plant is located four kilometres away from the reactor complex. A total of 76 settlements are found within a radius of 30 kilometres from the reactor. Kiev, the capital of Ukraine with more than 3 million inhabitants, is located 100 kilometres to the south.

The reactor: The four RBMK-1000 reactors at Chernobyl represent crude, 30 year old technology, similar to that used by Enrico Fermi at University of Chicago's Stagg Field in 1942 to create world's first chain reaction. About half of soviet reactors use graphite moderators. Reactor no. 4 was a light-water-cooled graphite-moderated Boiling Water Reactor (BWR). In this type of reactor, the neutrons released by the fission of uranium-235 nuclei are slowed down by graphite so as to maintain a chain reaction. The heat produced by the nuclear fission in this type of reactor is used to boil water. The steam thus generated drives the turbines of the power station.
Western nuclear experts have criticised this type of reactor primarily because it lacks a containment structure and requires large quantities of combustible graphite within its core. The reactor had an electrical effect of 1000 MW and a thermal effect of 3200 MW, http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/cherno2.html#c3

The accident: The accident in reactor no. 4 at the Chernobyl nuclear power station took place in the night of 25 to 26 April 1986 causing the biggest industrial disaster in the history of mankind. Hundred times more radiation than from the nuclear bombardments of Hiroshima and Nagasaki was released into the environment. The accident happened during a test. The operating crew planned to test whether the turbines could produce sufficient energy to keep the coolant pumps running in the event of a loss of power until the emergency diesel generator was activated. In order to prevent the test run of the reactor being interrupted, the safety systems were deliberately switched off. For the test, the reactor had to be powered down to 25 per cent of its capacity. This procedure did not go according to plan: for unknown reasons, the reactor power level fell to less than 1 per cent. The power therefore had to be slowly increased. But 30 seconds after the start of the test, there was a sudden and unexpected power surge. The reactor's emergency shutdown, which should have halted the chain reaction, failed. Within fractions of a second, the power level and temperature rose many times over. The reactor went out of control. There was a violent explosion. The 1000 tons sealing cap on the reactor building was blown off. At temperatures of over 2000°C, the fuel rods melted. The graphite covering of the reactor then ignited. In the ensuing inferno, the radioactive fission products released during the core meltdown were sucked up into the atmosphere, http://www.chernobyl.info/en/Facts/Accident/Explosion

Dealing with the accident: To put out the fire and thus stop the release of radioactive materials, fire fighters pumped cooling water into the core of the reactor during the first ten hours after the accident. This unsuccessful attempt to put out the fire was then abandoned. From 27 April to 5 May, more than 30 military helicopters flew over the burning reactor. They dropped 2400 tons of lead and 1800 tons of sand to try to smother the fire and absorb the radiation.
These efforts were however unsuccessful. In fact they made the situation worse: Heat accumulated beneath the dumped materials. The temperature in the reactor increased again, and thus also the quantity of radiation emerging from it. In the final phase of fire fighting, the core of

the reactor was cooled with nitrogen. Not until 6 May were the fire and the radioactive emissions under control.

The 600 men of the plant's fire service and the operating crew, who were employed in fire fighting, were the most severely irradiated group. 134 of them received doses of radiation between 0,7 and 13 sieverts (Sv). This means that within a few hours they received **a quantity of radiation up to 13.000 times higher than 1 millisievert**: In the European Union, 1 millisievert per year is the maximum effective dose of radiation to which individuals in the population near a nuclear power station should be exposed.

31 workers died shortly afterwards. A total of around 800.000 men were involved in the clean-up operations in Chernobyl up until 1989. Today, they are still suffering from the damage to their health. 300.000 of them are believed to have received doses of radiation of more than 0,5 Sv. How many of them have died to date from the effects is a controversial question. According to government agencies in the three former Soviet States affected, about 25 000 "liquidators" have so far died, http://www.chernobyl.info/en/Facts/Accident/DealingTechnical

Humanitarian measures: On 27 April, only 36 hours after the accident, the 45.000 inhabitants of Pripyat, 4 km away, were evacuated in buses. The town remains uninhabited to this day. In the period up to 5 May, people living within a radius of 30 km around the reactor had to leave their homes. Within 10 days, 130.000 people from the 76 settlements in this area were evacuated. The territory has been declared **an exclusion zone**. Special permission is required to enter it. The aim is to prevent the spread of contamination. From 1 May 1986, monitoring of milk and drinking water started in the contaminated territories. On 23 May 1986, far too late from a medical point of view, the official distribution of iodine preparations began. These were intended to prevent the absorption of radioactive iodine by the thyroid –- but the greatest proportion of radioactive iodine had already been released in the first ten days following the accident, http://www.chernobyl.info/en/Facts/Accident/DealingHumanitarian

The consequences of the disaster: Most of the released radioactive substances settled near the reactor as dust and litter. However, the lighter material was carried away by the wind, mainly to Ukraine, Belarus and Russia, but also to a certain degree to Scandinavia and the rest of Europe. Apart from the close surroundings of the nuclear power plant other regions were contaminated too. 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.**

The effects on public health: Even sixteen years after the event, the full extent of the effects of the Chernobyl accident on human health cannot be grasped. 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**. These figures are however disputed, because they include all deaths from diseases that the body could no longer control because the immune system had been weakened as a result of radiation. Certain international organisations have only recognised as casualties the 31 power station employees and fire-fighters who died immediately after their deployment at the burning

reactor (e.g. this applies for the WNA. About the estimates of the Danish Emergency Management Agency on this topic, see Annex 3).
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**, http://www.chernobyl.info/en/Facts/HealthLongterm/Overview

What is the link between radiation and cancer ? Radiation that enters the body through respiration or digestion damages the DNA - the material in the cell nucleus that carries the genetic blueprint for cellular replication, structure and function. Such damage to the DNA may cause cancer and other genetic abnormalities. Scientific debate remains focused on the question whether even a few altered cells, or small amounts of radiation, are sufficient to trigger the growth of malignant tumours.
Much of the expert opinion on the link between cancer and radiation is based on the findings of the Life Span Study (LSS), which examined about 100 000 survivors of the atomic bombings of Hiroshima and Nagasaki.
On the basis of these studies, scientists at the International Commission on Radiological Protection (ICRP) established a formula for calculating the statistical individual risk of fatal cancer: **5 x 10-2/Sv**. For example, if 1 million people receive an effective dose of 1 sievert (Sv), 50 000 will contract cancer in the following decades (1 million x 5 x 10-2/Sv). This means that, with a dose of 10 millisievert (mSv), there will still be 500 additional deaths from cancer for every million people exposed.
These projections are disputed by independent radiation experts, who accuse the ICRP of bias and point to their own studies, which demonstrate that the ICRP has underestimated the radiation risk by a factor of 3 to 5. They also note that the membership of the ICRP consists primarily of people who have been delegated by governments with their own extensive nuclear energy programmes.
Furthermore, whether the ICRP formula can be applied to the consequences of the Chernobyl disaster is a moot point. In Hiroshima and Nagasaki the victims were exposed to high doses of radiation over a short period. In Chernobyl this applied only to the liquidators and the inhabitants of the exclusion zone, while the majority of the others affected have been exposed to low doses of radiation over longer periods.
To put this statistical model into perspective, a few examples of radiation doses absorbed after the Chernobyl accident may be considered. Among the liquidators, 134 people received doses of 0,7 to 13 Sv. At least 30 000 received a dose of more than 0.5 Sv. In nearby Pripyat, the radiation dose received by the inhabitants on the first day after the accident is estimated to have been about 6 mSv per hour. In the severely contaminated territories of Belarus, Ukraine and Russia, the population is still exposed to between 6 and 11 mSv per year. **This is 3 to 5 times the average level of background radiation (2,4 mSv) to which people in Europe are exposed**, http://www.chernobyl.info/en/Facts/HealthLongterm/CancersInGeneral

Breast cancer and other tumours are increasing: An increased incidence of breast cancer as a direct consequence of the accident has been recognised internationally. The number of cases has doubled in the area around Homel in Belarus - one of the most severely contaminated territories. Belorussian and Ukrainian scientists also predict an increase in urogenital tumours and lung and stomach cancer, both among the liquidators and in the general male population of the severely contaminated areas. This prediction is supported by cancer specialists in other countries.
There is no doubt among national and international experts that the state of health of the people in the contaminated territories is extremely poor. The latest report by UNDP and UNICEF cites a number of different causes: Poverty, poor diet and living conditions. According to the UNDP/UNICEF report, these factors may be reinforced by the psychosocial effects of the accident. The conclusions of this report have however been challenged by national and international experts. **The Ukrainian government agency Chernobyl Interinform in Kiev**

reported in March 2002 that 84 % of the three million people in Ukraine who had been exposed to radiation were registered as sick. These include one million children. According to the latest data from the Belorussian governmental Chernobyl Committee in Minsk, the average rate of illness among the inhabitants of the contaminated territories is higher than in the uncontaminated areas. The people in the uncontaminated areas are not, however, subject to any special monitoring, and there have been calls for additional comparative studies, http://www.chernobyl.info/en/Facts/HealthLongterm/Overview

About the connection between **radiation and thyroid cancer among children and adults**, see http://www.chernobyl.info/en/Facts/HealthLongterm/ThyroidCancerChildrenAdolescents, about **leukaemia among children and adults** as a result of the Chernobyl disaster, see http://www.chernobyl.info/en/Facts/HealthLongterm/LeukaemiaChildrenAdults, about **cancer among adults** as result of the accident, see http://www.chernobyl.info/en/Facts/HealthLongterm/CancerInAdults, about **other diseases among children and adults**, see http://www.chernobyl.info/en/Facts/HealthLongterm/OtherDiseasesChildrenAdults, about the accident's effects on **pregnancy**, see http://www.chernobyl.info/en/Facts/HealthLongterm/ComplicationsPregnancy, about the effects of the Chernobyl disaster on **future generations**, see http://www.chernobyl.info/en/Facts/HealthLongterm/GeneticDefects and abouts its **psychologial effects**, see http://www.chernobyl.info/en/Facts/HealthLongterm/PsychologicalConsequences

Below follows a short description on the consequences of the Chernobyl disaster on the three countries that was mostly affected, http://www.chernobyl.info/en/Facts/Countries

The effects of the Chernobyl disaster on Ukraine: After the accident, the contaminated areas where the ground contained more caesium 137 than 1 Ci/km2 were 43.500 km2, i.e. 7,2 % of the country's total area. Today, this area is 38.000 km2, i.e. 6,3 % of the country's total area (these territories are not identical with the territories that according to Ukrainian law have been divided into four zones after the accident. The four zones have a total area of 53.500 km2. See below)[32]. The contaminated areas are found in Northern Ukraine and south and east of Russia and Belarus and in the western border area between Russia and Belarus. 1986 lived 2,6 million people in these areas of which 2,29 still live there. Contrary to Belarus Ukraine's economy is growing. The BNP grew 9 % 2001 and in the same period the industrial production grew 14,2 %. This was primarily due to a 28 % growth in the wood industry, but in spite of this positive development the country's economy is still suffering under the consequences of the Chernobyl disaster. 35.000 km2 of woodland corresponding with 40 % of Ukraine's total forest area has been contaminated. According to information from the Ukrainian government agency Chernobyl Interinform, the government expenditure caused by the accident was **6 billion USD between 1991 and 2000.** Currently, **5 % of the national budget** is spent dealing with the effects of the Chernobyl disaster. Ukrainian experts estimate that **it will have cost the country a total of 201 billion USD 2015**, http://www.chernobyl.info/en/Facts/Countries/SituationUkraine
2002 the government of Ukraine published its official version of the effects of the Chernobyl disaster[33]. **Considering the comparability of the worst possible accident in the Barsebäck**

[32] According to *Table from the Ministry of Emergencies of the Ukraine giving important figures on issues concerning the nuclear accident at Chernobyl* (http://www.chernobyl.info/files/doc/TabengKiew.pdf) 4.916 km2 were contaminated with **more than 5 Ci/km2 caesium 137** in 1986, 1.281 km2 with **more than 15 Ci/km2 caesium 137** and 515 km2 with **more than 40 Ci/km2 caesium 137**.

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

nuclear power plant with the Chernobyl accident and considering that it is a description of real events perceived by authorities whose task it is to remedy them, the scenario below could be one of the most realistic version of how the consequences of the worst possible accident in the Barsebäck nuclear power plant would be in Denmark. The document is rendered in excerpts.

” In accordance with the Laws of Ukraine the zones of radioactive contamination on the territory of the country have been classed into four categories.
The first zone is recognized as the exclusion Zone. It includes the most contaminated as the result of the accident areas, the population of which was resettled in April – May 1986. During this period an estimated 91.000 people were evacuated from 76 settlements of Kyiv and Zhytomyr regions (including towns Prypyat and Chornobyl).
The second zone is the zone of the absolute (mandatory) resettlement incorporates the territories, which were exposed to the intense contamination by long-lived radionuclides, where the density of soil contamination by caesium isotopes ranges from 15,0 Ci/km2 and higher, or 3,0 Ci/km2 and higher by strontium, or 0,1 Ci/km2 and higher by plutonium, and where the estimated equivalent radiation dose with due account of radionuclide migration in plants and other factors may exceed 5,0 mSv (0,5 rem) per year above the pre-accident radiation dose.
The third zone, which is recognized as the Zone of the guaranteed voluntary resettlement, qualifies as the territory, where the density of soil contamination exceeds the pre-accident level and ranges from 5,0 to 15,0 Ci/km2 by caesium isotopes, or from 0,15 to 3,0 Ci/km2 by strontium, or from 0,01 to 0,1 Ci/km2 by plutonium, and where the estimated equivalent radiation dose with due account of radionuclide migration in plants and other factors may exceed 1,0 mSv (0,1 rem) per year above the pre-accident radiation dose.
The fourth zone is distinguished as the Zone of the intensified radiological control. It is assigned to the territories, where the density of soil contamination exceeds the pre-accident level and ranges from 1,0 to 5,0 Ci/km2 by caesium isotopes, or from 0,02 to 0,15 Ci/km2 by strontium, or from 0,005 to 0,01 Ci/km2 by plutonium, subject to the condition that the estimated equivalent radiation dose with due account of radionuclide migration in plants and other factors may exceed
0,5 mSv (0,05 rem) per year above the pre-accident radiation dose.
(…)
The territories of the less contaminated third and fourth zones are used for agricultural production and the products received from these territories are used for consumption after they undergo radiation control. **With respect to the territory of the exclusion Zone along with the added territories of the Zone of absolute (mandatory) resettlement, together accounting for 2600 square kilometres, there are no prospects of their use for agricultural production for the years immediately ahead, because of the significant radionuclide contamination** (BBOFF’s accentuation).
(…)
At present the radioactively contaminated territories of the first and the second zones are not inhabited: The exclusion Zone, whose 91.000 inhabitants were resettled in 1986, and the zone of absolute (mandatory) resettlement, whose population was resettled in the last years.
(…)
The risk (of contamination for the population) exists in several planes:

- **first, the contamination of the population via the radioactively contaminated potable water, since around 30 million people inhabit the area of the Dnipro river basin** (BBOFF’s accentuation);
- second, via flora and fauna, to which radionuclides transfer through water;
- third, via hidrobionts exposed to radiation, in which radionuclides accumulate;

In addition the contaminated reservoirs represent certain hazard when using water for irrigation.
(…)
At present the population of the Ukrainian Polissya region receive from 80 to 95% of the total radiation dose at the expense of the consumption of contaminated foodstuffs of the local produce, and in some settlements it runs as high as 98%. It is formed mostly on account of the consumption of milk and meat of mainly individual production, and comprises 70-90% of the diet.
The network of the radiological control points plays an important part in prevention of additional exposure. The laboratories and radiological control points of seven ministries and departments have been implementing an extensive program of foodstuffs radiation control at all stages of their production. In 2000 more than one million samples of foodstuffs were analyzed for radionuclide content, and close to 900 thousand samples in 2001.
(…)
Commencing the time of the disaster the annual growth of morbidity rate has been registered among the suffered population. As many as 84% of the total three million people suffered from the consequences of the

Chernobyl disaster have been registered sick, over one million of them are children. About 92 % of the total number of over than 336 thousand mitigators of the consequences of the accident at the Chernobyl nuclear power plant have been recognized sick (BBOFF's accentuation).
In areas exposed to radiation the birth rate has drastically dropped and the death rate on the contrary has increased. This negatively affects the general demographic situation governing the depopulation processes.
(…)
As a result of the Chernobyl disaster about 3,5 million inhabitants of Ukraine received additional radiation doses. This figure includes 1,3 million children, who require close attention. More than 90 thousand people have already become disabled. The number of the thyroid cancer cases has increased several times (BBOFF's accentuation).
(…)
The Chernobyl accident caused severe losses in economy and social sphere.
The accident shattered the customary vital activities and energy output for the needs of the economy, considerable damage was caused to the agricultural and industrial facilities, and also to forestry and water management.
(…)
According to the estimates of Ukrainian experts the aggregate economic damage caused by the Chernobyl accident to Ukraine will approximate 201 billion US dollars by year 2115. The Ukraine's gross national product made up 201 billion 927 million hryvnyas (37 billion 533 million US dollars) in 2001 (BBOFF's accentuation)".

The effects of the Chernobyl disaster on Belarus: **Belarus is the country mostly affected by the accident.** 22 % of the country that has a size of 207.600 km2 or 46.100 km2 – an area the size of Switzerland or Denmark – was contaminated by caesium-137 with levels higher than 1 Ci/km2[34]. At the time of the disaster 2,2 million people lived in this area. Beginning of 1996 1,8 million people still lived there, including half a million children. As in Ukraine the contaminated territories are divided into four zones. The area with the highest level of radiation is situated around the regional capital of Homel where some of the ground is still contaminated with more than 40 Ci/km2 caesium-137. There are still contaminated areas around Mahilyow and south of Brest. The population has been decreasing in number since 1996 as has life expectancy. When the Soviet Union fell apart, Belarus was the most economically developed of all the Soviet republics, but **the Chernobyl disaster robbed the country of 22 % of its arable land and 21 % of its woodland**. The Chernobyl State Committee in Minsk that is responsible for dealing with the consequences of the accident estimates **the economic loss for the country to be 235 billion USD**. This amount is 32 times the 1985 national budget. Currently, 10 % of the budget is spent on dealing with the consequences of the accident, http://www.chernobyl.info/en/Facts/Countries/SituationBelarus
2002 the government of Belarus published its official version of how the country has been affected by the Chernobyl disaster[35]. **Together with the scenario for Ukraine this scenario could probably be one of the best descriptions of the consequences in Denmark of the worst**

[34] In *Table from the Belarussian governmental Chernobyl Committee of the Republic of Belarus on important issues concerning the nuclear accident at Chernobyl* (http://www.chernobyl.info/files/doc/TabE_Minsk.pdf) the size of the areas **contaminated with 1 to 5 Curie/km2 caesium-137** are estimated to be: In 1986 29.700 km2 (14%), in 1993 29.348 km2 (14%) and in 1996 30.520 km2 (15%). The areas **contaminated with 5 to 15 Curie/km2 caesium-137**: In 1986 9.400 km2 (4.5 %), in 1993 9.918 km2 (5 %) and in 1996 – 8170 km2 (4 %). The areas **contaminated with 15 to 40 Curie/km2 caesium-137**: In 1986 4.400 km2 (2 %), in 1993 4.179 km2 (2%) and in 1996 2.800 km2 (1.4 %). The areas **contaminated with more than 40 Curie/km2 caesium-137**: In 1986 2.600 km2 (1.3 %), in 1993 2.074 km2 (1 %) and in 1996 1.020 km2 (0.5 %). **The number of persons who lived and live in the contaminated areas:** In 1986 - 2,2 million 01.01.91 – 1.852.949, 01.01.95 – 1.840.951, 01.01.99 – 1.618.580, 01.01.00 – 1.571.036, 01.01.01 – 1.565.246, 01.01.02 – 1.558.441.
[35] *Official statement by the Chernobyl Committee of the Republic of Belarus on important issues concerning the nuclear accident at Chernobyl,* http://www.chernobyl.info/files/doc/InterMinskE.pdf

possible accident in the Barsebäck nuclear power plant. The document is rendered in excerpts.

”In Belarus at the moment, 43,400 square kilometres (21% of the Republic’s entire territory) are contaminated by caesium-137 (half-life 30 years) to levels above 37 kBq/km2 (1 Ci/km2) in the soil. The radioactive caesium is irregularly distributed over Belarussian territory; most of the contaminated areas are around Gomel, Mogilev and Brest.
Contamination of the Republic’s territory through radioactive strontium-90 (half-life 29 years) has a more local character. Strontium-90 (at levels above 5.5 kBq/km2) has been detected in the soil over an area of 21,100 square kilometres, or 10% of the Republic’s territory (mostly around Gomel and Mogilev).
Contamination of the soil by isotopes of trans-uranium elements (plutonium-238, half-life 88 years; plutonium-239, half-life longer than 20 thousand years; plutonium-240, half-life longer than 6 thousand years; plutonium-241, half-life 14 years) at concentrations above 0.37 kBq/km2 affects about 4000 square kilometres (the territories of six Rayons in the Gomel Oblast, and one Rayon in the Mogilev Oblast), or about 2% of the territory of Belarus.
According to prognoses, the area of soil contaminated with caesium-137 at levels above 37 kBq/km2 (1Ci/km2) will in 2016 still be 33,000 square kilometres or 16% of the Republic’s territory. Official prognoses have not been made for strontium contamination. If you consider that the half-lives of caesium-137 and strontium-90 are similar, this is however not difficult to estimate. Prognoses relating to radioactive americium- 241 (a natural decay product of plutonium-241) show that up to 2058 the specific activity of americium will be 1.8 times the total activity of all the plutonium isotopes, which will make careful monitoring necessary.
(…)
There is a risk of diseases occurring, linked to the contamination of people who work in agriculture and the population of contaminated territories. In this connection, a governmental programme has taken a whole range of risk-reduction measures. An existing, functioning network of radiological laboratories makes it possible to rule out completely that “dirty” foods from State-run farms are traded, or that contaminated produce from private cultivation turns up in markets.
(…)
There can be no talk of a broad offensive on the exclusion zone (BBOFF’s accentuation). Territories on which cultivation is currently prohibited will be used only when it is possible to secure an adequate safety level for the population to live and go about their business.
(…)
Groundwater is the principal supply of drinking and household water. Investigations have determined that the concentration of 137Cs and 90Sr in the groundwater is no higher than the limits laid down by the Republic’s law. **Nevertheless, we should mention that the average concentration of the radionuclides in groundwater has risen over the course of the 16 years since Chernobyl, to 10 to 100 times the values before the accident** (BBOFF’s accentuation).
(…)
The main hazard for the population, caused by pollution of the water system, is the consumption of fish that were caught in rivers and lakes. It is common knowledge that in most of the affected areas of Belarus, the greatest proportion of the radiation dose is made up by internal irradiation as a consequence of eating food contaminated with radionuclides. One peculiarity of national daily life in Belarus is that privately caught fish and forest produce (wild berries, mushrooms and game) form a significant proportion of the rural population’s food. Many families obtain about as much food through fishing or collection as they grow themselves. This means that in places there are so-called risk groups (poor families, families with many children, hunters, foresters). The radiation dose of members of these groups can exceed the average dose (assumed by the State in determining the extent of radiation protection and social support measures) to the rest of the population in that place by many times. Precisely for this group, the risk of radioactive damage to their health is particularly great, and compensated for least by the measures mentioned above.
(…)
We currently estimate the latency period for radiation-linked diseases to develop at 10 to 15 years. We must admit that our knowledge of radiation as a health hazard is not sufficient. This is particularly the case for Official statement by the Chernobyl Committee of the Republic of Belarus on important issues concerning the nuclear accident at Chernobyl chronic low-dose radiation. There are reasons to think that the official estimate of risk is too low. This conclusion is confirmed by the fact that the presence of a significant increase of radiation-caused pathological thyroid cases was disputed for a long time and only recognised by WHO in 1995. According to prognoses by Belarussian and Ukrainian scientists, we expect primarily an increase in cancer of the urinogenital organs, followed by breast, stomach and lung cancers (BBOFF’s accentuation).
(…)

Among the population living in the contaminated territories, we have already observed a higher rate of diseases of the nervous and lymphatic system, the digestive tract and the blood, and a higher level of ischaemic heart disease (closure of the blood vessels). Dysfunctions of the reproductive system have been unambiguously observed, and the frequency of birth defects and developmental disorders in utero has risen. An important insight into this issue is given by a medical comparison of the liquidators of the Chernobyl disaster (in 1986 and 1987), who are subject to mandatory special medical monitoring, and the Belarussian people who are not subject to this monitoring. Among the liquidators, the rate of the following diseases is higher: ischaemic heart disease, 9.5 times higher; circulatory and lymphatic disorders, 7.4 times; diseases of the digestive system, 6.4 times; nervous system disorders, 3.2 times; malignant tumours in the thyroid gland, 2.5 times; tumours in general, twice as high.

There are serious reasons to believe that the children born between 1986 and 1988 are a group with elevated genetic risk (BBOFF's accentuation). Finding out the radioactive cause of the pathologies and other risk factors that lead to an increase of cases – possibly not directly linked to radiation – requires extended scientific research.

(…)

The total damage to Belarus caused by the Chernobyl disaster (calculated for 30 years of dealing with the consequences) comes to 235 billion US dollars, or 32 times the Republic's domestic budget of 1985. This figure includes the following: losses linked the deterioration in the population's health; damage to industry, the social sphere, agriculture, the building industry, transport companies, communications and housing; contamination of mineral raw materials, soil, water, forest and other resources; additional expenditure for remediating and reducing the impact of the catastrophe, and for providing secure living conditions for the population.

The greatest proportion (81.6%) of the total damage was spending to support the functioning of the farms and to carry out protective measures (191.7 billion US$). Direct and indirect losses made up approximately 30.0 billion US$ (12.6%). Loss of profits are estimated at 13.7 billion US$ (5.8%). Direct losses consist of the value of the proportion of the Republic's national reserves lost: dormant and operating value of farms, objects of social infrastructure, housing and natural resources.

Indirect losses include the losses through economic and social factors (general and living conditions, population's health) that affected 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.

The components of financial loss of profit are: decrease in volume of production, work and services in the contaminated territories; value of the farms that cannot be used because of contamination; additional expense for substituting products not received; costs of the rebuilding of lost production quality; losses through dissolution of contracts, annulment of projects, freezing of credit, payment of fines and penalties, interest. 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. (BBOFF's accentuation)".

The effects of the Chernobyl disaster on Russia: Of the total area of 17 million km2 comprised by the Russian Federation, 1,5 % is contaminated by radiation from the Chernobyl accident. In Russia an area is considered contaminated if the caesium-137 levels exceed 1 Ci/km2. 19 regions corresponding with an area of 59.300 km2 were affected, especially the areas around the cities of Bryansk, Kaluga, Tula and Orel. These lie in the westernmost part of the Russian Federation, close to the border with Belarus. At the time of the accident, about 2,7 million people lived in these areas. Today, about 2 million men, women and children continue to live there. These figures, however, depict only part of Russia's Chernobyl problem. 200 000 of the 800 000 "liquidators" (soldiers deployed to clean up the reactor compound) came from Russia. According to official reports from the three former Soviet states affected, 25 000 of these liquidators have since died. 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, http://www.chernobyl.info/en/Facts/Countries/SituationRussia

The effects of the Chernobyl disaster on other countries: Between April 26th and May 5th 1986, as a result of variable wind conditions, clouds of radioactive fallout were carried from Chernobyl first to Scandinavia, and then over Poland, Czechoslovakia, Austria, southern Germany and northern Italy. A third cloud finally reached the Balkans, Greece and Turkey. Within these countries, the soil was contaminated to varying degrees, according to where local showers fell.
According to the report *Consequences in Sweden of a serious nuclear accident* the most toxid fallout in **Sweden** landed in Gävle and along the coastline up to Umeå and in Vestnorrland's county where the radioactive substances were washed out in the rain. The most contaminated areas received approximately 100-200 kBq/m2 caesium-137. The highest radiation dose that any individual received in Sweden was less than 6 mSv during the first year. On the average the Swedish population received less than 0,1 mSv the first year after the accident. SSI estimates that 500 cases of cancer will occur in Sweden during af 50-years period. Of these approximately 300 will result in deaths[36]. The report *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) 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)[37].
Whether the fallout from Chernobyl will produce long-term health effects in Western Europe is a highly controversial issue. Ten years after the accident, the National Research Centre for Environment and Health (GSF) in Munich concluded that for **Germany**, "so far no radiation-induced biological effects have been observed, or are to be expected in future, in humans, animals or plants." By contrast, the Munich Environmental Institute points to a series of studies on infant mortality, a statistical increase in the incidence of cancer among children in the districts that had been highly contaminated, and birth defects in Bavaria and Berlin following Chernobyl.
By the 16th anniversary of the disaster, a total of 200 cancer patients in **France** had taken legal action against the state because in the days following the accident, Paris did not publish measurements or warnings concerning contaminated milk. According to the plaintiffs, information now available shows that sheep's milk on the French island of Corsica was contaminated with up to 10.000 Bq caesium in the weeks following the accident, http://www.chernobyl.info/en/Facts/HealthLongterm/ConsequenceOtherCountries

G. Conclusion

If one compares the competing risk and consequence scenarios for the Swedish nuclear power plants the way they are described in the agency's answers to the two politicians and the September 26th 2001 memo, it is evident that they are a far cry from the scenarios described in the 1987 Secretariat Report and the 1989 Report. None of the two documents distinguishes between the Barsebäck nuclear power plant and the other Swedish nuclear power plants, consider the building material of the Swedish houses important or rejects the necessity of evacuating Malmø and Lund before the radioactive clouds pass by. **Nor are the agency's scenarios similar to those described in the 1995 report "Consequences in Sweden of a serious nuclear accident" which the agency refers to as its main source.** As a rule the report does not distinguish between Barsebäck 2 and the other Swedish reactors – on the contrary it emphatically

[36] P. 6-7 in *11 Annexa 2. SSI-PM. Inträffede reaktorolyckor.*
[37] 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.

states that its consequence scenarios as regards very serious nuclear accidents are representative of all the Swedish reactor types. In the cases where it distinguishes between the Barsebäck nuclear power plant and the other nuclear power plants it stresses that the effects of a "realistic accident release" and a "nominal accident release" are worse at the Barsebäck nuclear power plant than at the other nuclear power plants. In principle, a release from the reactors in Ringhals and in Forsmark in case of a so-called "rest risk release" can be higher than a release from Barsebäck 2, but on the other hand it will be necessary quickly to evacuate the population around the Barsebäck nuclear power plant. However, it will not be possible to evacuate the inhabitants of Malmø and Lund before the passing by of the radioactive clouds, because the release will happen so quickly that it cannot be done.
No less than compromising for the Danish Emergency Management is the way the report assesses 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, 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, thus confirming the worst-case scenarios of the 1987 Secretariat report and the 1989 Report.

Especially regarding the Danish Emergency Management Agency's September 2001 memo, in which the agency describes a scenario where a fully tanked passenger or military airplane crashes into the Barsebäck nuclear power plant when the reactor is still running, it is evident **that there is no similarity between the memo and the 1987 Secretariat Report, the 1989 Report or the 1995 Report**. Where the memo states that the increase of the number of cancer cases will be so limited compared with the total number of cancer cases in society that the increase cannot be registered statistically, **the 1995 report talks of up to 2.000-8.000 cancer deaths and in the most unfavourable cases up to the double of this figure.**
In the answers to the two members of parliament the agency claims that the consequence scenarios that constitute the basis of the Danish rescue preparedness planning are "in accordance with international practices for radiation protection" – i.e. the lessons learned from the Chernobyl disaster – and in the September 2001 memo the agency refers to Chernobyl, when it describes the consequences of the worst possible accident in the Barsebäck nuclear power plant. Since 1995 a number of reports from international organizations have presented information that throws new light on the consequences of the Chernobyl disaster, but the Danish Emergency Management Agency has chosen to ignore the last eight years of research in this field.

Initially, a comparison between the Chernobyl disaster and the worst-case scenario for a serious nuclear accident in the Barsebäck 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 Barsebäck 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. For instance, the 1995 report which the Danish Emergency Management Agency refers to, when it defends the Danish nuclear rescue preparedness plan, defines a rest risk release as "very substantial releases (in which apart) from the whole inventory of noble gasses more than a tenth of the reactor inventory of iodine, cesium and tellur is released. The heavier substances are expected to be more contained". **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, 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 Barsebäck 2 reactor derives from the released fraction of the core inventory. **The reactor core of Barsebäck 2** contains **a weight of 76.4 tons of uranium**. 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. **Based on these figures, a release of 7,7 % the reactor fuel in Barsebäck 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 Barsebäck 2 will exceed the release from the Chernobyl reactor.**
In this context it is worth noting that the scenario for the rest risk release described in the 1995 Report from SKI and SSI, which the Danish Emergency Management Agency claims that the Danish nuclear rescue preparedness plan is based on, is comparable to the above-mentioned actual Chernobyl release scenarios.

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 estimate by the UNSCEAR committee, **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, while the Barseback inventory of caesium-137 should be approximately **a total of 105 kg** in the core, i.e. **more than in the Chernobyl reactor**.
The Chernobyl release of caesium-137 equals a release of 25 % of the caesium-137 inventory in Barsebäck 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.**
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 Barsebäck nuclear power plant. Exact figures cannot be extracted from an outside reference. **A second uncertainty factor** is the fact that the Ukrainian Chernobyl reactor is a RBMK, very different from the Swedish design. **A third uncertainty factor** is the pattern of the release scenario itself. **A fourth uncertainty factor is the quantities of spent fuel stored in the Barsebäck nuclear power plant**. Approximately a sixth of the fuel in the reactor, i.e. **15 tons**, is changed every year. However, an inventory status December 31st 2001 revealed that 405 spent fuel assemblies totalling a weight of **72 tons** were stored in Barsebäck 2. 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.
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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 2 reactor could be comparable to the Chernobyl disaster.

A quick glance at the research on the effects of the Chernobyl disaster 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. On the other hand, the socio-economic consequences from the Chernobyl disaster for the two most affected countries, Ukraine and Belarus, are beyond discussion. Striking is also the fact that any new estimate of the consequences of the Chernobyl disaster seems to be more pessimistic than the previous. Therefore, 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 foundation of society itself.
All new information on the Chernobyl disaster indicates that the consequences of a serious nuclear accident are far more serious than the Danish Emergency Management Agency presupposes in its calculations of the consequences of the worst possible accident in the Barsebäck nuclear power plant. 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. 31 workers died shortly afterwards. A total of around 800.000 men were involved in the clean-up operations in Chernobyl up until 1989. 300.000 of them are believed to have received doses of radiation of more than 0,5 Sv. How many of them have died to date from the effects is a controversial question. According to government agencies in the three former Soviet States affected, about 25.000 "liquidators" have so far died, because they were exposed 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 Barsebäck nuclear power plant would in Sweden include Malmö, Lund, Landskrona, Eslöv, Staffanstorp and at least twenty villages and in Denmark all of Amager, Copenhagen City, Frederiksberg, Vesterbro, Nørrebro, Østerbro, Vanløse, Brønshøj, Valby, Vigerslev, Hvidovre, Avedøre Holme, Brøndbyøster, Rødovre, Utterslev, Nordhavn, Bispebjerg, Hellerup, Husum, Mørkhøj, Gladsaxe, Søborg, Buddinge, Bagsværd, Vangede, Gentofte, Charlottenlund, Skovshoved, Jægersborg, Ordrup, Lyngby, Sorgenfri, Virum, Klampenborg, Tårbæk, Rådvad, Søllerød, Holte, Gl. Holte, Øverød, Nærum, Trørød, Skodsborg, Vedbæk, Sandbjerg, Isterød, Ravnsbjerg, Høsterkøb, Brådebæk, Hørsholm, Usserød, Vallerød, Rungsted and Kokkedal.** In this context it is worth noting that the 1987 Secretariat Report consequence scenario, one of the directors of SKI recently confirmed, has an **exclusion zone 100 kilometres in the direction of the wind**, and that the 1995 Report from SSI and SKI 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 Barsebäck 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**. 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. So far, this amount is **more than twice the total Danish BNP for 2002**[38]. 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 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 Barsebäck nuclear power plant is situated in the most densely populated area in

[38] The BNP 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

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 Barsebäck 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 BNP 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 2000 BNP per capita in Ukraine and 8 times higher than the 2000 BNP per capita in Belarus[39].**

II. How safe are the Swedish nuclear power plants?

The safety level of the Swedish nuclear power plants has a central position in the risk and consequence scenarios, both as regards the the possibility of an accident happening during the normal operation of the plants on a everyday basis and as regards the occurrence of external and extraordinary events which it is difficult or impossible for the operators to protect themselves against.

All the probability calculations that for 50 years have been the basis of the 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. March 2002 American government regulators acknowledged for the first time that none of the country's operating nuclear reactors could withstand the impact of an airliner the size of those that crashed into the World Trade Center and the Pentagon. A Boeing 757 or 767 weighs 272.500 to 450.000 pounds. The planes used in those attacks traveled at speeds of 350 mph to 537 mph when they struck. The NRC conceded that even an accidental airplane crash was not factored into the designs of 96 percent of U.S. nuclear plants. At those plants where the threat was considered, design changes were aimed at smaller airplanes traveling at slower speeds. The agency also acknowledged that critical systems that provide cooling, electricity and storage of spent fuel are mostly in non-hardened buildings that could not withstand an aircraft or missile attack[40]. The NCR even admitted that **an aircraft impact at the auxiliary electrical or cooling facilities could trigger a core meltdown at a nuclear reactor**.

In the context of security the Barsebäck nuclear power plant holds a special position. The plant is situated less than 20 kilometres from Kastrup airport. When the fully tanked airplanes take off from Kastrup they are less than five minutes of flight time from the plant. If terrorists hi-jack an airplane in Kastrup in order to attack the plant, counter measures cannot be implemented before the disaster is a reality.

---

[39] About the BNP 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 BNP 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

[40] The revelations were included in a report made available by U.S. Rep. Edward J. Markey, D-Mass., a member of the House Energy and Commerce Committee, based on responses to his queries from NRC Chairman Richard A. Meserve. The report, *Security Gap: A Hard Look at the Soft Spots in Our Civilian Nuclear Reactor Security*, (http://www.house.gov/markey/iss_nuclear_rep020325.pdf) analyzed more than 100 pages of NRC correspondence Markey had requested from the agency.

As early as 1979 the plant was criticized in a study made by an American consultant agency[41] because of lack of security as regards airplane crashes and terrorist attacks. The study was commissioned by the Energy Commission of the Swedish Industrial Department. Its criticism applied to the five oldest Swedish nuclear power plants (Barsebäck 1 and 2, Oskarshamn 1 and 2 and Ringhals 1) built by the then-existing ASEA-atom. The study concluded that **"Barsebäck 2 would not have qualified for a U.S. operation licence, because the facility did not satisfy the Nuclear Regulatory Commission's (NRC's) demands".**

A serious accident in the Barsebäck nuclear power plant does not have to be caused by a terrorist attack, though. In a 14th June 2000 memorandum the now abolished OOA concluded that Barsebäck 2's reactor construction was outdated, a fact that was confirmed by SSI and SKI, according to which the reactor had to be renovated and modernized in order to be able to live up to current reliability and safety standards[42].

It is a fact that the official Swedish safety evaluations are characterized by a high degree of uncertainty. 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 Barsebäck nuclear power plant the nuclear incident frequency for the plant was stated as 1:256.410. 1996 SKI and SSI claimed that the nuclear incident frequency for Swedish reactors was 1:100.000. 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 standards neither for the new nor for the old reactors. June 1998 the Barsebäck 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 Barsebäck 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. 11th December 1998 the Barsebäck nuclear power plant published its final PSA-report (PSA = ”Probabilistic Safety Analysis”), concluding that the nuclear incident frequency was 1:16.666 for some types of occurrences.

That the safety level in the Swedish nuclear power plants is lower than what the nuclear incident frequency indicates can be established from Sweden's worldwide position as regards the International Nuclear Event Scale – "INES". 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 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, **out of which one has occurred in a Swedish nuclear facility**. 46 level 2 incidents have been registered, **out of which 7 have occurred in Swedish nuclear power plants, i.e. 15 % of all the nuclear incidents in the world**. This is a significant over-representation considering the fact that Sweden has only 11 reactors (12 before the decommissioning of Barsebäck 1) and on the average there were approximately 420 reactors in the world during the period 1991-2002.

---

[41] Industridepartementet. 1978. 1. Swedish reactor safety study Barsebäck risk assessment
[42] Se http://www.ooa.dk/bb/bbsvaghe.htm

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 heterogenous reporting is the division of serious incidents between the Swedish reactors. Allmost 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 (see the table below).

INES 2+ serious incidents in Swedish nuclear power plants *(Source: Fredrik Lundberg)*

Reactor	**INES 2+ serious incidents**
Forsmark 1	0
Forsmark 2	0
Forsmark 3	0
Ringhals 3	0
Ringhals 4	1
Oskarshamn 3	0
newer	**1**
Barsebäck 2	3
Oskarshamn 1	
Oskarshamn 2	1
Ringhals 2	2
Ringhals 1	
older	**6**

The above-mentioned statistics on PSA and INES are based on Fredrik Lundberg, *Världens dårligaste kärnkraft*, Ordfront 6/2002. 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 figures as well as INES events. The nuclear operators own association WANO make 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[43]. **SKI's figures differ slightly from Lundberg's**. According to SKI's website, there were 5 INES 1 anomalies and 2 INES 2 incidents in Barsebäck 2 1991-2002. **Statistically, that makes Barsebäck 2 the most dangerous nuclear power reactor in Sweden.** For the same period SKI mentions a total of 29 INES 1 anomalies in the Swedish nuclear power plants, but only 5 INES 2 incidents. The sixth INES 2 incident occurred in the nuclear research facility in Studsvik where also a serious INES level 3 incident has been reported.

Barsebäck 2 started commercial operation 1977, but even though the reactor was ordered later than Forsmark 1 and 2, it has a **much more primitive electricity system** with 2 separate cable systems (stråk) instead of the 4 that are installed in the more modern reactors. If the supply of

[43] 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

electricity stops through one cable system, the safety of the reactor depends on only one. If that cable is cut, disaster is a reality[44].

An indication of how old age is taking its toll on the Barsebäck nuclear power plant is the fact that the "**accessibility**" – the absence of production pauses due to repair, etc. - 1991-1997 was about **70 per cent**. During the eighties up to 1991 it was more than 90 per cent. A couple of months every year operation in the plant has to be suspended because defects have to be remedied.

In the most dangerous industry of all, in which most of the serious accidents have been caused by human errors, **the management and the employees in Barsebäck 2 have publicly been corrected by SKI for lack of motivation in their work**. In a newspaper article titled "Sloppiness in Barsebäck worries the authorities" in *Dagens Industri,* September 1st 2001[45], Christer Viktorsson, the head of SKI's department for reactor safety is quoted for the following remark: "We were down (in Barsebäck) 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 Barsebäck'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 Barsebäck's safety activities more closely".

Recently SKI has requested a criminal investigation into Barsebäck 2. This is the first time the inspectorate has made such a request as regards a nuclear power plant in Sweden. August 18th 2003 Swedish nuclear safety inspectors announced that they had asked prosecutors to launch a criminal probe into an alleged violation of safety standards at the plant. SKI said in a statement that it had "observed large deficiencies in the management" of the reactor during a power stoppage earlier this year. The statement said the managers' actions might have constituted a criminal violation of Sweden's nuclear safety regulations. The plant was shut down for three weeks starting January 16th 2003 because of a problem with the pipes feeding water to the reactor tank. Plant officials had noticed the problem before that date and should have shut down the plant January 3rd at the latest. According to a SKI spokesman plant officials had to revise their security procedures before they could restart the reactor, which was currently shut down for annual maintenance[46].

The incident in question has been classified as a INES level 1 anomaly. Although is has caused harsh reactions among leading Danish politicians, it is not likely that it will precipitate a decommissioning of the plant. Representatives of the Centre Party, the Leftist Party and the Swedish Green Party have stated that an imminent shutdown of the plant is not in the cards. A similar reaction has emerged from the Swedish Minister of Environmental Affairs[47].

---

44 Fredrik Lundberg, *Varför driver de Barsebäck ?*, http://www.glod.com/arkivet/textarkiv/Ovriga_medarbetare/fl_000601_karnkraft.html

45 http://www.skb.se/templates/Page.asp?id=2495http://www.skb.se/templates/Page.asp?id=2495

46 *Dow Jones Newswires*, 08-19-031238ET, and http://www.ski.se/dynamaster/file_archive/030819/428934af6855d8183bec455e986b9a6d/Anm%e4lan%20till%20%e5klagare.pdf

47 http://w1.sydsvenskan.se/Article.jsp?article=10055244

Examples of things gone wrong in the Swedish nuclear reactors: In Oskarshamn 2 the reactor was started November 1996 with the most important emergency cooling system disconnected which was discovered a week later.
June 1992 a small cooling water leakage occurred in **Barsebäck 2** 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 of the oven resulting in a subsequent meltdown**. The defect was found in the 5 oldest BWR's that in theory had not had an emergency cooling system since Oskarshamn 1 started 1971. SKI prohibited the operation of these reactors that were inactive for three and a half years, because other defects were discovered.
1994 it was discovered in Ringhals 3 that the safety valve of the steam generator had been wrongly adjusted since the start up of Ringhals 2, 3 and 4 in the beginning of the seventies. The result was the risk of explosion of a pressure chamber 18 metres high.
Ringhals 4, September 1997: Closed valves in a containment sprinkling facility (consequence: If the own melted the containment could rupture quickly and uncontrolled).
Barsebäck 2, May 1999: Seawater cooling system out of order.
Barsebäck 2, July 2000: Defective installation of the safety filter system designed to prevent a radiation release in case of a meltdown of the reactor core. This event has not been mentioned in SKI's website.
Ringhals 2, June 2001: Defective overload protection in a local electricity connection.
As recent as January 2003 serious defects led to a three weeks shutdown of **Barsebäck-2**[48]. This event has not been mentioned in SKI's website.

An indicator of how a company culture has been able to emerge in the nuclear power plants that has made possible the many anomalies and incidents are the numerous unchallenged violations of the Act on Nuclear Activities (Kärntekniklagen). For instance, from the founding of SKI 1974 and up to 2001 one reactor has been started up without the attachment of the quick stop system (Oskarshamn 3, 1987), one reactor was running for a whole season without proper containment (door not closed, Oskarshamn 2 1981-82) and as mentioned above five reactors were operative 15-20 years without a functioning emergency cooling system (**Barsebäck 2** among others, discovered 1992). Responsible for that no one was charged and punished is mainly SKI that opposed that a technician in Oskarshamn 2 was charged because he started the reactor 1996 with the emergency cooling system disconnected. Nevertheless, the case was tried in Oskarshamn's city court (two technicians were prosecuted and aquitted April 2002).
In the US NCR frequently has imposed fines on the operators, stopped operation, made unannounced visits to the nuclear facilities and in many other ways manifested scepticism towards the nuclear industry.

III. There is no longer any political pressure in Sweden to close down the Barsebäck nuclear power plant

As it has been established above, two main factors determine the estimates that the competing risk and consequence scenarios put forward: On one hand the conclusions that are drawn from

---

[48] Uffe Geertsen, Niels Henrik Hooge and Bo Normander, *60 år med atomvåben og atomkraft*, http://www.ecocouncil.dk/global/global_okologi_2003/nr1_2003_akraftoversigt.pdf

the Chernobyl disaster and on the other hand political demand. That these two factors are not always compatible with each other can be registered in the fluctuations in the Swedish authorities´ scenarios for the consequences of a serious accident in a nuclear power plant: While the international research agencies paint a still more bleak picture of the effects of the Chernobyl disaster, some of the Swedish authorities' scenarios for the consequences of a serious nuclear accident get more optimistic. **A likely explanation for this is the fact that the Swedish population is currently the one most friendly towards nuclear power in Europe**. Consequently, not only the technical responsibilities of the Danish Emergency Management Agency, but also its political role has increased, considering the fact that **there is no longer any political pressure in Sweden to decommission the Barsebäck nuclear power plant**.
This pressure comes from Denmark only. In Sweden today, electricity consumption is 2,6 times higher per capita than the EU average – more than even in France where 70 % of the electricity comes from nuclear power. Because of the accident in the Three Mile Island the Swedish population decided March 1980 in a referendum that nuclear power should be abolished before 2010 (the so-called track 2)[49], but the result of the referendum was abolished in a parliament decision 1997. Only one reactor, Barsebäck 1, has so far been decommissioned. The foundation of the current decommissioning of nuclear power in Sweden is a decision made by the parliament June 2002 after a proposal from the government on a new energy policy based on a voluntary agreement with the nuclear industry. **The Swedish government expects that such an agreement will have the effect that the nuclear power plants will continue operating for another 30-40 years with the Barsebäck nuclear power plant as a possible exception.** The parliament decision is in accordance with opinion polls that show that the Swedish population is currently the one **most friendly towards nuclear power in Europe** [50]. End of 2001 an enquete made by the opinion research institute Demoskop in Stockholm[51] showed that 77 % of the Swedish population do not want a decommissioning of the nuclear power plants before time. 53 % would like the 11 reactors to continue operating as long as the safety measures are satisfactory. An additional 24 % are for continued running without a fixed decommissiong date. Only 21 % support a quick phasing out of nuclear power. This figure is even set lower by the opinion research institute Temo that estimates it to be 14 %.
The change in public opinion has caused the Christian Democrats to go from track 3 to track 1 and the People's Party from track 2 to track 1. Critics of nuclear power claim that the Social Democrats now in reality champion track 1[52].

---

[49] The referendum offered three options, all in support of abolishment of nuclear power: **Track 3** intended to decommission the then six reactors before 1990, **track 1** and 2 to develop nuclear power with an additional six reactors and then abolish as the reactors wore out. **Track 2** that were supported by the Social Democrats and the People's Party emphasized in its campaigning that "decommissioning should happen sensibly" by help of the development of other energy sources and energy economy. Track 2 gained the majority of the votes, almost 39 %, a few more than track 3. Track 1 obtained 19 % of the votes. With a large majority, the Swedish parliament interpreted the election result in a decision to develop nuclear power and then abolish it before 2010, Fredrik Lundberg, *Varför driver de Barsebäck ?*, http://www.glod.com/arkivet/textarkiv/Ovriga_medarbetare/fl_000601_karnkraft.html

[50] Eurobarometer 56.2, "Europeans and Radioactive Waste", 19/4 – 02.

[51] http://www.politikforum.de/forum/archive/10/2001/02/2/6873

[52] In accordance with this assertion is the fact that the Swedish government has been criticized by the Swedish Green Party, the Centre Party and FMKK (the Swedish WISE), because the recently appointed leading government official who as the director of the Ministry of Industry, Employment and Communications' department of energy, forestry and basic industry is responsible for the abolishment of nuclear power has a past as a nuclear lobbyist for the Confederation of Swedish Enterprise. In this capacity he has fought against the decommissioning of both Barsebäck 1 and 2 and also parliament decisions on environment protection. When the Swedish parliament decided on a four per cent decrease of the carbon dioxide release, he worked instead for industry to be licensed to release twice as much carbon dioxide, Britta Kahanpää, *Pressmeddelande från FMKK*, 2003.07.28 and Peter Bratt,

A highly relevant aspect of the decommissioning issue is the Swedish state majority ownership control of 8 of the 11 nuclear reactors in Sweden[53]. **Vattenfall AB** - the fifth largest energy company in Europe with a turnover of more than 100 billion SEK in 2002 - is in possession of the majority ownership of the Ringhals Company Group that includes the Barsebäck, Forsmark and Ringhals nuclear power plants. **Vattenfall AB is owned 100 % by the Swedish state, i.e. the Ministry of Industry, Employment and Communications (Näringsdepartementet)[54].**

Hence, when it comes to the question of phasing out nuclear power, the Swedish government not only has to negotiate a voluntary agreement with itself about 8 out of 11 of the nuclear reactors in Sweden, but it also has to ask itself whether the conditions for decommissioning Barsebäck 2, of which it exercises full ownership control, have been met.

The most recent decommissioning basis for Barsebäck 2 is a **March 2003 agreement between the Social Democrats, the Centre Party and the Leftist Party**. According to this agreement **the question of decommissioning of Barsebäck 2 should be dealt with in the negotiations with the nuclear industry – i.e. mostly the state itself - on the decommissioning of the other reactors and the energy policy in its entirety** and if a negociation solution on the decommissioning of Barsebäck 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"[55]. The measures presuppose that a decommissioning of Barsebäck 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 decommissiong of Barsebäck 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**[56]. 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 totaling 1200 MW (gross quantity 3000 MW) – just as much as the two Barsebäck reactors together. Furthermore, the 5 oldest reactors were inactive summer/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 Barsebäck 2 only affects the price of electricity with a few ører /kWh or less than an øre. In connection with **the industry's access to electricity**: The Swedish industry's access to electricity is reduced when the electrity is used for heating up private houses. Since

---

Industriman ska avveckla kärnkraften, Dagens Nyheter 24/7 2003, http://www.dn.se/DNet/jsp/polopoly.jsp?d=147&a=163743

[53] The Swedish government exercises control over Barsebäck 2, Ringhals 1, 2, 3 and 4 and Forsmark 1, 2 and 3 through Vattenfall AB, http://www.analysgruppen.org/svekk/rst.html

[54] The Ministry of Industry, Employment and Communications administers ownership shares in 33 Swedish companies of which Vattenfall AB is by far the largest, http://naring.regeringen.se/fragor/statliga_foretag/foretagslista.htm

[55] Press release from Näringsdepartementet 18/3 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

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

1997 approximately 150.000 electrical heating punps 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 TWh/year. As regards **climate and 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.

If one only looks at the objective criteria that the political parties have set for decommissioning of Barsebäck 2, it seems incomprehensible that the reactor has not been closed down. However, the political trends cannot be ignored: **According to the opinion research institute Sifo, 52 % of all Swedes are against an early decommissioning of Barsebäck 2 and according to Temo as much as 67 %. 94 % of the inhabitants around the Barsebäck nuclear power plant and 88 % of the population in Skåne support that the plant continues operating**[57]. The industry and Swedish LO have clearly emphasized that they do not consider that the conditions for decommissioning Barsebäck 2 have been met. In the general elections 2002 the Social Democrats had their worst election in many years. If one assumes that the phasing out of nuclear power in Sweden and the decommissioning of Barsebäck are submitted to political demand, the probality that nothing will be decommissioned increases as time passes by.

Obviously, the Swedish nuclear industry has realized this: As a whole it is expected to invest more than 20 billion SEK in all of the reactors in the near future. The state-controlled Vattenfall AB is about to invest 10 billion SEK in the oldest reactors. The 3 reactors in the state-controlled Forsmark nuclear power plant are currently being upgraded with 130 MW at the cost of one billion SEK. The state-controlled Ringhals nuclear power plant is on its way with an application for an effect increase for Ringhals 3 of 70 MW and it is being looked into whether the other reactors can be upgraded. Similar investigations take place in the Oskarshamn nuclear power plant where there is an ambition for an effect increase of 170 MW[58]. In the Barsebäck nuclear power plant 400 million SEK were invested the last three years in overhauls, renovations and replacements. It has been revealed that a plan exists for an upgrading of the reactor 2 from 615 to 665 MW electrical effect. The plan is supposed to be initiated 2005[59]. According to Barsebäck Kraft AB's homepage www.barsebackkraft.se the demolition of Barsebäck 1 and 2 can begin 2020 at the earliest and is expected to be completed 2030, regardless of when decommissioning starts[60].

IV. The liability question

As mentioned above, the Barsebäck reactor 2 is one of 8 out of 11 Swedish nuclear reactors that are in reality controlled by the Swedish government. The state-owned **Vattenfall AB**[61] is

[57] The results of Demoskop's enquete are described in www.barsebackkraft.se.
[58] Ny Teknik 19/03 2003.
[59] Niels Sandø, *Dyr dødsdom*, Jyllandsposten 24/8 2003.
[60] Jf. http://www.barsebackkraft.se/index.asp?ItemID=1291
[61] According to its website www.vattenfall.com Vattenfall generates electricity and heat and delivers energy to about 6 million customers in Northern Europe. Over the past few years, the company has grown considerably through acquisitions in Germany and Poland. At the same time, the company has divested its commitments outside Europe. Today, its core business is concentrated to Finland, Germany, Poland and Sweden. According to its website, it is Vattenfall's ambition to be a leading European energy company. Serving 1.3 million customers across the industrial and household sectors in the Nordic countries, Vattenfall is the largest electricity generator, distributor and district heating company in the region. The market share is 20 % of the Nordic electricity market. It is the main regional and local network operator in Sweden with 900.000 customers. About 50% of Sweden's electricity production originates from the company. The main forms of power are nuclear power and hydropower. Vattenfall has 33,900 employees (Man-years, December 2002). Today, the largest electricity customers are industries and

in possession of the majority ownership (74,2 per cent) of the Ringhals Company Group that includes the Barsebäck and Ringhals nuclear power plants. According to the homepage of the Barsebäck nuclear power plant[62], the Ringhals Company Group is one of the largest nuclear power producers in the world. The Group was formed as a result of an agreement between the government, Vattenfall AB and Sydkraft AB after the Government and Parliament in Sweden November 30th 1999 had decided to shut down Barsebäck 1. The remaining 25,8 per cent of the Ringhals Company Group is owned by **Sydkraft Kärnkraft**, a company within the Sydkraft Group[63]. Since May 2001 Sydkraft is a part of the German **E.ON Group**[64]. E.ON owns 55 % of the shares. **Stakraft**, which is owned by the Norwegian State, owns 45 per cent of the shares.

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*[65], the national legislation in Sweden, which implements the obligations under the Paris Convention and the Brussels Supplementary Convention[66] on the

---

energy companies. Its electricity sales are 180 TWh per year. Elecricity generation: 160 TWh per year under normal conditions. Heat production and sales 34 TWh per year **Key figures for the fiscal year 2002:** The company's net sales: 101 billion SEK (11 billion EUR). Investments: 40 billion SEK (4,34 billion EUR). Return on net assets, excluding items affecting comparability: 10.1 %. Equity/Assets ratio: 20.0 % (EUR/SEK = 9,193 December 2002). Vattenfall has had a presence in the Danish energy market since 1995 and now sells electricity and energy solutions to energy companies with an existing end customer base in Denmark. The company also provides products for Danish electricity distributors. Its Danish subsidiary, **Vattenfall Danmark A/S**, is located in Hellerup. On the power generation side of its business Vattenfall works with the Danish energy company Energi E2, in operating the new multi-fuel plant **Avedøre 2**. The number of Vattenfall employees in Denmark is less than 50.

[62] http://www.barsebackkraft.se/index.asp?ItemID=1291 According to this website, The Ringhals Group was founded July 31, 2000 (financial year started in January 2000). It provides 21 percent of the electricity in Sweden. The number of employees is 1500. It has 5 reactors in operation. Its production capacity is 31 TWh and the net output is 4150 MW.

[63] The Sydkraft group includes approximately 35 subsidiary companies with a total turnover of about 20 billion SEK. It has 5.300 employees, 850.000 clients and operates in Scandinavia and Poland. 2002 the turnover was 19.383 million SEK, the result finance net 3.251 million SEK, http://www.sydkraft.se/index.asp?SECONDPARENT=74809&HIDENAVIGATION=.

[64] **E.ON is the world's largest private energy company** with about 25 million costumers. It includes more than 50 subsidiary concerns and companies in Europe and USA. It has its main office in Düsseldorf in Germany. Its turnover is approximately 750 billion SEK and it has about 150.000 employees, http://www.eon.com/.

[65] 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

[66] 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. Its **objectives** are to "ensure adequate and equitable compensation for persons who suffer damage caused by nuclear incidents, whilst ensuring that the development of nuclear energy for peaceful purposes is not thereby hindered and to unify the basic rules in various countries relating to liability incurred for such damage". Its **main provisions** are the following: (a) That the operator of a nuclear installation is liable for damage to or loss of life of any person and damage to or loss of any property upon proof that such loss or damage was caused by a nuclear incident involving either nuclear fuel or radioactive products or waste in, or nuclear substances coming from, such an installation (art. 3). b) That the maximum liability of the operator is defined (art. 7). c) That actions must be brought within 10 years from the date of the nuclear incident (art. 8). (d) That the operator is not liable if the incident caused by act of armed conflict, invasion, civil war or grave natural disaster of an exceptional character (art. 9) and (e) that the operator must maintain insurance to cover his liability (art. 10), 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. Its **objective** is to "supplement the measures contained in the Paris Convention with

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). A person wishing to claim compensation under the Nuclear Liability Act must do so within three years of becoming aware of his or her entitlement to compensation, or, in any case, **within 10 years of the nuclear incident** which caused the damage complained of. The Act also contains provisions establishing which Swedish courts have jurisdiction over a particular claim for compensation.

Each plant is insured for nuclear responsibility in accordance with Swedish law and the Paris and Brussels conventions. In addition property loss and damage is insured through insurance companies on the market or, in the case of **Vattenfall – the majority owner of Barsebäck 2 - through its own captive company Vattenfall Insurance, which reinsures its risks on the open market**.

Recently, **the European Commission** has given the green light for **extending international cover for nuclear risks**[67]. It has adopted two proposals for decisions authorizing the Member States that are Parties to the Paris Convention to sign and ratify the Protocol amending the Paris Convention on third party liability in the field of nuclear energy. As mentioned above, the Paris Convention lays down requirements concerning the third party liability of nuclear operators and the rules for the compensation of victims in the event of an accident. The new Protocol will make it possible to **increase compensation for the victims of nuclear accidents** and to broaden the scope of the Convention. It will supplement the Community environmental liability regime, which is in the process of being adopted.

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

---

a view to increasing the amount of compensation for damage which might result from the use of nuclear energy for peaceful purposes". The **main provisions** of the Supplementary are the following (a) To establish a maximum compensation in respect of damage caused by nuclear incidents defined. Such compensation is to be provided out of funds created by insurance or other financial security, **out of public funds to be made available by the contracting party in whose territory the nuclear installation is situated, and out of public funds created according to a special formula for contributions**. The liability of operator established (art. 3). (b) To set a formula for contributions according to which the contracting parties shall make available the public funds determined (art. 12), http://www.nuclearfiles.org/redocuments/1963/630131-liability-suppl.html

[67] **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

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). The Council of the European Union has not yet expressed its opinion on these proposals.

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**[68]. This would probably mean that **the operator of Barsebäck 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**[69].

Another relevant provision is the one that states that if a person suffering damage has contributed hereto due to gross negligence on his part, the operator might be exonerated wholly or partially[70]. **This could pertain to the Danish Emergency Management Agency, if a Swedish court deems the Danish nuclear rescue preparedness insufficient. People in Denmark who suffer personal injury because they were not evacuated in time would then have to bring actions against the Danish Ministry of the Interior instead**.

Just as striking as the fact that neither the operator of the Barsebäck 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 one described in section I.F (the Chernobyl scenario) will practically not be compensated**. **Although the owners of Barsebäck 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 will only be compensated 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 0,56 %, again presupposing that there are no claims in Sweden.**

V. Conclusion

The organizing of the Danish nuclear emergency response plan is based on risk and consequence scenarios founded on a certain perception of the hazards of nuclear power. Apart from protecting people against the consequences of a nuclear accident, the rescue preparedness plan has a vital influence on the public's perception of nuclear power. In this context it is worth noting that the influence of the Danish Emergency Management Agency transcends just handling the emergency measures against the consequences of a serious nuclear accident, because the long-term consequences for the environment, public health and the economy in Denmark cannot be remedied by emergency measures alone.

For many years the Danish Emergency Management Agency was criticised by the now abolished *Information on Nuclear Power* (OOA – The Danish WISE) for downplaying the consequences of the worst possible accident in the Barsebäck nuclear power plant. OOA argued that NGOs that

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

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

[70] Ibid. Section 13, paragraph b.

were critical or at least neutral towards nuclear power should have an input in the risk assessments that were the basis of the Danish nuclear emergency response plan.

The examples, how the Danish Emergency Management Agency estimates the worst possible consequences of a serious accident in the Barsebäck nuclear power plant, analyzed in this paper, show that the consequences are still being downplayed. If one compares the competing risk and consequence scenarios for the Swedish nuclear power plants the way they are described in the agency's answers to the two politicians and the September 26th 2001 memo, it is evident that they are a far cry from the scenarios described in the 1987 Secretariat Report and the 1989 Report. **Nor are the agency's scenarios similar to those described in the 1995 report "Consequences in Sweden of a serious nuclear accident" which the agency refers to as its main source.** Especially as regards this last report it is worth noting how it assesses 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, 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, thus **confirming the worst-case scenarios of the 1987 Secretariat report and the 1989 Report.**

Especially regarding the Danish Emergency Management Agency's September 2001 memo, in which the agency describes a scenario where a fully tanked passenger or military airplane crashes into the Barsebäck nuclear power plant when the reactor is still running, it is evident **that there is no similarity between the memo and the 1987 Secretariat Report, the 1989 Report or the 1995 Report**. In the answers to the two members of parliament the agency claims that the consequence scenarios that constitute the basis of the Danish rescue preparedness planning are "in accordance with international practices for radiation protection" – i.e. the lessons learned from the Chernobyl disaster – and in the September 2001 memo the agency refers to Chernobyl, when it describes the consequences of the worst possible accident in the Barsebäck nuclear power plant. Since 1995 a number of reports from international organizations have presented information that throws new light on the consequences of the Chernobyl disaster, but the Danish Emergency Management Agency has chosen to ignore the last eight years of research in this field.

Initially, a comparison between the Chernobyl disaster and the worst-case scenario for a serious nuclear accident in the Barsebäck 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 Barsebäck 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. For instance, the 1995 report which the Danish Emergency Management Agency refers to, when it defends the Danish nuclear rescue preparedness plan, defines a rest risk release as "very substantial releases (in which apart) from the whole inventory of noble gasses more than a tenth of the reactor inventory of iodine, cesium and tellur is released. The heavier substances are expected to be more contained". **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

Barsebäck 2 reactor derives from the released fraction of the core inventory. **The reactor core of Barsebäck 2** contains **a weight of 76.4 tons of uranium**. 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. **Based on these figures, a release of 7,7 % the reactor fuel in Barsebäck 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 Barsebäck 2 will exceed the release from the Chernobyl reactor.**
In this context it is worth noting that the scenario for the rest risk release described in the 1995 Report from SKI and SSI, which the Danish Emergency Management Agency claims that the Danish nuclear rescue preparedness plan is based on, is comparable to the above-mentioned actual Chernobyl release scenarios.

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 estimate by the UNSCEAR committee, **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, while the Barseback inventory of caesium-137 should be approximately **a total of 105 kg** in the core, i.e. **more than in the Chernobyl reactor**.
The Chernobyl release of caesium-137 equals a release of 25 % of the caesium-137 inventory in Barsebäck 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.**
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 Barsebäck nuclear power plant. Exact figures cannot be extracted from an outside reference. **A second uncertainty factor** is the fact that the Ukrainian Chernobyl reactor is a RBMK, very different from the Swedish design. **A third uncertainty factor** is the pattern of the release scenario itself. **A fourth uncertainty factor is the quantities of spent fuel stored in the Barsebäck nuclear power plant**. Approximately a sixth of the fuel in the reactor, i.e. **15 tons**, is changed every year. However, an inventory status December 31st 2001 revealed that 405 spent fuel assemblies totalling a weight of **72 tons** were stored in Barsebäck 2. 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.
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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 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 Barsebäck 2 reactor could be comparable to the Chernobyl disaster.

All new information on the Chernobyl disaster indicates that the consequences of a serious nuclear accident are far more serious than the Danish Emergency Management Agency presupposes in its calculations of the consequences of the worst possible accident in the Barsebäck nuclear power plant. All people within a radius of 30 kilometres around the Chernobyl reactor were evacuated from their homes. The area has since been declared an **exclusion zone**, where no one is allowed to live. **An exclusion zone within a radius of 30 kilometres around the Barsebäck nuclear power plant would in Sweden include Malmö, Lund, Landskrona, Eslöv, Staffanstorp and at least twenty villages and in Denmark all of Amager, Copenhagen City, Frederiksberg, Vesterbro, Nørrebro, Østerbro, Vanløse, Brønshøj, Valby, Vigerslev, Hvidovre, Avedøre Holme, Brøndbyøster, Rødovre, Utterslev, Nordhavn, Bispebjerg, Hellerup, Husum, Mørkhøj, Gladsaxe, Søborg, Buddinge, Bagsværd, Vangede, Gentofte, Charlottenlund, Skovshoved, Jægersborg, Ordrup, Lyngby, Sorgenfri, Virum, Klampenborg, Tårbæk, Rådvad, Søllerød, Holte, Gl. Holte, Øverød, Nærum, Trørød, Skodsborg, Vedbæk, Sandbjerg, Isterød, Ravnsbjerg, Høsterkøb, Brådebæk, Hørsholm, Usserød, Vallerød, Rungsted and Kokkedal.** In this context it is worth noting that the 1987 Secretariat Report consequence scenario, one of the directors of SKI recently confirmed, has an **exclusion zone 100 kilometres in the direction of the wind**, and that the 1995 Report from SSI and SKI 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 Barsebäck 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**. 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. So far, this amount is **more than twice the total Danish BNP for 2002**. Contrary to the Chernobyl nuclear power plant that is situated in a thinly populated agricultural area, the Barsebäck 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. The Danish capital is inhabited with more than 660.000 people. 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 Barsebäck 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 BNP 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 2000 BNP per capita in Ukraine and 8 times higher than the 2000 BNP per capita in Belarus.

The security level of the Swedish nuclear power plants has a central position in the risk scenarios. **All the probability calculations that for 50 years have been the basis of the 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.** In this context the Barsebäck nuclear power plant has a special position. The plant is situated less than 20 kilometres from Kastrup airport. When the fully tanked airplanes take off from Kastrup they are less than five minutes of flight time from the plant. If terrorists hi-jack an airplane in Kastrup in order to attack the plant, counter measures cannot be implemented before the disaster is a reality.

A serious accident in the Barsebäck nuclear power plant does not have to be caused by a terrorist attack, though. It is a fact that the official Swedish safety evaluations are characterized by a high degree of uncertainty. **That the safety level in the Swedish nuclear power plants is lower than what the public perception indicates can be established from Sweden's worldwide position as regards the International Nuclear Event Scale – "INES".** This information system has existed since 1991. According to one source, 7 level 2 incidents have taken place in Swedish nuclear power plants out of a total figure of 46 during the period 1991-2002, i.e. 15 % of all the nuclear incidents in the world. This is a significant over-representation considering the fact that Sweden has only 11 reactors (12 before Barsebäck 1 was decommissioned) and that on the average there were approximately 420 reactors in the world during the period 1991-2002. According to SKI's website, there were 5 INES 1 anomalies and 2 INES 2 incidents in Barsebäck 2 1991-2002. **Statistically, that makes Barsebäck 2 the most dangerous nuclear power reactor in Sweden.** For the same period SKI mentions a total of 29 INES 1 anomalies in the Swedish nuclear power plants and 5 INES 2 incidents. The sixth INES 2 incident occurred in the nuclear research facility in Studsvik where also a serious INES level 3 incident has been reported.

In general, two main factors determine the estimates that the competing risk and consequence scenarios put forward: On one hand the conclusions that are drawn from the Chernobyl disaster and on the other hand political demand. That these two factors are not always compatible with each other can be registered in the fluctuations in the Swedish authorities´ scenarios for the consequences of a serious accident in a nuclear power plant: While the international research agencies paint a still more bleak picture of the consequences of the Chernobyl disaster, some of the Swedish authorities' scenarios for the consequences of a serious nuclear accident gets more optimistic. **A likely explanation for this is the fact that the Swedish population is currently the one most friendly towards nuclear power in Europe.** Consequently, not only the technical responsibilities of the Danish Emergency Management Agency, but also its political role has increased, considering the fact that there is no longer any political pressure in Sweden to decommission the Barsebäck nuclear power plant.

A highly relevant aspect of the decommissioning issue is the Swedish state majority ownership control of 8 of the 11 nuclear reactors in Sweden. Vattenfall AB - the fifth largest energy company in Europe with a turnover of more than 100 billion SEK in 2002 - is in possession of the majority ownership of both the Forsmark and the Ringhals Company Group that includes the Barsebäck and Ringhals nuclear power plants. **Vattenfall AB is owned 100 % by the Swedish state, i.e. the Ministry of Industry, Employment and Communications (Näringsdepartementet).**

Hence, when it comes to the question of phasing out nuclear power, the Swedish government not only has to negotiate a voluntary agreement with itself about 8 out of 11 of the nuclear reactors in Sweden, but it also has to ask itself whether the conditions for decommissioning Barsebäck 2, of which it exercises full ownership control, have been met.

So far, the Swedish government has promised five times[71] to decommission Barsebäck 2 and each time broken its promises. **Considering that it is still uncertain when Barsebäck 2 will be shut down and one could argue that the likelihood that the reactor will be decommissioned is dwindling as time passes by, because of the growing popular support for nuclear power in Sweden, the Danish government should increase its pressure on the Swedish government and at the same time play with open cards as regards the evacuation plans for the many people who will be affected by the worst possible accident in the plant.** It is only natural that economic estimates of the consequences of the various scenarios should be integrated into this political and administrative transparency strategy.

Consequently the Danish government should

- *initiate an independent investigation of the Danish nuclear rescue preparedness– preferably with the involvement of one or more independent international research agencies.*

- *initiate an independent investigation of what the consequences of the worst possible accident in the Barsebäck nuclear power plant would be for the environment, public health and the economy in Denmark.*

This investigation should be based on the newest international findings in this field and should try to reach a clarification of

- the short-term and long-term effects of such an accident on the *environment* and *public health*, including its influence on the frequency of thyroid cancer, leukaemia, other cancer diseases and diseases in general among children and adults, its influence on pregnancy and on the new generations and not least its psychological effects.

- *the risk dimension*, including the extent of the service duty for the personnel expected to carry out the sanitation in Denmark after the worst possible accident in the Barsebäck

71 According to an "irrevocable" Swedish government decision March 2nd 1988, a nuclear reactor was supposed to be decommisioned 1995 and another one 1996 in Barsebäck and Ringhals respectively, but the decision was set aside three years later. February 5th 1998 the Swedish government made a formal decision to decommission Barsebäck 1 no later than July 1st 1998 and Barsebäck 2 no later than 2001 as part of the phasing out of nuclear power. Barsebäck 1 was shut down November 30th 1999, but May 2001 the Danish government accepted a proposal from the Swedish government that the decommissioning of Barsebäck 2 could be postponed until 2003 if the energy production that was lost if the reactor was shut down had not been compensated. Presently, it has all been postponed until 2004/05, where a new decision has to be made.

nuclear power plant. To throw light on this problem is highly relevant considering that the number of casualties among the 800.000 mitigators of the consequences of the accident in the Chernobyl nuclear power plant is estimated to be between 25.000 and 100.000 and considering that 92 % of the 336.000 mitigators in Ukraine have officially been recognized sick.

- the *direct losses* from the accident - expenditure on decontamination work in the affected territories, emergency aid and medical help to the affected population, research of the environment, public health and production of non-contaminated foodstuffs, organizing the monitoring of the radioactive situation, radiation-ecological improvements of residential areas and radioactive waste management, resettlements of the most affected parts of the population and improvements in their living conditions – and the *indirect losses* - long-term production loss caused by loss of arable land and forests, shutting down of agricultural production facilities and industrial facilities and loss of profit opportunities.

In this context is has to be taken into consideration that the economic damage done to the Danish society if literally hundreds of thousands of citizens will have to give up their residences, while at the same time hundreds of thousands of jobs are lost, will not be compensated in full by Vattenfall AB and Sydkraft AB that own the Barsebäck nuclear power plant, or by the Swedish state. It is also worth noting that **according to the Swedish nuclear liability act, the operator might be exonerated wholly or partially if a person suffering damage has contributed hereto due to gross negligence on his part**. This could pertain to the Danish Emergency Management Agency, if a Swedish court deems the Danish nuclear rescue preparedness insufficient. People in Denmark who suffer personal injury because they were not evacuated in time would have to bring actions against the Danish Ministry of the Interior instead.
Just as striking as the fact that neither the operator of the Barsebäck 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 one described in section I.F (the Chernobyl scenario) will practically not be compensated**. As part of the privileges that the Swedish government has granted the nuclear industry, the maximum limit of the insurance policies of the Swedish energy companies is 2,67 billion DKK (3,3 billion SEK). The Swedish state itself will cover nuclear damage that the operator does not compensate due to the above-mentioned ceiling, though not more than with 4,86 billion DKK (6 billion SEK). **Although the owners of Barsebäck 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 magnitude 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.**

- *Consequently, the Danish government and the Danish parliament should as quickly as possible negotiate a liability agreement with the Swedish government that compensates for nuclear damage in Denmark in a realistic way and at the same time increase the pressure that is put on the Swedish government to decommission Barsebäck's reactor 2*

Niels Henrik Hooge, Copenhagen, August 31th 2003

Annex 1

What is Barsebäcksoffensiv ?

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

GREEN NGO's:

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: kimejler@post7.tele.dk and 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, 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

BBOFFs contact person in Denmark is Niels Henrik Hooge, tel. +45 46 35 38 79 and +45 21 83 79 94, E-mail: nielshenrik_hooge@yahoo.dk
BBOFF's contact person in Sweden is Roland Rittman, tel. +4641020748 and +46703968948, E-mail: roland@barseback.org and roland.rittman@swipnet.se
BBOFF's contact person in Germany is Bernd Frieboese, tel. +49 30 43409598 and +49 163 3139351, E-mail: bernd@barseback.de

For further information on BBOFF, see www.barseback.org, www.bboff.cjb.net and www.barsebacksoffensiv.cjb.net

Annex 2

The answers of the Minister of the Interior to Keld Albrechtsen and Pernille Blach Hansen 6/6 2003

Question no. S 3374.

The spokesperson for Environmental affairs for Enhedslisten, Keld Albrechtsen, to the Minister of the Interior:

"Does the minister agree that the Danish emergency response plan as regards a serious nuclear accident in the nuclear power plant Barsebäck II should be based on the most recent Swedish risk assessments ?"

Answer (6/6 03)

The Minister of the Interior (Lars Løkke Rasmussen):

The minister has contacted the Danish Emergency Management Agency that deals with the Danish nuclear rescue preparedness and asked the agency to make a statement. As regards this question, the agency has stated the following, which I take ad notam:
"The Danish rescue preparedness as regards a serious accident in the Barsebäck nuclear power plan is included in "The nation-wide response plan for a nuclear emergency" that was thoroughly revised October 2001 and is updated regularly when it is required.
The plan is based on a worst-case scenario as regards a serious nuclear accident in the nuclear plants situated near Denmark, including the Barsebäck nuclear plant, and is founded on established international principles for radiation protection.
The Danish Emergency Management Agency is in permanent contact with the Swedish nuclear authorities, e.g. in meetings every six months where safety issues have a high priority. In this forum know-how and estimates on new developments in the field of risk analysis are exchanged, including Swedish risk estimates. This information is evaluated in connection with the Danish nuclear emergency response plan in order to ensure that this plan at all times take into consideration the consequences in Denmark of even the worst possible accidents in nuclear power plants.
It should be mentioned that the Swedish nuclear authorities September 1995 published the report "Consequences in Sweden of a serious nuclear accident" which is the most recent Swedish consequence estimate. The Danish Emergency Management Agency looked at the report October 1995 and found no reason to reevaluate the Danish nuclear rescue preparedness.
The Danish nuclear rescue preparedness takes into consideration the newest Swedish consequence estimates".

Question no. S 3375.

The spokesperson for Environmental affairs for Enhedslisten, Keld Albrechtsen, to the Minister of the Interior:

"Does the minister agree that Denmark as a minimum should have an contingency plan that corresponds with the Swedish "worst case scenario" as regards a serious accident in the Barsebäck II nuclear power plant ?"

Answer (6/6 03)

The Minister of the Interior (Lars Løkke Rasmussen):

"I agree that Denmark should have a nuclear contingency plan that includes a worst case scenario for accidents in nuclear power plants near Denmark, including the Barsebäck nuclear power plant, and that is based on international principles for radiation protection.
In my judgement, the Danish nuclear contingency plan lives up to this standard".

Question no. S 3376.

The spokesperson for Environmental affairs for Enhedslisten, Keld Albrechtsen, to the Minister of the Interior:

"What will be the consequences for a possible economic compensation in case of a serious accident in the Barsebäck nuclear power plant, if the Danish contingency plan not as a minimum lives up to the Swedish "worst-case scenarios" ?"

Answer (6/6 03)

The Minister of the Interior (Lars Løkke Rasmussen):

Answer:

"I refer to my answer to question no. 3375".

Question No. S 3377.

The spokesperson for Environmental affairs for the Social Democrats, Pernille Blach Hansen, to the Minister of the Interior:

"Will the minister describe the differences between the two risk assessments for the Barsebäck nuclear power plant by The Danish Emergency Management Agency 2001 and the Swedish Ministry of Defence (Försvarsdepartementet) 1987 respectively and give a reason for these differences ?"

Grounds for the question: May 20th 2003 MetroXpress writes the following: "The consequences of a terror attack against the Barsebäck nuclear power plant near Malmø was downplayed, when the Danish authorities made a risk assessment after the attack on World Trade Centre 2001 (…) After the Tjernobyl disaster 1986 Swedish experts reached a far more serious conclusion. The Swedish Ministry of Defence established that an evacuation of the entire population 60 kilometres in the direction of the wind would be necessary, if radioactivity escapes the safety filters of the plant".

Answer (6/6 03)

The Minister of the Interior (Lars Løkke Rasmussen):

As regards this question I have contacted the Danish Emergency Management Agency that deals with the Danish nuclear rescue preparedness and asked the agency to make a statement. As regards this question, the agency has stated the following, which I take ad notam:
“The objective of the Danish Emergency Management Agency’s memorandum 21st of September 2001 on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebäck nuclear power plant was to describe the effects of a possible terrorist attack compared to the established threat scenario which the nuclear rescue preparedness is based on. In the memo it is concluded that the nationwide nuclear rescue preparedness takes into consideration the effects of a terrorist incident where an areroplane crashes into the Barsebäck nuclear power plant. Consequently, the Danish Emergency Management Agency has found no particular reason to describe the rescue preparedness measures dealing with such an accident. The Danish Emergency Management Agency’s September 26th 2001 memo has been sent to the parliament’s municipality committee September 27th 2001 as part of the answer of the then Minister of the Interior to the committee’s question no. 58.
The Danish nuclear emergency response plan is based on a worst-case scenario as regards serious nuclear accidents in nuclear power plants near Denmark and it is based on established international principles for radiation protection. The plan contains among other things a possibility for evacuation if the need should emerge.
In the Swedish report from 1987, which the questioner refers to, the assessment calculations are based on a bigger reactor than Barsebäck reactor II. Consequently, the report over-estimates the possible consequences for Denmark of the worst possible accident in the Barsebäck nuclear power plant.
September 1995 the Swedish nuclear regulatory authorities published the report "Consequences in Sweden of a serious nuclear accident" where they more specificly take the lessons learned from the Tjernobyl disaster into consideration. The Danish Emergency Management Agency evaluated the report October 1995 and found no reason to revise the Danish nuclear emergency response plan. In the Swedish report’s general conclusions evacuation 100-150 kilometres from Swedish nuclear power plants is mentioned as a possibility. The report does not distinguish between evacuation before or after a possible radioactive cloud passage.
The Danish Emergency Management Agency has compared the analyses of the report with the Barsebäck situation and it is the opinion of the Agency that even in the case of the worst possible accident in the Barsebäck nuclear power plant, it will not be necessary to carry into effect an evacuation *before* a possible radioactive cloud passage over Denmark. However, it has to be expected that the protective measure "go inside" will be brought about. The primary cause that there will be no need for an evacuation is that Barsebäck reactor II has only 600 MW electrical effect compared to other Swedish reactors that are 1000 MW and that Danish houses generally offer a better protection against radiation that the Swedish wooden houses. Furthermore, the international standard only prescribes evacuation before the passage of the (radioactive) clouds in the immediate vicinity of the nuclear power plant, i.e. within the limitations of the inner emergency zone 10-15 kilometres from the plant. These guidelines are also followed in Sweden.
SSI has informed The Danish Emergency Management Agency that there are no plans to

evacuate Malmø and Lund before a possible radioactive cloud passage over these cities, even though they are situated closer to the nuclear power plant than Copenhagen itself**.**

In connection with a possible radioactive cloud passage over Denmark measures of the size of a possible radioactive contamination will be made. On the basis of among other things these measurements it will be decided, whether the protective measure "go inside" can be annulled *after* the cloud passage or if there is a need to bring about more far-reaching measures such as cleaning-up and evacuation of the contaminated areas".

Annex 3

The Danish Emergency Management Agency's memorandum 21st of September 2001 on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebäck nuclear power

THE DANISH EMERGENCY
MANAGEMENT AGENCY
The direction secretariat

DIS j.nr. 005-102/2001

September 26th 2001

Memorandum on the consequences in Denmark of a possible terrorist attack in the form of an airplane crash against the Barsebäck nuclear power plant

The oblective of this memorandum is briefly to describe the consequences of a possible terrorist attack against the Barsebäck nuclear power plant in the form of an airplane crash, including a discussion of the organization of the Danish nuclear rescue preparedness in case of such an event.

The memorandum discusses

1. the construction of nuclear power plants as regards airplane crashes,
2. an estimate of the consequences of an airplane crash, when a reactor is running,
3. an estimate of the consequences of an airplane crash, when a reactor is stopped,
4. the organization of the Danish nuclear rescue preparedness and
5. a short summary.

1. Basicly, 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.

Even if there are no direct requirements for nuclear power plants to withstand airplane crashes, the construction of the plant iself offers a basic protection. The reactor is encapsuled by a meter thick concrete mantle designed to protect against radiation from the reactor, but the mantle can also offer protection against external mechanical influences like for instance an airplane crash. Apart from that, the whole reacor system is protected by a containment, normally built in concrete.

According to information from among others the Swedish nuclear authorities and the International Atomic Energy Agency (IAEA) it is expected that the construction of the Barsebäck nuclear power plant could withstand a crash from a small airplane. A crash from a fully tanked larger traffic airplane or a military fighter would – if the reactor itself is hit – probably cause a destruction of the reactor system.

2. If a reactor is running during such an airplane crash, the consequence of the destruction of the reactor system might be that the reactor's cooling systems do not function. Consequently, there might be a risk of a meltdown of the reactor fuel. Radioactive material could be released from the fuel. At the same time a heavy fire might erupt following the ignition of the airplane fuel. The fire might send radioactive material high up into the atmosphere, thereby causing a major geographic dispersion of the radioactive substances.

On the basis of the lessons learnt from the Chernobyl accident – as they are presented to the Danish Emergency Management Agency - the following consequences can be anticipated for Denmark and especially for the metropolitan area:

- No acute casualties. The Barsebäck nuclearpower plant is situated 20 kilometres from Copenhagen. After the Chernobyl accident no acute casualties were registered at such a distance from the reactor.
- A number of children suffering from thyroid gland cancer. After the Chernobyl accident approximately 2000 cases of thyroid gland cancer caused by the accident were registered among children – in Belarus and Ukraine within a distance of 200 kilometres from the plant. According to information presented to the Danish Emergency Management Agency there is a general consensus that the primary cause of these cancer cases is the consumption of radioactive iodine in foodstuffs and only to a lesser degree through the inhaling of radioactive iodine. Therefore, implementation of food restrictions could reduce such negative effects considerably.
- Long-term effects. According to a 1981 report published by the Danish Department of the Environment, "Radioactive ground-contamination in Denmark after a possible serious nuclear accident in the Barsebäck nuclear power plant", the consequences of the "worst-

case" release from the Barsebäck nuclear power plant over Danish territory as a principal rule manifest itself in long-term effects such as leukaemia and other cancer types, hereditary (genetic) diseases and foetus damage. The cancer cases would emerge over a generation. However, the increase in the cancer cases would be so limited compared to the total number of cancer cases in society that it probably could not be registered statistically.

- In the report of the Danish Department of the Environment an accident is analyzed where the radiation release is similar to or exceeds the Chernobyl release. It is stated in the report that a weather situation with an eastern wind over Copenhagen and Seeland with a velocity of 5 m/s in dry weather would have the most serious effects in Denmark and that the assessments in the report are made on the basis of these weather conditions. It is emphasized in the report that other weather conditions, typically in connection with rain, could cause other release dispersion patterns that would expose smaller population groups to significantly larger doses of radiation, but at the same time the contamination would be concentrated in a smaller area. New assessments have not been made, but the conclusions in the report are still considered to be valid.
- Acute radiation damage without fatal consequences. According to the above-mentioned report from the Danish Department of the Environment it cannot be excluded that single individuals who stay outdoors during the passage of the (radioactive) clouds would receive doses that could cause acute radiation damage. Such damage could be avoided by going inside. Under the above-mentioned weather conditions it would take approximately 1 hour for a radioactive cloud to pass from the Barsebäck nuclear power plant to Danish territory. We refer to the description under item 4 of the Danish nuclear rescue preparedness, including warning of the population.

3. The above-mentioned assessments are based on a scenario where the Barsebäck reactor is running just before the airplane crash and that the reactor is shut down when the plane crashes, thereby stopping the chain reaction and the nuclear fission. The shutting down of the reactor takes 4 seconds and is done by pushing the reactor's control rods into the reactor core. This could happen either manually or authomatically. For instance, the authomatic shut down could happen because of the shocks caused by the airplane crash (earthquake protection) or a a rupture in the cooling system.

Even though the reactor is shut down the reactor fuel still develops heat. Consequently, the release of radioactice isotopes does not stop just because the reactor is shut down.

While the reactor heat is decreasing the concentration of radioactive isotopes in the reactor fuel is decreasing (the decaying). The decaying of the various radioactive isotopes is determined by their half-life that defines the time of a given substance being reduced to half of its original quantity.

The half-life of the different isotopes covers a broad spectre, from fragments of seconds to thousands of years. Therefore, a lot depends on which radioactive isotopes are released, when the effects of a radioactive release on the surroundings have to be determined and also, whether the reactor has been shut down in a given period before the accident.

As an important example can be mentioned radioactive iodine which is the most dominant substance in the first phase of an accident. Iodine has a half-life of 8 days. This means that the dose and consequently the risk of for instance thyroid gland cancer would be halved if the reactor had been stopped a week before the airplane crash. After a month the ground dose would have been reduced 16 times, after 2 months 256 times, etc.

Generally, it can be concluded 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.

4. As regards the Danish nuclear rescue preparedness it can be stated that this is a nation-wide rescue preparedness aiming at the implementation of the necessary measures against a broad spectre of nuclear accidents. The rescue preparedness is organized in such a way that it can deal with accidents in nuclear power plants, nuclear fuelled ships, nuclear weapons (in peace-time), spent reactor fuel transports and nuclear fuelled satellites.

As regards the conception of “Plan for the nation-wide nuclear rescue preparedness” situations are considered that could emerge as a consequence of the worst possible accident in nuclear plants situated close to Denmark, including the Barsebäck nuclear power plant. Generally, the plan is adapted to these types of accidents and therefore it would be without importance for a possible implementation of protectice measures what the cause of the accident is.

In this connection it should be noted that a serious reactor accident caused by an airplane would considered to be one of the worst possible scenarios, both as regards the effects and how quickly a release could occur.

As regards the Barsebäck nuclear power plant there is included a “Warning Catalogue” in a special Annex to the rescue preparedness plan that makes it possible – on the basis of meterological information from Denmark’s Meteorological Institute – in few minutes to decide which municipalities in the metropolitan area that have to be warned and to initiate the warning itself.

The Danish Emergency Management Agency maintains a rescue preparedness watch on a twentyfour hour basis in the form of a rescue preparedness manager on duty. Within fifteen minutes, the rescue preparedness manager on duty would be able to warn the relevant municipalities in the metropolitan area after a possible notification about a release from the Barsebäck nuclear power plant. The warning will happen through the Communication Centre of the Commissioner of the Police that can call the relevant police districts instantly.

5. Consequently it can be concluded that

- even though a nuclear power plant is not specifically constructed to withstand an airplane crash, the nuclear power plant´s construction offers a basic protection,
- on the basis of the lessons learned from the latest major accident in the Chernobyl nuclear power plant it is the assessment of the Danish Emergency Management Agency that there will be no acute casualties in Denmark, including in the metropolitan area, which is the one closest to the Barsebäck nuclear power plant,
- implementation of foodstuff restrictions and staying indoors during the passing by of the clouds could reduce the risk of thyroid gland cancer significantly,
- the longer a reactor has been shut down before an accident, the less harmfull a possible release. However, if the time horizon is hours only, this will have limited effect,
- the nation-wide nuclear rescue preparedness aims at the implementation of the necessary measures against a broad spectre of nuclear accidents,
- "Plan for the nation-wide nuclear rescue preparedness" takes its starting point in situations that could emerge as a consequence of the worst possible accident in nuclear plants situated close to Denmark, including the Barsebäck nuclear power plant. The plan is adapted to these types of accidents and therefore it would be without importance for a possible implementation of protectice measures what the cause of the accident is.
- the Danish Emergency Management Agency maintains a rescue preparedness watch on a twentyfour hour basis in the form of a rescue preparedness manager on duty. Within fifteen minutes, the rescue preparedness manager on duty would be able to warn the relevant municipalities in the metropolitan area after a possible notification about a release from the Barsebäck nuclear power plant,
- a possible increase in the amount of cancer cases related to a serious accident in the Barsebäck nuclear power plant would be so small as compared to the amount of cancer cases in society as a whole that such an increase probably could not be registered statistically.

Annex 4

Glossary

Absorbed dose - The energy imparted by radiation to matter or tissue (also known as the organ dose). The unit of measurement is the gray (Gy). See also *dose equivalent* (biologically effective dose).

Activity - The rate of radioactive decay, which is measured in becquerels (Bq). 1 Bq is equivalent to one radioactive disintegration per second. Instead of the becquerel the curie (Ci), the old unit, is still often used. 1 Ci is equivalent to 3.7×10^{10} Bq or 1 Bq = 2.7×10^{-11} Ci (27 picocuries).

Alpha, beta and gamma rays - Radioactive substances emit different types of radiation, which have different ranges. Iodine-131 and caesium-137, for example, are gamma-emitters. Strontium-90, on the other hand, is a beta-emitter. Gamma radiation is a high-energy form and is highly penetrating, but beta radiation can only penetrate a few centimetres in body tissue, or a few metres in the air.

Atom - The smallest particle of an element that has the chemical properties of the element. An atom consists of a comparatively massive central nucleus of protons and neutrons carrying a positive electric charge, around which electrons move in orbits at relatively great distances away.

Atomic - Strictly, relating to the behavior and properties of entire atoms - nuclei and orbital electrons. More usually a synonym for “nuclear” as in “atomic energy”.

Background radiation - Radiation from natural sources, such as cosmic rays or that emitted by natural radioactive elements such as uranium and radon. It is expressed in sieverts (Sv) or millisieverts (mSv).

BBOFF - *Barsebäcksoffensiv*, a loosely organized network consisting of activists, green NGOs and political parties in Denmark, Sweden and Germany.

Becquerel, Bq. -The unit of activity in the SI System, measuring the rate at which atoms decay. 1 Bq is equivalent to one disintegration per second. The activity is usually expressed in relation to one cubic metre (m^3) of air or one kilogram (kg) of food. Becquerels can indicate the activity of all the radioactive substances in a sample, or – and this is the more common procedure – the activity of a particular radioactive element such as caesium-137. Instead of the becquerel, the old unit, the curie (Ci) is often still used. 1 Ci is equivalent to 3.7×10^{10} Bq or 1 Bq = 2.7×10^{-11} Ci (27 picocuries).

Beta Particles - Negatively charged particles emitted from an atom. Beta particles have a mass and charge equal to that of an electron. They are very light particles (about 2,000 times less mass than a proton) and have a charge of -1. Because of their light mass and single charge, beta particles can penetrate more deeply than alpha particles. A few millimeters of aluminum will stop most beta particles.

BWR - Boiling Water Reactor.

Caesium-137 - The most widely distributed long-lived radioactive element (half-life 30 years) following the Chernobyl accident. The measurements and maps of the contaminated territories in Belarus, Russia and Ukraine therefore relate to caesium-137. The names of radioactive substances are often given as follows: the chemical symbol for caesium (Cs) is followed by the atomic mass: Cs-137.

CLAB – *Central medium-term repository for spent fuel.* The spent fuel is stored in water pools for approximately 30 years, before it is long-term stored in a deep repository. CLAB is owned by SKB.

Collective dose - Total dose over a population group exposed to a given source. It is represented by the product of the average dose to the individuals in the group by the number of persons comprising the group. It is measured in personsieverts (person-Sv).

Control rod - A usually rod-shaped device to control the chain reaction, a sort of "brake" for the nuclear reactor. Control rods consist of neutron-absorbing material, such as graphite, as in the case of the reactor at Chernobyl. As control rods are lowered into the core, the number of neutrons available is reduced and the chain reaction stops.

Core - The central portion of a nuclear reactor containing the fuel elements, moderator, neutron poisons, and support structures.

Critical Mass - The minimum mass of a fissionable material that will just maintain a fission chain reaction under precisely specified conditions, such as the nature of the material and its purity, the nature and thickness of the tamper (or neutron reflector), the density, and the physical shape. For an explosion to occur, the system must be supercritical (i.e., the mass of the material must exceed the critical mass under the existing conditions).

Critical organ – That part of the human body which is most liable to be damaged, either by a stated radionuclide taken into the body, or by radiation from an external source.

Curie, Ci - The old, but still used, unit of activity, measuring the rate at which atoms decay. The unit of radioactivity, being the quantity of radioactive material of 1 gram of radium-226. The curie has been superseded under the SI System by the Becquerel (Bq), equal to 1 disintegration per second.

Damage, nuclear – (Swedish legal definition) (1) Any damage caused by the radioactive properties of nuclear fuel or radioactive products or a combination of radioactive properties with toxic, explosive or other hazardous properties of such fuel or products. (2) Any damage caused by ionizing radiation emitted from any source of radiation inside a nuclear installation other than nuclear fuel or radioactive products.

Decay, radioactive - The disintegration of a nucleus through emission or radioactivity. The decrease of activity due to such disintegration.

Decommissioning -The final closing down and putting into a state of safety of a nuclear reactor or other plant when it has come to the end of its useful life.

Decontamination - The complete or partial removal of radioactive contaminants using chemical or physical processes, washing or cleaning using chemicals.

Depleted Uranium - Uranium having less than the natural 0.7% U-235. As a by-product of enrichment in the fuel cycle it generally has 0.25-0.30% U-235, the rest being U-238. Can be blended with highly-enriched uranium (eg from weapons) to make reactor fuel.

Disintegration - Any transformation of a nucleus, either spontaneous or by interaction with radiation, in which particles or photons are emitted. Used in particular to mean radioactive decay.

Dose equivalent (biologically effective dose) - A measure of the harmfulness of radiation for humans. The dose equivalent takes into consideration the differing biological effects of different types of radiation. It can be calculated by multiplying the dose absorbed by a quality factor (depending on the type of radiation). The SI unit of dose equivalent is the sievert (Sv).

Dose, radiation - Generally, the quantity of radiation energy absorbed by a body. There are many special definitions to cover different applications. See Rad, Rem, Roentgen, etc.

Dose rate - The dose absorbed in unit time, e.g. rems per year, also used as the level of intensity of radiation at a given point, e.g. millirads per hour.

Emergency Management Agency, The Danish - Governmental agency under the Ministry of the Interior. According to the Danish Preparedness Act the principal task of the Emergency Management Agency is to manage the National Rescue Preparedness Corps, to supervise the national and municipal rescue preparedness and to advice the authorities on matters of preparedness. The national rescue preparedness has a staff of some 700 persons. About 140 of these are employed in the central Emergency Management Agency. The rest are employed at the Agency's seven rescue centres and three schools.

Emergency preparedness - generally refers to actions that can and should be performed prior to an emergency. Actions such as planning and coordination meetings, procedure writing, team training, emergency drills and exercises, and pre-positioning of emergency equipment all are part of emergency preparedness.

Emergency response - refers to actions taken in response to an actual, ongoing event. Emergency response can be either organized and effective, or disorganized and chaotic. The difference can often be attributed to the level of communication and cooperation established among the various response organizations (licensee, state, county, local) during pre-emergency preparedness activities.

Fissile Material - Any element capable of nuclear fission, e.g., uranium or plutonium.

Fission - The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium-235 and plutonium-239; fission is caused by the absorption of neutrons.

Fission Products - A general term for the complex mixture of substances produced as a result of nuclear fission.

FOA - *The Swedish Defence Research Centre*.

FMKK – *Folkkampanjen mot Kärnkraft-Kärnvapen*. The Swedish anti-nuclear movement.

Fuel, nuclear - Fissionable material consisting of uranium or plutonium metal, alloy or chemical compound or other fissionable material.

Genetic effects - Damage to germ cells, which may be passed on to future generations.

Gray, Gy - The SI unit of absorbed radiation dose, one joule per kilogram. 1 Gy = 100 rads.

Half-life -The characteristic time taken for the activity of a particular radioactive substance to decay to half of its original value - that is, for half the atoms present to disintegrate, i.e. a measure of how long a radioactive substance represents a problem in the environment. Half-lives vary from less than a millionth of a second to thousands of millions of years, depending on the stability of the nuclide concerned. For example, the half-life of caesium-137, the most widely distributed element after the accident in Chernobyl, is about 30 years. This means that after 30 years, half of the radioactive atoms in a given quantity of caesium will have decayed. After another 30 years, only a quarter of the caesium is radioactive, and so on. Iodine-131, another element released in the nuclear accident at Chernobyl, has a half-life of only 8 days and had thus decayed almost completely after a few months.

Health Physics - The study and administration of radiological protection.

IAEA - *The International Atomic Energy Agency*. UN's nuclear energy organization located in Wienna. IAEA was founded 1956 and deals with the peaceful exploitation of nuclear power, supporting research and education and providing technical support. IAEA monitors the so-called non-proliferation treaty, i.e. that nuclear substances (uranium, plutonium) are not used for production of nuclear weapons.

Incident, nuclear – (Swedish legal definition) Any occurrence or series of occurrences having the same origin which causes nuclear damage.

INES - *The International Nuclear Event Scale*. The scale is a tool intended to promptly and consistently communicate to the public the safety significance of reported events at nuclear installations. The INES was designed by an international group of experts convened jointly by the IAEA and the NEA. The INES consists of a 7-level event classification system. Events of greater safety significance (levels 4-7) are termed "accidents", events of lesser safety significance (levels 1-3) are termed "incidents", and events of no safety significance (level 0 or below scale) are termed "out-of-scale deviations". INES creates a common understanding of nuclear events among the nuclear community, the media, and the public. It is widely used within the nuclear community and among the 48 Member States participating in the system to describe the magnitude of an incident. On INES, for example, the Three Mile Island accident would have rated as a level five; the on-site damage was severe but the offsite release of radioactivity was minor. Chernobyl, which had extensive off-site effects, would have rated at the top of the scale, as a level seven. Since its creation, INES has been used predominantly to describe events at nuclear power plants, but recently it was adapted to include potentially all civil nuclear installations and transport incidents involving radioactive materials.

Installation, nuclear – (Swedish legal definition) Any nuclear reactor other than one with which a ship or any other means of transport is equipped for use as a source of power. Any factory for the production or processing of nuclear substances. Any factory for the separation of isotopes of nuclear fuel. Any factory for the reprocessing of irradiated nuclear fuel; any facility where nuclear substances are stored with the exception of any facility intended exclusively for storage incidental to the carriage of such substances. Any such other installation containing nuclear fuel or radioactive products.

Iodine - One of the radioactive elements released into the environment following the nuclear accident at Chernobyl. In terms of radiation exposure, iodine, with a half-life of 8 days, posed the greatest immediate risk. In Belarus, for example, in the first week after the accident, increased iodine levels were measured almost everywhere. The human body cannot distinguish radioactive iodine from its natural, stable counterpart, and stores it primarily in the thyroid gland. Iodine is considered to be responsible for the dramatic rise in the incidence of thyroid cancer, especially among children and adolescents, following Chernobyl.

Ion - An atom that has lost or gained one or more orbital electrons, thus becoming electrically charged.

Ionization - The process by which neutral atoms of molecules are divided into pairs of oppositely charged particles known as ions.

Ionizing Radiation - Radiation that removes orbital electrons from atoms, thus creating ion pairs. Alpha and beta particles are more densely ionizing than gamma rays or X-rays of equivalent energy. Neutrons do not cause ionization directly.

IRSN - *Institute de Radioprotection et Sûreté Nucléaire*.

Isotope - One of the different “varieties” of a radioactive element. Atoms of the same element having different atomic weights due to differences in the number of neutrons in their nuclei. Isotopes have the same atomic number but different mass numbers. (A useful working definition is "atoms that are the same outside but different inside"). For example, caesium exists as caesium-134 and caesium-137. See also *radioactivity.*

Meltdown - A nuclear reactor is fueled with many thousands of ceramic uranium pellets located within metal fuel rods. As the reactor performs its intended function (uranium atoms fission, releasing heat energy, generating steam for electrical power production) many of the uranium atoms are converted into new atoms that are highly energetic and highly radioactive. Under normal conditions these highly radioactive “fission products” remain safely within the confines of the metal fuel rod. It is possible however, that the energy released by the fission products could be sufficient to damage metal fuel rod, and even melt the ceramic fuel pellet itself. Fuel pellet melting is a significant concern because it indicates that multiple protection systems and radiation barriers have failed, and that other systems and barriers are about to be challenged. Accidents of this magnitude are classified at the highest severity level (general emergency).

NEA – *The Nuclear Energy Agency*.

Nuclear Energy - Heat energy produced by the process of nuclear fission within a nuclear reactor. The coolant that removes heat from the reactor core is normally used to boil water. The resultant steam drives turbines that rotate electrical generators.

Nuclear fuel cycle - All the processes involved in providing fuel for a nuclear reactor and disposing of it. This includes the extraction and preparation of nuclear fuel, the manufacture of fuel rods, the reprocessing of spent fuel rods and the final disposal of radioactive wastes.

Nuclear Materials - Nuclear materials are the key ingredients in nuclear weapons. They include fissile, fussionable and source materials. Fissile materials are those that are composed of atoms that can be split by neutrons in a self-sustaining chain-reaction to release energy, and include plutonium-239 and uranium-235. Fussionable materials are those in which the atoms can be fused in order to release energy, and include deuterium and tritium. Source materials are those that are used to boost nuclear weapons by providing a source of additional atomic particles for fission. They include tritium, polonium, beryllium, lithium-6 and helium-3.

Nuclear substances – (Swedish legal definition) Nuclear fuel other than natural uranium or depleted uranium and radioactive products other than radio-isotopes which are used or prepared to be used for any industrial, commercial, agricultural, medical or scientific purpose.

Neutron - An elementary particle with mass of 1 atomic mass unit approximately the same as that of the proton (approximately 1.67 x 10-27 kg). Together with protons, neutrons form the nuclei of all atoms. Being neutral, a neutron can approach a nucleus without being deflected by the positive electric field, so it can take part in many types of nuclear interaction. In isolation neutrons are radioactive, decaying with a half-life of about 12 minutes by beta emission into a proton. See Nucleon.

Nucleon - A proton or a neutron, the particles from which all atomic nuclei are composed.

Nucleus - The central part of an atom at which the positive electric charge, and nearly all the mass, is concentrated and around which the orbital electrons revolve. See Nucleon.

Nuclide - An individual species of atom characterized by its mass number, atomic number and the energy state of its nucleus. See Isotopes, Radionuclide.

OOA - *Information on Nuclear Power*, the Danish anti-nuclear movement. Abolished in 2000.

Operator – (Swedish legal definition) In relation to a nuclear installation situated in Sweden, the (legal) person operating or in charge of the installation, whether authorized thereto under the Atomic Energy Act or not.

Paris Convention - The Convention on Third Party Liability in the Field of Nuclear Energy, signed in Paris on 29th July 1960 and amended by the Additional Protocol signed in Paris on January 28th 1964.

Plutonium - One of the radioactive elements released into the environment following the nuclear accident in Chernobyl. Some of the isotopes of plutonium have a half-life of up to 24 000 years. Plutonium is not found naturally in significant quantities. It is produced in a nuclear reactor

through the absorption of neutrons by Uranium 238. The Plutonium emerges from a nuclear reactor as part of the mix in spent nuclear fuel, along with unused uranium and other highly radioactive fission products. To get plutonium into a usable form, a second key facility, a reprocessing plant, is needed to chemically separate out the plutonium from the other materials in spent fuel.
Once plutonium is separated, it can be processed and fashioned into the fission core of a nuclear weapon, called a "pit". Nuclear weapons typically require three to five kilograms of plutonium. Plutonium can also be converted into an oxide and mixed with uranium dioxide to form mixed-oxide (MOX) fuel for nuclear reactors.
A number of isotopes of plutonium are produced in a reactor, the most common being Pu-239 which is easily fissionable, and Pu-240 which is not. The relative proportion of Pu-239 determines the weapons grade of the plutonium. Reactor grade Pu, i.e. Pu with 18% or more Pu-240, can still be used to make a “crude” nuclear bomb.
Plutonium is an alpha particle emitter and so does not penetrate the skin. However, when ingested into the body, plutonium is incredibly toxic as alpha particles cause a very high rate cell damage. It is possible, for example, to contract lung cancer from one millionth of a gram.

PSA - Probabilistic Safety Analysis.

Rad - A unit of absorbed radiation dose, equivalent to 0.01 joules per kg. The unit is being replaced by the SI unit, the Gray (Gy), equal to 100 rads. See Roentgen and Rem.

Radiation - Electromagnetic waves especially (in the context of nuclear energy), X-ray and gamma rays, or streams of fast-moving particles (electrons, alpha-particles, neutrons, protons), i.e. all the ways in which an atom gives off energy.

Radiation area - An area to which access is controlled because of a local radiation hazard.

Radiation sickness - The acute non-stochastic effects caused by a large dose of radiation to the whole body, such as might be received in a reactor accident or from a nuclear weapon explosion or its fall-out. The symptoms and their outcome vary with dose size, ranging from temporary nausea to death.

Radioactive products – (Swedish legal definition) Any radioactive material other than nuclear fuel and radioactive waste, if the material or waste has been produced in the process of producing or utilizing nuclear fuel or has become radioactive by exposure to radiation incidental to such production or utilization.

Radioactivity - Emission of radiation caused by the disintegration of unstable atomic nuclei. This radioactive decay creates another element, which is often itself radioactive. The decay series (see also *half-life*) continues until a stable (no longer radioactive) element is reached. This is why there are different “varieties” of each radioactive chemical element. For example, caesium exists as caesium-134 and caesium-137, iodine as iodine-129 and iodine-131. The names of radioactive substances are often given as follows: the chemical symbol for caesium (Cs) is followed by the atomic mass: Cs-137. These different varieties are often described as isotopes or radionuclides.
Numerous radioactive substances exist in nature (see *background radiation*). The most wellknown of these include radium and uranium. In reactors and laboratories, atomic fission produces artificial radionuclides such as caesium, iodine, strontium and plutonium. These differ

in the length of their half-life and the type of radiation (alpha, beta or gamma rays) they emit. The nuclear accident at Chernobyl primarily released caesium-137, iodine-131, uranium-235 and strontium-90 into the environment.

Radioactivity, induced - Radioactivity that has been induced in an otherwise inactive material, usually by irradiation with neutrons.

Radioactivity, natural - The radioactivity of natural occurring materials, e.g. uranium, thorium, radium, lead, potassium, carbon, hydrogen.

Radioisotope - Short for radioactive isotope.

Radiology - The branch of medicine specializing in the uses of ionizing radiation's for medical diagnosis, and in studying their effects.

Radionuclide - Radioactive nuclide.

Radiotoxicity - A measure of the harmfulness of a radioactive substance to the body or to a specified organ following its uptake by a given process.

Reactivity (1) Of fuel, the ability to support a chain reaction. (2) Of a reactor, a measure of the possible departure from the critical condition, where the chain reaction is just self-sustaining (reactivity zero). Added reactivity, e.g. by withdrawal of a control rod, will cause the reaction to diverge with an increase in power output; conversely, removal of reactivity will cause it to die down, e.g. as fuel burns up or as fission-product "poisons" develop.

Reactor, nuclear - Any structure containing nuclear fuel in such an arrangement that a self-sustaining chain process can occur therein without an additional source of neutrons, i.e. an installation used to initiate, maintain and control a fission chain reaction. Its main components are the core, containing fissionable fuel, the coolant and moderator, control rods, and shielding.

Rem - Roentgen equivalent man: the unit of effective radiation dose absorbed by tissue, being the product of the dose in rads and the quality factor. The rem is being replaced by the SI unit, the Sievert (Sv), equal to 100 rem.

RMBK – *Light-water-cooled graphite-moderated reactor*. A nuclear reactor in which the water used as a coolant boils and the turbines are driven directly by the steam generated. Reactor 4 in Chernobyl was of this type (Russian abbreviation: RBMK).

Roentgen - A unit of exposure to radiation based on the capacity to cause ionization. It is equal to 2.58 x 10-4 Coulomb per kg in air. Generally an exposure of 1 Roentgen will result in an absorbed dose in tissue of about 1 Rad. See also Rem.

Safety rod - One of a set of additional reactor control rods used specifically for emergency shut-down and for keeping the reactor in a safe condition during maintenance etc.

Sievert, Sv - The SI unit of radiation dose equivalent; the product of absorbed dose in grays and the quality factor 1 Sv = 100 rem. The new unit takes into account the differing biological effects of the different types of radiation.

Sievert: A unit of dose equivalent. 1 Sv= 100 roentgens, 10 µSv/hr = 1 milliroentgen/hr. (µSv micro-Sievert, micro is one millionth, milli is one thousandth.)

SKI - *The Swedish Nuclear Power Inspectorate.* Investigates, monitors and promotes the safety of the nuclear installations. That also applies to all activities connected with transport, processing and storage of nuclear waste. SKI carries out an extensive research program.

Spent Fuel - Nuclear fuel elements that are discharged from a nuclear reactor after they have been used to produce power.

Spent fuel burn-up – Measured in the unit GWd/t as 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 (measured in tons of material) is obtained by multiplying a power (GW) by a length-time (day). A burn-up of 50 GW.d/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.

SSI - *The Swedish Radiation Protection Authority.* Monitors all radiation protection activities in Sweden connected with nuclear power and other activities. Carries out research of radiation and characteristics of radioactive substances.

Stochastic effect - A radiation-induced health effect, the probability of occurrence of which is greater for a higher radiation dose. The severity of such an effect (if it occurs) is independent of the dose.

Strontium -One of the radioactive elements released into the environment following the nuclear accident at Chernobyl. Some of the isotopes of strontium have a half-life of up to 90 years.

Supplementary Convention – The Convention supplementary to the Paris Convention, signed in Brussels on January 31st 1963 and amended by the Additional Protocol signed in Paris on January 28th 1964**.**

Units of radioactivity - The units used to measure radioactivity in the soil or in food (as detected by a Geiger counter) are becquerels (Bq) and curies (Ci). One becquerel is equivalent to one radioactive disintegration per second. 1 Bq = 27 trillionths of a curie = 27 picocuries.
Activity is usually expressed in relation to one cubic metre (m3) of air or one kilogram (kg) of food. On maps the reference area is often 1 square kilometre (km2). Caesium-137 is the most widely distributed long-lived radioactive element (half-life 30 years) following the Chernobyl accident. The measurements and maps of the contaminated territories therefore usually relate to caesium-137.
The value "more than 1 Ci/km2 caesium-137" does not in itself indicate how much radiation is absorbed by the people who live in the area. The internationally recognised unit used to measure the harmfulness of radioactivity is the sievert. The biologically effective dose is often expressed in sieverts (Sv) or millisieverts (mSv).

Uranium - Uranium occurs naturally in underground deposits consisting of a mixture of 0.7% uranium-235, which is easily fissionable, and about 99.3% uranium-238, which is not fissionable. Nuclear weapons require “enrichment” to increase the proportion of U235 to 90% or more. This is called Highly Enriched Uranium (HEU). Nuclear reactors require enrichment to about 3 - 5 % of U-235. This is called Low Enriched Uranium (LEU).
HEU can be combined with plutonium to form the "pit", or core of a nuclear weapon, or it can be used alone as the nuclear explosive. The bomb dropped on Hiroshima used only HEU. About 15-20 kgs of HEU are sufficient to make a bomb without plutonium.