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Nordisk kernesikkerhedsforskning
Norrænar kjarnöryggisrannsóknir
Pohjoismainen ydinturvallisuustutkimus
Nordisk kjernesikkerhetsforskning
Nordisk kärnsäkerhetsforskning
Nordic nuclear safety research

NKS-239
ISBN 978-87-7893-311-9

Nuclear Safety Culture in Finland and Sweden – Developments and Challenges

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February 2011

Abstract

The project aimed at studying the concept of nuclear safety culture and the Nordic nuclear branch safety culture. The project also aimed at looking how the power companies and the regulators view the current responsibilities and role of subcontractors in the Nordic nuclear safety culture as well as to inspect the special demands for safety culture in subcontracting chains. Interview data was collected in Sweden (n = 14) and Finland (n = 16) during 2009. Interviewees represented the major actors in the nuclear field (regulators, power companies, expert organizations, waste management organizations). Results gave insight into the nature and evaluation of safety culture in the nuclear industry. Results illustrated that there is a wide variety of views on matters that are considered important for nuclear safety within the Nordic nuclear community. However, the interviewees considered quite uniformly such psychological states as motivation, mindfulness, sense of control, understanding of hazards and sense of responsibility as important for nuclear safety. Results also gave insight into the characteristics of Nordic nuclear culture. Various differences in safety cultures in Finland and Sweden were uncovered. In addition to the differences, historical reasons for the development of the nuclear safety cultures in Finland and Sweden were pointed out. Finally, results gave implications that on the one hand subcontractors can bring new ideas and improvements to the plants' practices, but on the other hand the assurance of necessary safety attitudes and competence of the subcontracting companies and their employees is considered as a challenge. The report concludes that a good safety culture requires a deep and wide understanding of nuclear safety including the various accident mechanisms of the power plants as well as a willingness to continuously develop one's competence and understanding. An effective and resilient nuclear safety culture has to foster a constant sense of unease that prevents complacency yet at the same time it has to foster a certain professional pride and a feeling of accomplishment to maintain work motivation and healthy occupational identity. The report gives several recommendations for further developing nuclear safety culture in Finland and Sweden.

Key words

Safety culture, human and organizational factors, safety management, contractors, evaluation

NKS-239
ISBN 978-87-7893-311-9

Electronic report, February 2011

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Acknowledgements

The report sums up work that has been carried out within the NKS-R/MOSACA-project during 2008-2010. The report is a revised and updated version of the intermediate report published in 2009 by the same authors (Safety Culture in the Finnish and Swedish Nuclear Industries – History and Present, NKS-213). The goal of the project in 2010 was to deepen the results concerning especially the role of contractors in the Nordic nuclear safety culture. Major revision has been done for all the original chapters included in the 2009 report and results from the new analyses have been integrated into the existing findings. The only part of the report that has been left largely unaltered is the Section 5 on the similarities and differences between the Swedish and Finnish nuclear branches. A new chapter focusing on contractors has also been added to the report (Section 7 “Contractors’ role in the Nordic nuclear industry“).

The work has been funded by the Nordic Nuclear Safety Research (NKS). Additional funding has been provided by the Finnish Research Programme on Nuclear Power Plant Safety SAFIR2010, and VTT. The authors wish to thank all the interviewees for their time and their insights on the difficult issues of safety culture and nuclear safety.

1. Introduction

The International Atomic Energy Agency IAEA (1991) defines safety culture as follows: "Safety culture is that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" (IAEA, 1991, p. 1). The concept of safety culture was coined in the aftermath of the Chernobyl nuclear meltdown in 1986 (IAEA, 1986, 1991) in an attempt to develop a concept for gaining an overview and an indicator of the safety level of the organization now and in the future. The concept tried to grasp some of the personnel related and social factors (such as safety attitudes, norms, management focus) affecting safety. The roots of the safety culture concept lie in the wider concept of organizational culture[1]. The early theories of organizational culture emphasized the social integration and equilibrium as goals of the sociotechnical system (Meek 1988). Only shared aspects in the organization were considered part of the culture. These theories of organizational culture had often a bias toward the positive functions of culture in addition to being functionalist, normative and instrumentally biased in thinking about organizational culture (Alvesson, 2002, pp. 43-44). This means that culture was considered a tool for the managers to control the organization. The safety culture concept bears a strong resemblance to these early traditions of organizational culture (cf. Cox & Flin, 1998; Richter & Koch, 2004). Thus, safety culture became a tool for the management to lead and influence the personnel, but also a tool for the regulator and the society to influence the power plant management. A common aim was to address the human contribution to serious accidents. The regulatory authorities quickly required a proper "safety culture", first in the nuclear area and gradually also in other safety-critical domains. The role of the managers and their leadership activities in creating and sustaining a safety culture were emphasized.

Recently, the definition of organizational culture has been revised in less functionalistic terms (see e.g. Smircich, 1983; Hatch, 1993; Schultz, 1995; Alvesson, 2002; Martin, 2002). In contrast to the functionalistic theories of culture, the more interpretive-oriented theories of organizational culture emphasize the symbolic aspects of culture such as stories and rituals, and are interested in the interpretation of events and creation of meaning in the organization. The power relationships and politics existing in all organizations, but largely neglected by the functionalistic and open systems theories, have also gained more attention in the interpretive tradition of organizational culture (cf. Vaughan, 1999; Alvesson, 2002). Cultural approaches share an interest in the meanings and beliefs that the members of an organization assign to organizational elements (structures, systems and tools) and how these assigned meanings influence the ways in which the members behave themselves (Schultz, 1995; Alvesson, 2002; Reiman & Oedewald, 2007; Rollenhagen, 2010).

Despite over two decades of research, no clear and widely accepted definition of safety culture and of the means to develop it exists. There are two main sources of confusion. First, the definitions of safety culture emphasize to varying degrees the attitudes, behaviour, or knowledge of the personnel, with some definitions placing emphasis on the structural features of the organization. This leads to very different ideas about the best means of developing safety culture. Second, the definitions of safety culture are often generic in nature. Thus, they do not take into account the varying demands of different functions operating at the power plants or the life-cycle of the given unit. For example, how does safety culture manifest in a design organization or construction work? Should it be different in young companies in comparison to mature organizations or in waste management organizations in comparison to power companies? What is the relation of national culture to safety

[1] For the history of the concept and various definitions and operationalizations of organizational culture, see e.g., Alvesson (2002) and Martin (2002).

culture, i.e. should all national cultures have the same nuclear safety culture? Generic definitions of safety culture concept easily lead to overgeneralizations about what is the best safety culture and limit the usefulness of the approach in actual safety improvement. The concept of safety culture needs to be looked within the context of nuclear power production taking into account the historical and institutional influences in the given country and the international field

The study reported in this paper had three goals. The first goal was to develop a dynamic view on safety culture based on existing literature and previous case studies of the authors and test it in the Nordic nuclear industry by interviews. The second goal was to study whether there is a shared Nordic nuclear branch safety culture and what characterizes it. The preliminary theoretical model of safety culture has been reported at Reiman et al. (2008), Rollenhagen (2010), see also Reiman and Oedewald (2009). The third goal was to look at how the power companies and the regulators view the current responsibilities and role of the subcontractors in the Nordic nuclear safety culture as well as to inspect the special demands for safety culture in subcontracting chains.

Safety can be conceptualized as an emergent property of the entire sociotechnical system (Reiman & Oedewald, 2009). The technology on one hand creates the inherent hazards that then need to be controlled. On the other hand technology is also utilised to control the hazards (safety systems), meet production targets and carry out tasks of various kinds. Also, the goals and priorities are defined in the organization, including preventive maintenance and fuel load schedules. Thus, safety management requires the management of the organization, taking into account the core task of the organization. This approach sets also the concept of safety culture into a new perspective by emphasizing the entire sociotechnical system as its context. Safety is a dynamic non-event (Weick, 1987), not a consistent and invariable outcome of formal organizational systems and technical barriers. As a starting point, we have defined the following aspects as important in terms of indicating a *good* safety culture (see also Reiman and Oedewald, 2009):

- Safety is genuinely valued and the members of the organization are motivated to put effort on achieving high levels of safety and carrying out their tasks effectively
- It is understood that safety is a complex phenomenon. Safety is understood as an emergent property of the entire system that has to be created again daily, and not just as an absence of incidents (cf. Weick 1987)
- People feel personally responsible for safety of the entire system, they feel that they can have an effect on safety and are willing to make a difference
- The organization aims at understanding hazards and anticipating the risks in their activities
- The organization is alert to the possibility of unanticipated events and remains mindful in its daily activities (Weick & Sutcliffe 2007)
- There exist good prerequisites in terms of resources and tools for carrying out the daily work
- The interaction between people promotes a formation of shared understanding of safety as well as situational awareness of ongoing activities

These statements were used as background in devising the interview questions (see Appendix A) for the representatives of Nordic nuclear branch concerning the characteristics of safety culture.

2. Methods

As indicated by figure 1, the data for this study was collected by interviews. The content of the interviews was designed based on a theoretical framework of safety culture (Reiman et al., 2008; Rollenhagen, 2010; Reiman & Oedewald, 2009) and the criteria proposed in the Introduction. The actual interview questions were created together with the entire research group (the authors of this report and Pia Oedewald from VTT).

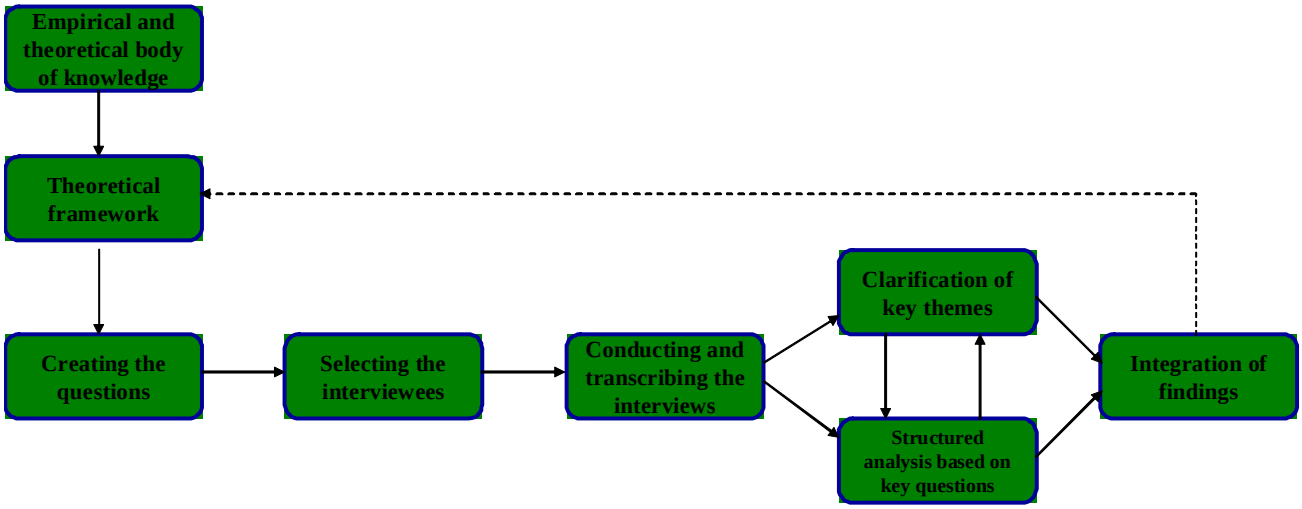

Figure 1. Model of the research process

The interview questions concerned the following content areas:

- Nuclear safety as a concept
- Characteristics and differences of the nuclear industries in Finland and Sweden
- Psychological characteristics of the nuclear safety culture at the Nordic countries
- Development and current challenges of the Nordic nuclear field

In Sweden there were two interviewers collecting the data but only one interviewer was present in each interview session. Most of the interviews lasted from one to two hours. Two of the interviews were conducted by telephone. Interviews were conducted in Swedish. The organizations in Sweden that took part in the study were:

Organization	***Number of persons interviewed***
Oskarshamn Power Plant	2
Ringhals Power Plant	1
Forsmark Power Plant	4
RiskPilot AB	1
Vattenfall Staff	2
SSM (regulator)	2
KSU (training support)	1
SKB (spent fuel management)	1
TOTAL:	**14**

In Finland two interviewers were present in each interview except for the interviews done at TVO. At TVO one interviewer conducted the interviews. The interviews lasted from one to two hours

(except for one interview at Loviisa NPP that was shortened due to interviewee's busy schedule) and were made in Finnish. The organizations in Finland that took part in the study were:

Organization	***Number of persons interviewed***
Loviisa Power Plant	6
Radiation and Nuclear Safety Authority Finland. (STUK)	3
Posiva Oy	3
Olkiluoto power plant (TVO)	3
Fortum Power & Heat	1
TOTAL:	**16**

The interviewees in both countries were selected so that they would represent the major actors in the nuclear field, i.e. the regulators, power companies, expert organizations and waste management organizations. Contractor interviews were left outside the scope of this study. Most of the interviewees currently held, or had experience of, a management position. Most of the interviewees had worked in the nuclear industry for at least ten years. Interviewees all had a fair amount of experience in many different positions, including operation, maintenance, engineering and human factors related issues. Most of them had a technical basic education.

The interviews were semi-structured and followed a predefined outline of open questions that were supplemented with follow-up questions when something interesting, unclear or new / surprising came up. The interviews started with a short introduction:

> *"We are interested in the Nordic nuclear community and safety. We're interested in various groups and organizations that are primarily involved in and influencing the nuclear industry. We're trying to find out whether there are similarities in terms of how people think and behave in relation to nuclear safety."*

The interviews were recorded and transcribed into their original language. The researchers made preliminary analysis of the data and clarified key content themes in the Nordic nuclear safety culture. The results of the structured analysis were distributed within the project group in a summary analysis table written in English. This summary table was further analysed jointly by the research group.

In the second stage of the project carried out in 2010, the interview data was analysed from the point of view of subcontracting. The topical issues and different roles attributed to contractors were extracted from the material. In addition, an email survey was sent to all the Nordic power plants as well as both waste management organizations on topical issues in assuring safety culture of the contractors. Responses were received from OKG AB and RAB.

3. Nuclear power in the Nordic countries[2]

3.1 The early days

The basics of science of atomic radiation, atomic change and nuclear fission were developed during 1895-1945. Ionising radiation was discovered by Wilhelm Rontgen in 1895, by passing an electric current through an evacuated glass tube and producing continuous X-rays. Henri Becquerel and Pierre and Marie Curie continued work on radiation, and the Curies coined the term radioactivity. Ernest Rutherford developed a fuller understanding of atoms. Niels Bohr was another scientist who advanced our understanding of the atom and the way electrons were arranged around its nucleus. Nuclear fission was first experimentally achieved by Enrico Fermi in 1934 when his team bombarded uranium with neutrons. The work focused on military applications, and over 1939-45, most development was focused on the atomic bomb in the Manhattan project.

Electricity was generated for the first time by a nuclear reactor on December 20, 1951 at the EBR-I experimental station near Arco, Idaho, which initially produced about 100 kW (the Arco Reactor was also the first nuclear facility to experience partial meltdown, in 1955). Since 1956 the prime focus has been on the technological evolution of reliable nuclear power plants. The address given by Dwight D. Eisenhower, "Atoms for Peace," before the General Assembly of the United Nations on 8 December 1953 planted seeds for the creation of the International Atomic Energy Agency (IAEA) in 1957 and helped shape international co-operation in the civilian use of nuclear energy (Fischer 1997). At the beginning of the 1960s, also OECD took up co-operation in the nuclear field. This work has been very practical in generating reference data for the reactors used in the industrialised countries.

3.2 International development during 1965-1999

The WASH-1400 report (also known as the “Rasmussen report”) in 1975 was a landmark event in the development of Probabilistic Risk Assessment (PRA) of nuclear power plants. The report established PRA (in the Nordic countries mostly known as PSA, with S standing for safety) as the standard approach in the safety-assessment of modern nuclear power plants (Hollnagel, 2009, p. 138). In the report the hypothetical accident scenarios and their probabilities in Light Water Reactor plants were considered with the use of fault and event trees, which are the most important tools that are used in PSA.

Nuclear energy became very early a politically sensitive topic, and the Rasmussen report was one attempt to reduce the political pressure on nuclear power. In the United States the nuclear regulation was originally the responsibility of the Atomic Energy Commission (AEC), which Congress first established in the Atomic Energy Act of 1946. Eight years later, Congress replaced that law with the Atomic Energy Act of 1954, which for the first time made the development of commercial nuclear power possible. The act assigned the AEC the functions of both encouraging the use of nuclear power and regulating its safety. An increasing number of critics during the 1960s charged that the AEC's regulations were insufficiently rigorous in several important areas, including radiation protection standards, reactor safety, plant siting, and environmental protection. The Energy Reorganization Act of 1974 created the Nuclear Regulatory Commission; it began operations on January 19, 1975.

[2] Unless otherwise noted, the following reference sources were used for writing the history of nuclear power in Section 3: Lehtinen & Sandberg 2004, Kettunen et al. 2007, http://www.world-nuclear.org/, Wikipedia, www.tvo.fi, www.stuk.fi, www.posiva.fi, www.skb.se, www.oecdnea.org/html/rwm/, www.vattenfall.com, www.nea.fr, www.nrc.gov

The accident at the Three Mile Island near Harrisburg on 28 March 1979 showed some serious shortcomings in the safety provisions of nuclear power plants. The accident stirred a widespread concern about the safety of nuclear power in general. In consequence, several actions were taken nationally and internationally, including the formation of the Institute of Nuclear Power Operations (INPO) by the US nuclear electric industry in 1979. "The analysis of the accident made clear that it was necessary for risk assessments to go beyond a description of how the technological system functioned and include the effects of actions by the operators in the system, the human factor, as well" (Hollnagel, 2009, p. 132). Human Reliability Assessment (HRA) was then introduced as a compliment to PSA to calculate the probability of a human action failure. The concept of human error mainly denoted the negative human influence on the system, but does also take into consideration that humans can also stop a chain of events that has the potential to lead to an accident.

Most of the nuclear power plants, which are in operation today, were built during the twenty-year period from 1965 to 1985. There are many reasons for the practical standstill in new construction projects following that period. The most important one is political opposition, which is mostly based on three main issues: risks for severe accidents, handling and final disposal of nuclear waste, and proliferation of nuclear weapons. Also many non-governmental organisations, such as Greenpeace, have been actively campaigning against nuclear power. Various societal pressures led to political decisions to phase out nuclear power at least in Belgium, Germany, Italy and Sweden. (Kettunen et al. 2007)

One of the most influential events in shaping the public opinion on nuclear power was the Chernobyl accident on 26 April 1986 in the present-day state of Ukraine. In the accident the reactor core and part of the reactor building were destroyed and clouds of radioactive particles were released (IAEA 1986). The Chernobyl accident led to the signing of the Nuclear Safety Convention on 17 June 1994 in the Vienna Diplomatic Conference under the auspices of IAEA. Its aim is to legally commit participating States operating land-based nuclear power plants to maintain a high level of safety by setting international benchmarks to which States would subscribe. As of September 2009, all countries with operating nuclear power plants are now parties to the Convention. A related industry action was the formation of the World Association of Nuclear Operators (WANO) in May 1989, in which each electricity-producing nuclear power plant in the world is a member.

The concept of safety culture was introduced in the aftermath of the Chernobyl nuclear meltdown (IAEA, 1991). A proper "safety culture" for the nuclear power plant organizations was quickly required by the regulatory authorities in western countries. For example, a requirement for a good safety culture was included into the Finnish nuclear law. In Sweden, safety culture issues are addressed in the regulations but they are not explicitly addressed in either the Swedish nuclear law (Lag [1984:3] om kärnteknisk verksamhet), including updates until 2009), or the Swedish radiation law (Strålskyddslag [1988:220]).[3]

Declining job opportunities and the general climate also affected the number of young people applying into the field. The study conducted by the Committee for Technical and Economic Studies on Nuclear Energy Development and Fuel Cycle of the OECD Nuclear Energy Agency in 1998 revealed that the number of students graduating at bachelor's and master's level in nuclear science

[3] In a governmental proposition from 2005 regarding changes in the Swedish nuclear law, radiation law, and secrecy law, the word säkerhetskultur (safety culture) is mentioned three times in the appendix, but it is not included in any of the proposed changes (Regeringens proposition 2005/06:76 Kärnsäkerhet och strålskydd).

and engineering had been decreasing since 1990 in the OECD member countries (OECD/NEA 2000).

3.3 Nordic development

Sweden was active in the nuclear area right after the Second World War. AB Atomenergi was formed in 1947 for the purpose of developing, building and operating nuclear power stations in Sweden. The company started the National Nuclear Power Laboratory at Studsvik in the late 1950s.[4] The Swedish Government issued its first nuclear energy law in 1956 (1956:306), permitting the development of nuclear power. Vattenfall, at that time closely connected to the government and AB Atomenergi (also State owned), decided in 1957 to build a small reactor for the production of heat and electricity. The name was Ågesta and it started in 1963 to produce 65 MW(th). 55 MW was used for the heating of a suburb in Stockholm and 10 MW for electricity production. The reactor was shut down in 1974.

Eight non state-owned utilities, with Sydkraft as the leader, founded in 1955 Atomkraftkonsortiet, AKK (the Atomic Power Consortium) with the purpose to follow the international development of nuclear power. AKK had early and direct contacts with utilities and vendors in the US. AKK was transformed into OKG AB in 1965 with seven shareholders. OKG ordered in 1966 Oskarshamn 1 from ASEA. Oskarshamn 1 was the first LWR reactor in the world to be designed without licence from US vendors. It started commercial operation in 1972.

In the 1960s the Swedish Nuclear Power Inspectorate (SKI) was set up and became responsible for licensing, regulation and supervision under the Nuclear Activities Act. The Swedish Radiation Protection Institute (SSI) operated under the Radiation Protection Act 1988. In mid-2008, the two organisations were merged to become the independent Swedish Radiation Safety Authority (SSM) encompassing both radiation protection and nuclear safety regulation.

The construction of a heavy water power reactor, Marviken, based on slightly enriched uranium with the possibility to change to natural uranium, with a planned electric output of 140 MW using saturated and superheated steam, commenced in 1963. The reactor was planned to be in operation in 1967 but the construction project faced a number of obstacles. The project was stopped in 1970 only a few months before fuel loading. The project was started in co-operation between AB Atomenergi and Vattenfall, but Vattenfall withdraw from the project already in 1964. Vattenfall decided that heavy water reactors very not commercially viable options for the Swedish industry.

In 1968, part of AB Atomenergi (mainly the fuel manufacturing) was transferred to ASEA, and a contract between the state and ASEA was signed. The contract also resulted in AB Atomenergi closing its reactor design office. AB Atomenergi later evolved into a research and development company, first with emphasis on nuclear energy, but later other types of energy sources were included. The company ASEA Atom was founded with ownership equally divided between ASEA (Allmänna Svenska Elektriska Aktiebolaget) and the state. The contract with ASEA Atom was in force until 1979, when the ASEA Group became the sole owner of ASEA Atom (later ABB Atom and now Westinghouse Atom).

In 1968, Vattenfall ordered Ringhals 1, a 750 MW BWR from ASEA, and Ringhals 2, a 800 MW PWR from Westinghouse. The primary reason for two orders signed with two different vendors, one Swedish and one foreign, was that Vattenfall wanted to establish a real competitive market in

[4] Later the laboratory was transformed into a general energy laboratory, although most of the activities at the site are now managed by Studsvik AB, which is still involved in the nuclear area. Studsvik AB is today a private organisation and offers components, services and consulting. The test reactor R2 (50 MW) was permanently shut down in 2005.

Sweden for the future development of nuclear power. Later, Vattenfall ordered two more Westinghouse PWRs to be built at Ringhals. Vattenfall's first two nuclear reactors, Ringhals 1 and 2 were commissioned during 1975-1976.

In 1969 OKG ordered Oskarshamn 2 and Sydkraft ordered Barsebäck 1 with an option for Barsebäck 2. Thus four nuclear power units were ordered from ASEA Atom before the company's first unit had started to operate. ASEA has been the reactor supplier for nine out of twelve reactors in Sweden as well as the two reactors at Olkiluoto.

After the partial meltdown at the TMI in 1979, there was a referendum in Sweden about the future of Swedish nuclear power. As a result of this, the Swedish parliament decided in 1980 that no further nuclear power plants should be built, and that a nuclear power phase-out should be completed by 2010. So far two out of twelve units have been prematurely shut down in Sweden, Barsebäck 1 in November 1999 and Barsebäck 2 in May 2005 (the decision to phase out the remaining 10 reactors by 2010 is no longer relevant, see the first sections in the next chapter).

In Finland the development of nuclear power was strongly motivated by the wish to avoid excess reliance on export power, high price of electricity as well as the need to increase the production of electricity for the growing industrialization of Finland after the Second World War. In 1963 an advisory board for the Finnish government proposed that Finland should build a nuclear power plant before the end of the 60s. The still running FiR research reactor had already been built in 1962 at Otaniemi to facilitate the development of nuclear expertise. Still, in financial terms the resources that Finland put into the development of nuclear power have been estimated to have been as low as 1 percent of the money spent by Sweden into nuclear power development (Lehtinen & Sandberg 2004).

In 1965 the Finnish state-owned energy company Imatran Voima (IVO) sent a bid for a nuclear power plant to ten potential suppliers. The idea was to purchase the nuclear power plant as a turn-key delivery based on financial calculations. Soon it was evident that the purchase of a nuclear power plant was a major decision that could not be done based on financial considerations only. The political climate and especially the eastern trade had to be taken into account. Finally, in 1969 the decision was made by the Council of State to purchase Finland's first nuclear power plant from Soviet Union. A deal was made with V/O Technopromexport for two 440 MW power plants to be built at the island of Hästholmen at Loviisa. The deal included an agreement that Finland would return the spent nuclear fuel to Soviet Union. That agreement was cancelled in 1996 when the Finnish nuclear law was changed. The two VVER-440 pressurized water reactors were built by Soviet Atomenergoeksport but fitted with Western instrumentation and control systems. The units started electricity production in 1977 and 1980 and now produce 488 MWe each. The units are owned by Fortum.

The private industry was also eager to get its own nuclear power plant. Teollisuuden Voima Oy was founded in 1969 by 16 Finnish industrial and power companies operating mainly in the wood industry. In 1970, the Board of Directors of TVO made a decision to build a nuclear power plant unit with an output of about 600 MW. In 1972, the Swedish company ASEA Atom (today Westinghouse Electric Sweden AB) was chosen to deliver the power plant. Construction on Olkiluoto 1 began in winter 1974, and the unit went on stream in September 1978. Construction on Olkiluoto 2 began in summer 1975, and the unit went on stream in February 1980.

STUK was established in 1958. At first STUK inspected the radiation equipment used in hospitals. In the beginning STUK was a small Institute of Radiation Physics attached to the National Board of

Health. As nuclear safety regulation was assigned to the institute, the Institute of Radiation Protection (STL) was founded as an independent safety authority under the Ministry of Social Affairs and Health. In 1984 the name of the institute was changed to Finnish Centre for Radiation and Nuclear Safety (Säteilyturvakeskus). At the same time the abbreviation STUK was established. The English name was changed to Radiation and Nuclear Safety Authority in 1997. STUK's operational area has constantly been diversified with technological and scientific development. Today STUK functions as an expert organisation in the entire field of radiation and nuclear safety.

The fifth nuclear power plant unit has been planned in Finland since the 70s. An application for a decision in principle was made by IVO and TVO in the end of 1985, but the Finnish government together with the industry decided to abandon the project after the public opinion toward nuclear power deteriorated due to the Chernobyl nuclear accident in April 1986. In 1988 a new nuclear energy law required that the Finnish parliament has to validate the decision in principle made by the Council of State. In 1993 the parliament voted against the positive decision in principle of the Council of State for building a new reactor at Loviisa or Olkiluoto.

3.4 Recent developments

Modernization and upgrades have been done or are ongoing on all the three nuclear sites in Sweden. Perceived in an international perceptive these upgrades are extensive. Due to various circumstances many of the modernisation projects have put heavy pressures on the organisations. Difficulties with some of the large projects have also caused media attention. Another development worth mentioning is the big emphasis on security that has been primarily due to the 9/11 terrorist attack in the USA. The emphasis on security has for example meant that major construction work has been performed in and around the Swedish sites for the last years.

A shift in the nuclear policy has taken place in Sweden. From a decision of phasing out the reactors by 2010 there are now discussions about replacing the current 10 reactors with new ones. The Swedish Government announced an agreement allowing for the replacement of existing reactors on February 5, 2009.

Radioactive waste management (RWM) is taken care of by The Swedish Nuclear Fuel and Waste Management Company (SKB) in Sweden and by Posiva in Finland. Posiva was established in 1995 whereas SKB has been established already in the 70s. SKB and Posiva are responsible for the final disposal of spent nuclear fuel of their owners, research into final disposal and other expert nuclear waste management tasks. Both of these companies are jointly owned by the nuclear power plant operators in each country. From 1990s onwards, RWM policies in Sweden have focused around the selection of candidate sites for a deep geological repository and to further technical development of the disposal concept. In June 2009 SKB announced that it had selected Forsmark as the site for the final repository for the spent nuclear fuel and that the applications for permits, that include the environmental impact assessment and a safety analysis, will be submitted in 2010. The final repository of spent nuclear fuel at Forsmark is planned to start in 2023.

In Finland the Finnish Parliament accepted a decision in principle applied by Posiva for deep geological disposal of spent nuclear fuel in the bedrock at Olkiluoto in 2001. The disposal site is near to the site of the existing nuclear power plant operated by TVO. The construction of an underground rock characterisation facility called ONKALO is at the moment under way at Olkiluoto. The final disposal of spent nuclear fuel at Olkiluoto is planned to start in 2020.

In December 2000 Teollisuuden Voima Oy (TVO) submitted to the Finnish Government an application for a Decision-in-principle in accordance with the Nuclear Energy Act for the

construction of a fifth Finnish nuclear power plant. According to the application, the new nuclear power plant unit would be located on the site of either Loviisa or Olkiluoto nuclear power plant. The Finnish Government made in January 2002 a favourable decision-in-principle on the construction of the nuclear power plant unit plan put forward by TVO. The Finnish Parliament ratified the decision on 24 May 2002. In December 2003, TVO made the decision to invest in the construction of a third nuclear power plant unit at Olkiluoto. Consortium formed by AREVA NP S.A.S, AREVA NP GmbH and Siemens was chosen to deliver the unit on a fixed-price turnkey agreement. STUK made a review of design and safety analyses, and gave a statement to the ministry of Trade and Industry in January 2005. Finnish government granted the construction licence on 17 February 2005. Construction of the unit began in 2005, and after some delays the unit is expected to be operational in 2012 (original plan was that the unit would be operational in 2009). The unit is based on the French-German European Pressurised water Reactor (EPR) concept. The thermal output of the reactor is 4300 MW with a net electric power output of approximately 1600MW.

In 2010 the Finnish parliament ratified the Government's decisions-in-principle on the construction of the nuclear power plant units put forward by Fennovoima and TVO. Both companies got permission for one unit, the TVO unit to be located at Olkiluoto (OL4) and the Fennovoima unit at either Simo or Pyhäjoki.

Currently the ownerships for the utilities in Sweden and Finland are largely shared. For example, for the Oskarshamn power plant the responsible Utility is OKG, short for the Oskarshamnsverkets Kraftgrupp OKG, which was acquired by Sydkraft in 1993, which is currently called E.ON Sverige. E.ON Sverige owns 54.5% and the other partner Fortum 45.5% of OKG. On the other hand, Loviisa is owned 100 percent by Fortum.

One interviewee from the Swedish industry summarized his views on the historical development of nuclear power in Sweden as follows:

> "If one starts with the first Swedish nuclear power plants – it was much technique, it was a pioneering spirit, if was a fighting spirit and a national venture while also very early on realizing that one had to consider safety even though that consideration would not live up to what is called safety requirements today. So it was also in a way insane… that such a small nation as Sweden… it was an insane, bold venture and a national risk-taking And they did it.. just got going and started to produce power. One started to build plants that were economical…. One learned safety requirements. After a few years, I would say, Sweden became one of the leading nuclear power nations, both regarding construction of plants, reactor safety, and, operations and maintenance. One had low radiation doses, high availability; one could build many plants that were economical and so on. The optimum was probably when Forsmark 3 and Oskarshamn 3 were put into operation.
>
> One had their own ideas about nuclear power safety, Sweden introduced the FILTRA-concept[5] first of all, we very early had PSA-studies …… one were at the front, And it was done only a few years after one had become questioned politically. But after that the development in Sweden has, according to my opinion, stagnated; we don't construct our own reactors anymore, we are definitely not in lead when it comes to nuclear power safety. When it comes to Vattenfall, I had the experience that one to a large degree concentrated upon its own perfection, without looking around and considering what the world around says. If you take the measures because of SKIFS, just as an example, and what we are doing there in comparison with how they have modernized other power plants in Europe, we are on a low level. And that means that one still… still lives in the glory days that once were. Then you can always consider other parameters – we don't have the lowest radiation dosages, we don't have the lowest radiation outlet, our availability is not miserable, but

[5] FILTRA-concept means that in the extreme case of nuclear meltdown, the plant has a separate building for releasing pressure from the containment building. Internationally, the concept is known as Filtered Containment Venting System.

> soon in the lower half. And this is also related to the function of the inspectorate that has not been developed."

From the Finnish side, the early days in Sweden and Finland were seen as follows by one informant:

> "One perspective, that also benefited TVO, is that they build many plants of the same type. Of course they had their own generations these ASEA ATOM plants, but they were developed from a certain baseline and still they have a lot of common characteristics. ... They [Sweden] truly have only ASEA ATOM's plants of a bit different generations, and then off they went to buy a couple of Westinghouse's pressurized water reactors too. When they strived to develop and standardize the design that of course benefited TVO, that they learned to build their plants in a quite fast schedule. And for that reason TVO got one of its units very fast, the other one had the fire that delayed the construction. And there was the strong plant supplier, strong in a sense of having a good technical competence and was all the time there to support the power companies, TVO as well. But the support from the plant supplier eventually started to fade out and that reflected to TVO's way of working too. Slowly, when modifications have recently been made at at TVO, they have had to take more responsibility for the design. And there was a learning phase clearly at TVO, that they learned to cope with the new situation where everything is not coming ready-made from the plant supplier. ... And in a way they did get everything a little bit "too easily" from Sweden ... that the competence at TVO did not initially develop in a manner that one could have hoped for and expected. Instead, IVO or Fortum had to take care of everything by itself. They had to develop their own competence, plant know-how, from the start. The situation was completely different for them."

As many of the interviewees mentioned, the early days of the Finnish government owned energy company Imatran Voima Oy, IVO, (that later evolved into Fortum) differed from the other power companies. One interviewee described the history as follows:

> "Here it actually started when the Loviisa plant was purchased [by IVO] from the then Soviet Union. Actually it started in the education sector a bit earlier. I mean that this was when the generation that build these plants and operated them until today was educated. In Finland it also pretty much happened so that when it, I mean we made our legislation then, the first versions of our YVL-guides, then in the late years of the 70's, let's say from -74 onwards until -80, when these plants, Loviisa 1 and 2 and Olkiluoto 1 and 2 were built. And then there was also formed this kind of, then there was Finnatom, that operated as a sort of a body of co-operation and that also produced equipment. This same kind of phenomena emerged then that will most likely emerge now, if there are these new plants coming. I mean there was Ahlström that made the reactor coolant pumps [for the Loviisa power plant] … Rauma-Repola, that made different pressure vessels for steel industry and things like that, very broadly inside Finnatom. And then, as I already mentioned, we created our own criteria then, because we got this Soviet plant, we had to write our own instructions. It is quite rare, there aren't so many countries in the world that have their own instructions, it is rather unique. Let's say that USA and us, we sort of have, and others have then followed the Americans. Of course we also imitated the Americans, but then we diverged from them rather fast. And then of course it also happened so in the beginning of the 80's that when there were plenty of these different types of accidents then, the public support for nuclear power was terribly low and the new plant options weren't built. We in fact operated so that there were always these projects, these decisions in principle -types of projects going on, where all the operating nuclear power plants were looked trough once in ten years and reports were written from them. We maintained our knowhow through these different types of projects. Then there was this increase of power output in the 90's. Then we had to sort of evaluate the safety of these equipment again from a whole new perspective, and it wasn't a very easy thing to do, because it was maybe more difficult than building a new plant in many ways. After that we moved into this situation that we nowadays have and it happened there in the beginning of 2000s, I mean that there came this first positive decision from the parliament. Actually it is the first decision in principle that was done according to this contemporary legislation that got through. And now we go on like this that the crowd in this branch is getting bigger, the amount of crowd in this branch."

In Sweden the Swedish Radiation Safety Authority (SSM) works under the Ministry of the Environment. The authority took over the responsibility and tasks from the Swedish Radiation Protection Institute (ISS) and the Swedish Nuclear Power Inspectorate (SKI) as these two organizations were merged into SSM in July 2008.

3.5 Incidents at the Nordic nuclear power plants

In this report several Nordic incidents are discussed by the interviewees. Three of them are briefly described below.

On July 28, 1992, one safety valve of the main steam system opened at Barsebäck unit 2 in Sweden. The steam jet disintegrated coverings and insulation materials from adjacent pipelines. Parts of disintegrated mineral wool insulation was transported to the condensation pool in the reactor containment and caused clogging of the strainers for the emergency core cooling system. Investigations of the incident revealed that the amount of disintegrated insulation material was much larger than previously calculated and that the rate at which the strainers were blocked was much higher than previously anticipated. The five oldest Swedish BWRs were ordered to be shut down until the problems were rectified. The units at Forsmark, the unit 3 in Oskarshamn and the Olkiluoto units had far larger strainers and it was calculated that the sequence did not pose a similar risk. (Wahlström & Kettunen 2000)

In July 2006 maintenance work was being performed in the 400 kV power grid switch yard outside of the Swedish Forsmark Nuclear Power Plant. A deficiency in the working procedures led to the power grid switch yard not being grounded when the electricity was turned on. This caused voltage transients to propagate through the power pants electricity systems and during a few seconds the voltage varied between 80 to 120 %. The reactor effect was automatically regulated down. Some equipment, such as generator breakers, rectifiers, and alternators etc. were “knocked out”. In an event such as this, the power plant’s own redundant electricity systems should take over the supply of electricity. The power plant has got four diesel generators and batteries to ensure the supply of electricity in all events. But in this case, the batteries were “knocked out” due to the voltage transient and only two of the four diesel generators started, this is however sufficient in order to provide the plant with electricity for various important functions such as for example residual heat removal. The battery malfunction, however, meant that a number of important safety systems, computers, and measuring devices, such as for example the water level indicators in the reactor, turned dead. Approximately 23 minutes later the remaining two diesel generators were started manually. The incident was classified as an INES 2.

On 7 March, 2006, the Finnish Radiation and Nuclear Safety Authority STUK appointed an investigation team after having noticed that the management of organisations participating in the construction of Olkiluoto 3 -unit did not fully comply with STUK’s expectations concerning good safety culture. The problems detected have hampered the progress of the project and increased pressures on the schedule of the subsequent construction phases. In its report the investigation team states that the major problems involve project management, in particular with regard to construction work, but nuclear safety has not been endangered (STUK 2006). Despite improvements in several areas, the quality problems at the construction site have continued and in the end of 2009 the power plant unit was three years behind schedule.

A reactor trip occurred at Olkiluoto 1 as a result of a transient in the generator voltage regulator on 30 May 2008. The unit was to be started after the annual outage. When the power was 60% the voltage regulator of the main generator had a failure which caused an over voltage (155%) in the

plant's electrical systems. The generator voltage at the plant unit began to increase as a result of an incorrect function in the new voltage regulator installed during the annual maintenance. The overvoltage peak caused by the opening of a plant breaker shut down all six reactor coolant pumps. The direct power supply from flywheel generators was interrupted when part of the control electronics of the reactor coolant pumps and flywheels was damaged. Consequently, there was a momentary transient in fuel cooling. After the event, the power of Olkiluoto 2 was also reduced to about 80% for the duration of diagnosing and rectifying the fault, because a similar incident at full power could lead to damage in the fuel cladding as the cooling flow is disturbed. When the reactor coolant pumps were replaced in the 90s, it was not realised that overvoltage may, in certain situations, cut off the direct power supply from the flywheel generators to the reactor coolant pumps. (Kainulainen 2009)

4. Model of safety culture

In the interviews, the respondents spontaneously described their views on what nuclear safety is, how it should be evaluated and what kind of things should be taken into consideration in the evaluation. In addition to spontaneous comments these issues were also addressed directly in the interviews. The interviewees were asked to define nuclear safety and to describe how in their view the level of nuclear safety should be evaluated in a power plant. The interviewers also tested the face validity of the preliminary theoretical model of key psychological safety culture dimensions (see Reiman et al. 2008, Reiman & Oedewald 2009) by asking each interviewee directly whether they considered these dimensions important. All in all these responses give important information about the nature and evaluation of safety culture in the nuclear industry.

4.1 Defining and evaluating nuclear safety

What is nuclear safety?

Each interview was started with a question "How would you define the concept of nuclear safety". The respondents approached the question from a wide variety on viewpoints. According to the analysis of the responses, the definitions of nuclear safety seem to differ in terms of a couple of qualitative dimensions. *First, the definitions differ in terms of whether nuclear safety is seen as process or activity or as an end state or set of outcomes.* Many respondents defined nuclear safety in terms of various activities. Thus, these people do foremost see nuclear safety not as a state but a set of activities to produce a specific state. Some respondents on the other hand emphasized the outcomes of good or bad safety, such as INES-events or scrams. This view emphasizes nuclear safety as a state where the outcomes are stable (or non-existent as in terms of events). The following citation on what is nuclear safety exemplifies a definition in terms of activities:

> "It is a way of working that the issues connected to [nuclear safety] are taken into account, and in the plant's functions the issues related to this are taken into account in our work practices, operating instructions and so on. I see it very holistically that it is the way of action of the entire organization, these safety issues are taken into account."

The following citation on what is nuclear safety exemplifies a definition of nuclear safety in terms of outcomes:

> "Well, I don't know exactly, but I would classify it as that we don't have nuclear related outlets, or damage the fuel so to say. We shouldn't have any major cracks or destruction that leads to fission products in the water, actually that what's its all about."

Some respondents argued that safety has an ingredient of "will power" – safety thus needs motivation and *will* to act in such a manner that safety will be produced. Another way of looking at nuclear safety is in terms of *technical functions* necessary to control the reactor and prevent release of radioactive material. This view also emphasizes nuclear safety as a state (an outcome) where the safety functions are operational.

The second dimension that separates different definitions of nuclear safety is the scope of the definition; do the informants consider nuclear safety widely by including various types of issues, or narrowly by including only for example technical outcomes or technical functions. An example of a wide approach to nuclear safety is expressed in the following citation:

> "It is not its own separate thing; that something is nuclear safety and another thing is something else. Nuclear safety is part of everything. In the back of your head whatever you are doing."

In contrast to the above, some interviewees emphasized that nuclear safety means for example the strict adherence to instructions or the amount of radiation dosages.

> "Nuclear safety or lack of it shows always or in most cases as radiation dosages. Avoiding them is nuclear safety."

Majority of the informants took quite a wide view on nuclear safety, however.

A couple of respondents from Sweden mentioned that they do not use the term nuclear safety (kärnsäkerhet) at all. Rather, they talk about safety in general. In Finland nuclear safety (ydinturvallisuus) was a common term. Moreover, a few interviewees expressed their worry over the use of the term "safety" since it has acquired a strong connotation with occupational safety issues. They wished for a more clear focus on the nuclear safety related issues in addition to issues dealing with occupational safety.

How to evaluate nuclear safety?

The question about what issues the interviewees would consider if their job was to evaluate the safety of some specific plant demonstrated the various domains of importance that the employees at the nuclear industry associate with nuclear safety. Similar to the question about the definition of nuclear safety, this question received a wide variety of answers.

Many people emphasized that they would look for technical data and performance measures that can be compared with other power plants. This viewpoint is quite similar to the definition of nuclear safety in terms of outcomes as the following citation illustrates:

> ”Level of safety? First of all the disturbances, how many disturbances they have that threaten the safety systems, just scrams, scram-type disturbances. Then you have the functioning of the safety systems, that is, availability, meaning how and what types of repairs they have had, how well they have been available. From a technical viewpoint. Then, the number of INES-events is somewhat descriptive, even though their definition has bad national characteristics. They are not comparable, INES ones, and zeros and threes. … Then more specific indicators could be, fuel leakages, that tell quite much, as strange as it sounds, about the level of cleanness at the plant. That is, how much loose parts get into the process, small pieces of metal. That maybe tells a bit about the safety culture, how seriously these are taken.

Some people emphasized that they would consider human and organizational aspects and various activities that the organization has to perform in order to achieve a good safety level:

> "Competence and resources is one of the things [that I would look at], that the organization is healthy in a way that it has its resources at the right places and has optimal competence to control and supervise all its processes. And related to managing the big picture, that is related to leadership and culture, that they are, could I say, healthy. And the attitudes are of the right kind. [That] everybody knows what kind of things we are dealing with … what are the effects of one's own work on the nuclear safety. From the technical side I should make sure that the procedures and instructions and routines and such are in order. That the plant is maintained in stable condition and not allowed to deteriorate. … And then, related to these procedures and learning the plant should have resources for networking and learning from the others. … Some kind of research activity is needed too … one has to follow and influence [the research on nuclear safety] … And then some kind of independent evaluation from time to time, safety committees and such, WANO peer reviews, to get an external view on the safety issues. Healthy investment programs. And then continuous development and monitoring of trends and development of indicators. That culture is non-punitive and inspiring."

The respondents in general departed from their own speciality when describing what should be taken into consideration when evaluating the safety level of a plant. The scope concerning what areas one should look at seemed rather wide, thus most people thought technology, personnel and organisational factors should all be evaluated. Only a few answers however described the complex connections and causality existing among these areas. This indicates that there still is no accepted and commonly used model of the "total" which people can use to evaluate safety – perhaps that is one explanation to why safety culture seems to figure as a "model for the whole" or a metaphor for

the organization. The problem with this is that the metaphor is seldom explicitly defined in terms of issues that it covers and the issues that it leaves out or does not sufficiently cover.

All the issues that the interviewees considered as indicative of the safety level were combined into one model, as illustrated in Figure 2. Overall, 128 partly overlapping indicators were extracted from the answers. The largest thematic area - as measured by the number of mentioned indicators - was "outcomes" with a total of 31 mentions. The category of management and owners had 12 mentions and the category of original technical design had 8 mentions. The three remaining categories had quite similar amount of mentions, from 23-28 per category. From the individual indicators, "quality of instructions" and "events" were both mentioned by 7 interviewees, making them the biggest category in terms of number of mentions.

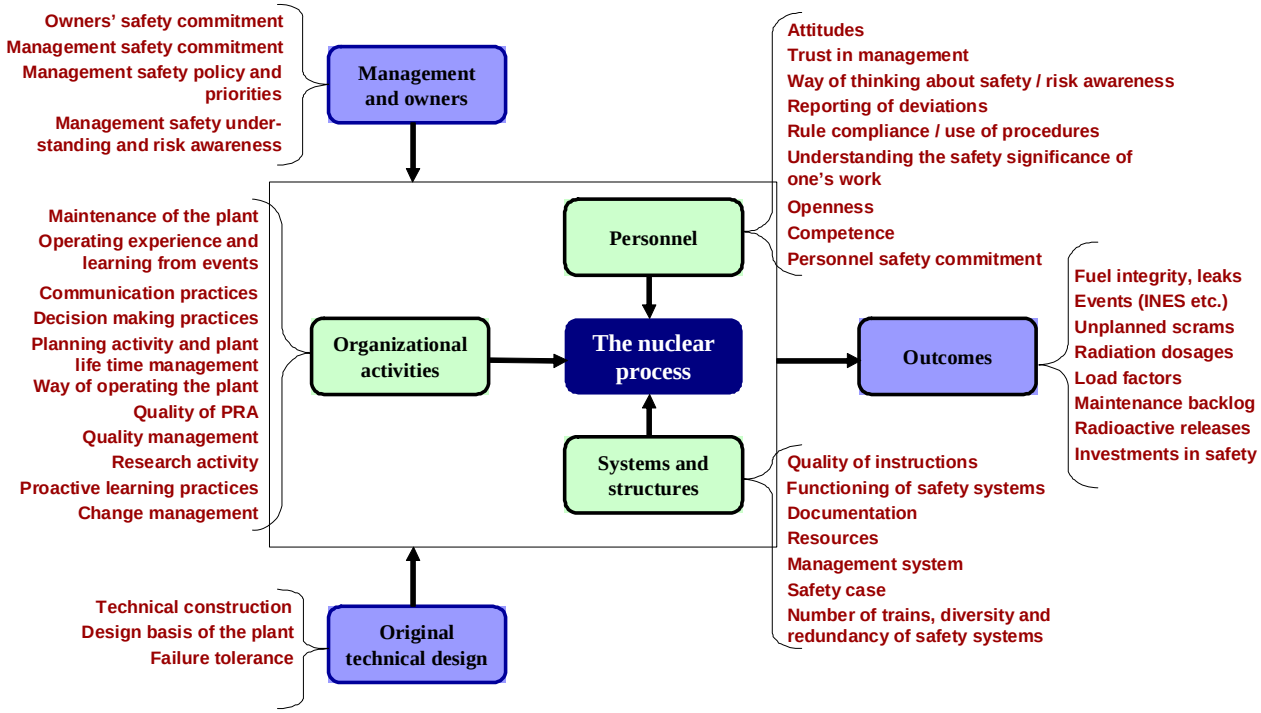

Figure 2. Indicators that the interviewees explicitly raised as signals of the safety level of the plant. The indicators have been arranged according to general themes that emerged from the definitions – management and owners, technical design of the plant, organizational activities, personnel, systems and structures, and finally, the outcomes.

As shown in Figure 2, the issues that people raised all bear some relation to the nuclear process, either in terms of indicating outcomes, current activities and systems or preconditions for the safe control of the process. What the respondents seemed to lack was an overview of the relation of different indications of the safety level. A few divided the evaluation of nuclear safety explicitly into a) the technical condition of the plant and b) its operation and management.

There was a large variance on how many of the indicators from Figure 2 each informant raised as important for nuclear safety in his or her opinion. A small minority of interviewees considered nuclear safety as being mainly a question of attitudes and adherence to instructions. Most interviewees pointed out the need for a deeper understanding of the nature of nuclear power and the risks of one's own work as a necessity for being able to work safely in all situations. Many emphasized the importance of communication and cooperation inside the organization to be able to utilize all the competence available.

Taking all the interview findings together a rather comprehensive view emerged on the critical factors to consider in terms of nuclear safety (Figure 2). The original design basis of the plant sets

certain constraints and requirements for nuclear safety. Management and owners have a big influence on how safety issues are handled and resources allocated. They have to prioritize safety in both their public statements as well as concrete actions. The organizational activities form an important precondition for nuclear safety. It is by these activities that the nuclear safety is created. These activities are influenced by the structural and personnel issues in the organization, and the activities in turn influence them. Both of these are important to acknowledge. Finally, the outcomes of the power plant in terms of safety related incidents, radiation dosages and other events provide information on how successful the safety management efforts have been in the past.

It is interesting to note that certain indicators seem to be missing from the figure when the indicators are compared with normative models of safety culture such as that of Reiman and Oedewald (2009). For example, issues dealing with contractors and management of supply chain networks do not arise from the data. Also, work motivation and job satisfaction of the workers do not show up in the thematic area related to personnel issues. Only one interviewee mentioned personnel safety commitment as a criterion for nuclear safety. Finally, the responses seemed to deal with either the management or the worker level with little mention of the middle managements' and supervisors' role in nuclear safety.

4.2 Psychological elements of safety culture

The face validity of the model of key psychological safety culture dimensions (see Reiman et al. 2008, Reiman & Oedewald 2009) was tested by analysing responses to direct questions about their importance as well as indirect mentions of psychological issues during the course of the interview. Issues dealing with psychological requirements of safety culture came up in many statements from the interviewees. For example, a representative from the Finnish industry considered the things that everyone working in the nuclear field should know and tackled issues such as responsibility and understanding of hazards:

> "The things that everyone should know, of course one's own field, that is, the technical basics of nuclear power production. Radiation, radiation issues. Then there is this certain sense of responsibility for what one is doing and for the fact that the work that one is doing affects the safety of all the others. Reporting of everything that is a deviation. … Basic knowledge of radiation, basic knowledge of the functioning of the plant. … And then that, what is the safety significance of one's own work also for the process. So if one goes to some system to conduct some work, one does not merely go there to service a valve, but rather one knows that it is *this* valve in *this* particular system."

In addition to spontaneous comments that referred to issues dealing with the contents of the psychological dimensions, explicit question about the dimensions were asked. Based on theoretical work on the characteristics of safety culture (see Reiman et al 2008, Reiman & Oedewald 2009) six psychological dimensions that are postulated to have a significant influence on nuclear safety have been abstracted: sense of responsibility, motivation, mindfulness, sense of control, understanding of hazards and understanding of nuclear safety. The face validity of these dimensions was tested in the interviews.

When asked directly, the dimensions were perceived as being important for safety by nearly everyone. Only work motivation was something that was considered as being nice to have but not absolutely necessary by a couple of interviewees. This was due to the fact that the power plants have extensive procedures and instructions, and these informants considered that in most cases it is sufficient just to follow them. However, even these views represented a minority opinion.

A more nuanced picture emerged during the interviews when the various challenges and ways of thinking regarding the effects of the psychological dimensions on nuclear safety were uncovered. Even if the view on the significance of the dimensions was shared among the interviewees, the

reasons given for their significance or the underlying mechanisms by which the dimensions were considered affecting nuclear safety showed more variation. Figure 3 illustrates some of the opinions on each dimension in the adjacent boxes. Inside the circle formed by the dimensions we have devised summary statements about the proposed significance of the concepts based on the interviews and theoretical work.

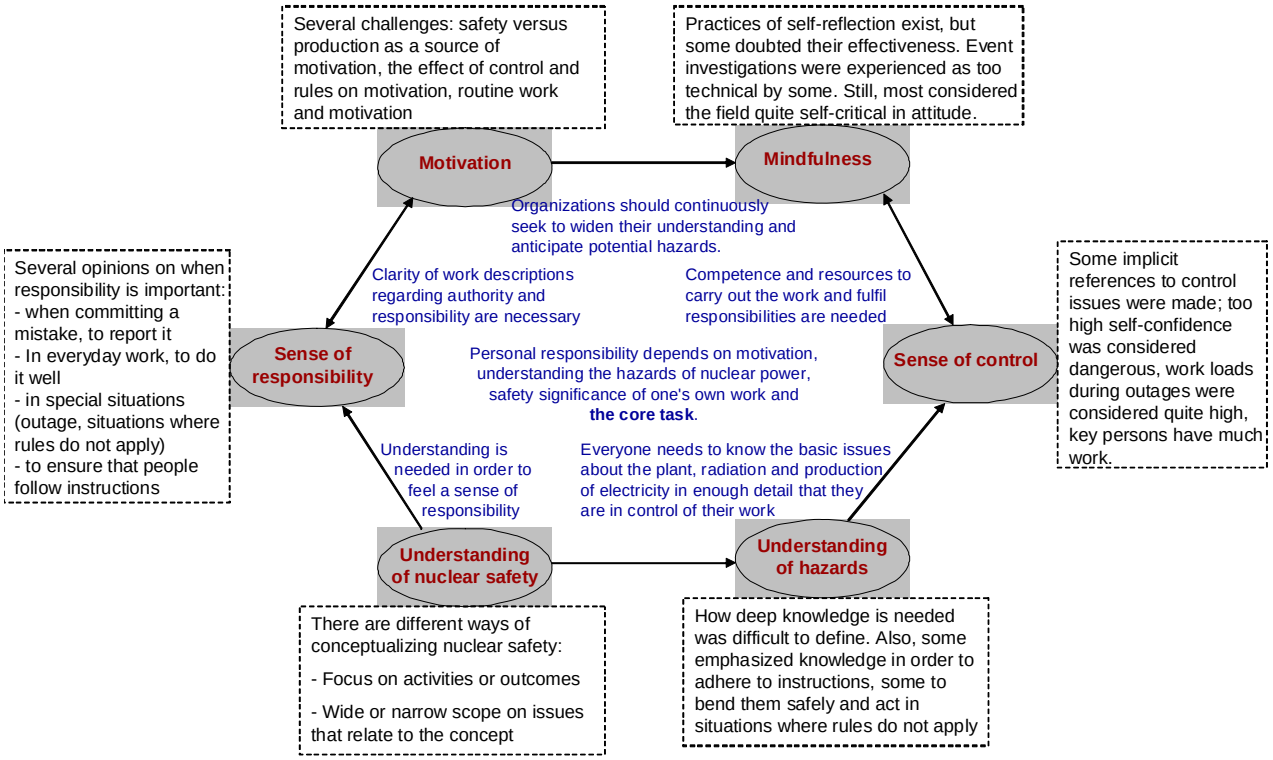

Figure 3. The psychological dimensions with examples from the findings from the interviews.

Responsibility issues raised a lot of comments from the interviewees, spontaneously and as a response to the specific questions. For example, a representative from the Finnish industry contemplated the question "What is the individual worker's responsibility for nuclear safety":

> "At least one responsibility is to bring forth one's worry. And if you can prevent an accident with your actions, then do it. That is the second responsibility in my mind. But as I have said, we do not trust in the one individual, rather it is the system, and the redundancies and diversities built into the system, that take care of nuclear safety, irrespective of what the one individual does. And then we have, I could mention the STAR principle, that means Stop, Think, Act and Review. This is something everyone should adhere to before they turn any switches, that 'am I in the right place', and 'is this the right unit'. And when one has turned the switch, then one should make sure that the right component really stopped or functioned as it was supposed to. That one does not just continue on to the next target and maybe do the same mistake there as well."

There were different emphases on the issue of responsibility; some informants emphasized the organizational responsibility whereas others emphasized the individual responsibility. One informant from the industry considered the issue ambiguously by referring simultaneously to both individual and organizational responsibility:

> "Every individual should have the responsibility for those issues that the organization has assigned for him. And in addition to that one can think that the individual has a certain wider moral responsibility too. Sense of responsibility, it's probably the thing that really is important, that people should feel the responsibility that has been given to them, and what really belongs to them in their work and the organization. But in general the responsibility lies in the organization and it grows when you go upwards in the organization … the responsibility should be perceived in relation to the power and authority that one has."

The importance of sense of responsibility was perceived along with the many challenges associated with responsibility issues. Overall, the concept of responsibility is multidimensional and it is important to recognise its different facets. One can distinguish for example legal responsibility, moral responsibility and task responsibility (or accountability). The significance of each of these responsibilities to nuclear safety depends on the specific situation (e.g. routine work requiring adherence to instructions and task responsibility versus special situations requiring moral responsibility for the safety of others).

Work motivation was considered very important for nuclear safety. A representative from the Finnish industry contemplated the issue as follows:

> "The personnel make the nuclear safety happen, so the personnel do it, the personnel does all the tasks, even if … Of course we have the structural nuclear safety, what kind of plant concept has originally been had. That counts too, that is, what safety functions it has, and what kind of a containment building as so on. But I would say that in the long term operations when the plants are 30 years old and all, the structural safety still exists for sure, but when we make modernizations and operate and maintain the plant, no technical concept no matter how good lasts forever if it is modernized, operated or maintained wrongly. But of course the technical safety is important too."

Maintaining high work motivation was also considered a challenge in a nuclear power plant domain. The amount of external control together with routine work was considered a threat to the work motivation. As mentioned above, a couple of respondents considered work motivation as of lesser importance, but they were clearly in the minority. It is interesting to note the importance attributed to work motivation when asked directly with the fact that no mention of work motivation was made when evaluating nuclear safety (Figure 2).

The importance of **mindfulness** was not directly asked in the interviews, but many comments were made that clearly implied that many interviewees considered it of big significance for nuclear safety. Confidence and especially over-confidence were mentioned as one of the typical hazards of operating a smoothly running nuclear power plant. The recent events in the Nordic nuclear power industry were seen as shedding some of that over-confidence and reminding people that the hazards are real and have to be actively taken care of. One of the interviewees contemplated what the recent Nordic nuclear incidents have taught us about the nature of safety culture in the nuclear field:

> "At least these events have taught us that one should never be too confident about things. This electrical disturbance at TVO last summer, it had similarities in its nature to the electrical disturbance at Forsmark, even though they were different. … Both these cases should at least have taught that one should not think that all things are known perfectly. … One must always think about what we do not know or understand. And the 91 Barsebäck containment sump strainer event, it was similar in that regard. One had not understood sufficiently well what kind of risks are associated with the functioning of the emergency cooling systems. … The event demonstrated that a very essential risk factor had not been recognized. So what else has not yet been recognized? That's what is common to these events, that they teach you humility. And that's an essential thing here, in this field, in order to believe that safety will continuously be improved, one must be humble in that there can be something that has not been recognized. It is something that you cannot emphasize publicly too much, but it is a question of attitude."

The importances of good operating experience feedback practices, communication practices, as well as continuous improvement of the organization, were raised as necessary manifestation of mindfulness. A few people pointed out the improvements in safety that recent research on severe accidents has achieved.

Sense of control was not directly asked in the interviews. Some interviews referred to issues having to do with confidence and workload. Workload issues were discussed by the regulators in relation to outage periods and the large amount of work falling on a limited number of key personnel during the short time period. Time pressure was mentioned as being a source of concern with regard to tight work schedules and perceived (real or imagined) production pressures.

Understanding of hazards. Interviewees emphasized very uniformly that some kind of knowledge of the potential hazards of nuclear power is necessary for all the personnel. The following citation illustrates a common view among the respondents that especially the safety significance of one's own work has to be understood, and for that one needs some conception of the general risks of nuclear power:

> "…especially [the hazards] concerning one's own work, what can in that work be such that would significantly influence more widely this .. production safety. And of course everyone should know the risks in general, of a nuclear power plant, what consequences it might have if something goes wrong. But especially on the individual level one should know at least what issues are most essential and important [in one's own work]."

It was difficult for the interviewees to define how deep knowledge of nuclear power production and its hazards the personnel need. Also, some interviewees emphasized the importance of understanding the hazards in order to increase adherence to instructions when their significance is better understood. On the other hand, some informants emphasized the importance of the knowledge of the hazards in order to be able to bend the instructions safely and act in situations where rules do not apply. The role of instructions was one of the human factors dilemmas identified by the informants (see next Section).

Figure 4 illustrates some of the ways in which the interviewees contemplated the psychological dimensions of safety culture. The citations in the cloud callouts in Figure 4 do not necessarily represent the majority opinion. Rather the citations are chosen to illustrate the richness of the content of each of the six issue domains.

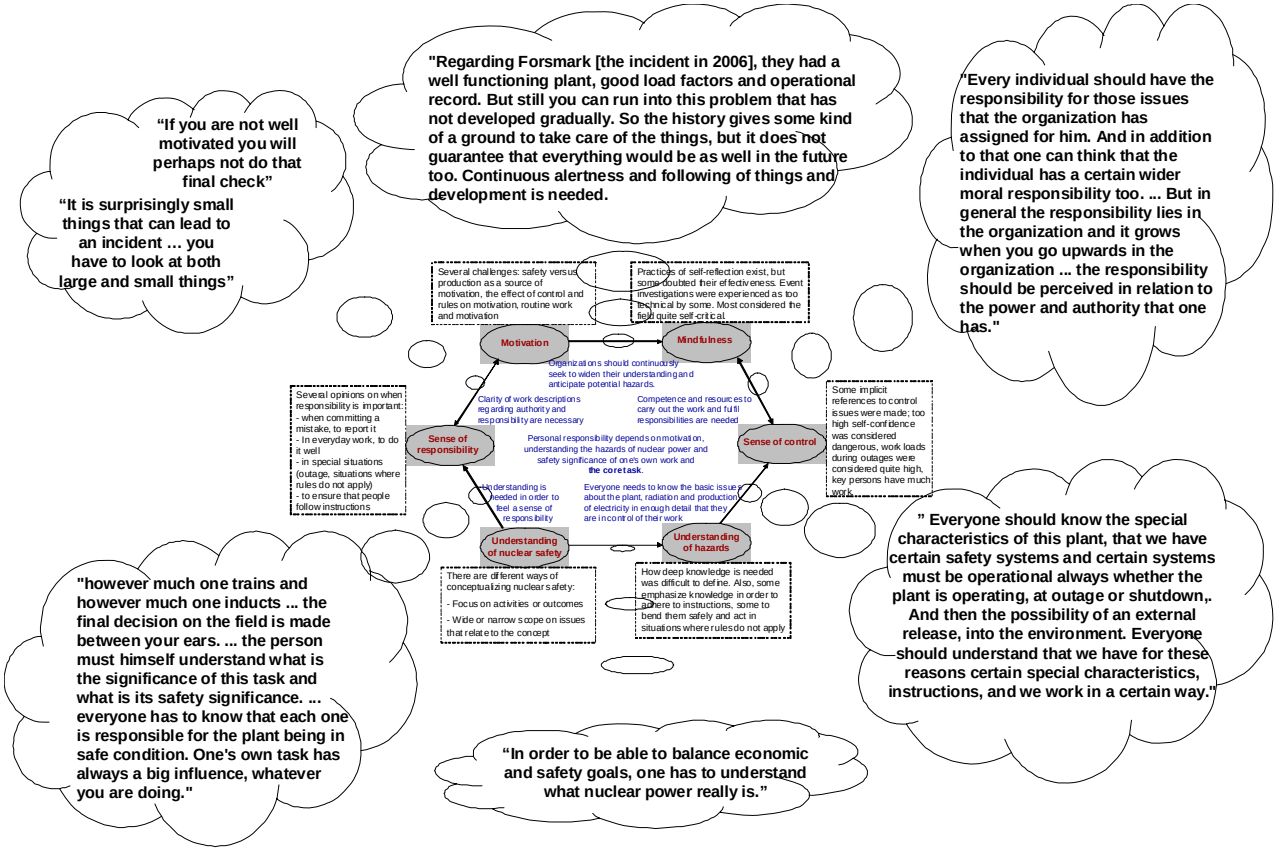

Figure 4. Examples of various ways of conceptualizing the psychological dimensions and their significance

In the next section we will consider the various dilemmas associated with for example motivation and responsibility in the nuclear domain.

4.3 The human factors dilemmas in nuclear safety

The interviews uncovered a number of dilemmas or conflicting solutions associated with various human factors related issues. The main dilemmas that we identified concern *autonomy versus compliance*, *individual responsibility,* and *the direct and indirect effects of various control measures on safety*.

A representative from the Finnish industry contemplated the challenges of work motivation and its relation to the organizational control measures:

> "I guess if a person is not motivated, he turns into indifferent, and that does not go together with maintaining nuclear safety. This is also one of the small dilemmas of nuclear power. We need diverse people, but there is quite a lot, there has to be control and there is supervision. Some people might be demotivated from the amount of control. Of course some people are motivated by control, but we also need those people who reflect a bit, who want to think a bit wider. So where does the border for the control go when it starts to demotivate. So work motivation has a huge influence on everything we accomplish, and by that way also to nuclear safety. But of course the processes must be able to handle the issue that somebody is not so motivated. You cannot motivate everyone all the time, we are humans and humans have civilian life worries and other things that surely reflect to work from time to time."

Organizational functions should aim, on the one hand, at enhancing employee motivation, and on the other hand, at controlling and guaranteeing that individual human errors or negligence do not cause harm.

The dilemma of autonomy and compliance is related to adherence to instructions and the role of humans in general in assuring nuclear safety. A representative from the Finnish industry contemplated the challenges of individual responsibility and adherence to instructions:

> "Well, in my opinion the responsibility of the individual is to do his job as well as possible and bring forth those things that … I wouldn't say that, this adhering to instructions is a little bit, adhering to instructions one hundred percent is not right either, if you feel that the instruction is wrong, that also has to be said. But still one should not deviate from the instructions by oneself, that's how I would put it. That is the most important thing. But this questioning and bringing forth of things and doing one's job well, that is the individual's responsibility. The organization then should not leave the individual by himself if he brings any problems forth as so on. These issues have to be then considered and thought through. But the thing is, when somebody works in some specific area that area is the most important thing in the world for him, but the area not necessarily so important in the whole scheme of things. That is why these things have to be raised up and considered, until the issue is either a) taken care of immediately or b) decided that considering the whole, we can live with this thing until the next year. That it is not so meaningful. But still these issues should be raised."

The dilemma extended also to contractors. One interviewee mentioned struggling with the issue of how much the contractors should be educated about the basic principles of nuclear power and how much emphasis should be placed on guiding the work with strict instructions. This is related to the general dilemma of responsibility. Many interviewees discussed the dangers of shifting personal responsibility to the organization, to instructions or to the regulators.

In the interviews the representatives of the branch were asked whether there are or should be special requirements for a good safety culture in different stages of the power plant's lifecycle. This was a difficult question for the interviewees to answer. Most of the interviewees could not specifically point out differences in the requirements of a good safety culture in different phases of the life-cycle. This is understandable, since the existing safety culture theories rarely take into account the different phases of life-cycle of the plant or organization. However, the interviewees emphasized the significance of the life-cycle thinking and felt that it was important to consider the level of

safety culture in each phase. A representative of a Swedish power company contemplated on the different requirements of a good safety culture in different phases of the life-cycle as follows:

> "A: Yes, so they set different requirements, these different phases of life-cycle. In the design, construction phase there are requirements for having, that you, then it is about constructing a reactor or a nuclear power plant that has good properties, technical properties, that has some kind of robust construction that is merciful in terms of incidents that can affect safety. It is a matter that it is really engineer intensive so to speak. Technology intensive. And it requires one type of culture that is very much related to, yes, to technology as such.
> Q: Quality and precision, perhaps.
> A: Yes, exactly. Operation phase sets requirements for other things, it is about how you handle technology and that you really see to that you … know and understand the background for why this here looks like it does and so that you run it in a safe way and maintain it in a safe state. So it requires a bit different, different kind of competence and sets a bit different preconditions. Decommissioning, yes, we're not there yet. But it is really the furthermost, it brings out other questions, doesn't it. Then the operations period is what actually produces energy and there we have potentially the biggest risk. When we have closed down this and when we'll decommission it, then these others aspects come in, how you can store it, what can you make of it and how can you make it environmentally acceptable. So it is again, it is the third type.

A representative of STUK felt that safety culture was too often connected only to the operation phase of the plant. He emphasized some extra challenges faced in the construction phase of a plant:

> "A: Very often safety culture is perceived as an operation phase thing only. But it is not like that, that the design, construction and manufacturing and setting-up can be followed through by just doing things according to instructions. But it's not like that. It is like that of course in ideal cases, I guess it can be pulled off. But since we're not in an ideal world and there aren't always instructions and the instructions are sometimes wrong and plans are wrong so then they should be intervened and addressed and brought out so that…
> Q: Is there a certain feature that is emphasized or seems challenging if you think of the construction phase especially … What seems to stand out as a special challenge?
> A: Well… I think the most significant thing is the actions of the supervisors in the construction site, so that they understand their task and can explain it to their workers, what they are dealing with. Possesses these good management or supervisor skills, encourages workers to bring out quality and safety deficiencies and if they do bring, then give feedback and positive feedback. And also tells them later what happened to that problem, what has been done. Can handle people, of course chooses competent people, responsible people to the task. If you can sort that level out then you do have preconditions for success there."

A similar point can be made about the application of the safety culture concept to for example contractor work or design activities. This topic will be dealt with in Section 7. An interesting observation concerning the criteria for nuclear safety is the role of supervisors. As mentioned in Section 4.1 supervisory activity was not explicitly raised as an evaluation topic for nuclear safety evaluation. However, according to this interviewee, at least in the construction of a nuclear power plant supervisory work is of crucial importance. One could raise the question of whether the supervisory work is less significant in the operating plants or whether there have been more problems in it at the constructions site, making its relevance more apparent.

Other dilemmas were also perceived. For example, a representative from the Finnish industry contemplated the challenges of having managers that are good in both substance and leadership skills. He considered both qualities as essential for being a good manager at the nuclear industry, but acknowledged that such persons are hard to come by. The potential tension between activities aiming at developing occupational safety and activities aiming at developing nuclear safety was also mentioned. Sometimes it had been difficult for the personnel to differentiate whether a certain activity was targeted toward occupational or nuclear safety or both.

5. Similarities and differences between Swedish and Finnish nuclear branch cultures

5.1 What things are shared in the Nordic nuclear branch?

The interviewees typically emphasized the fact that Finland and Sweden have had very different historical development in terms of nuclear power. Most interviewees were sceptical of the idea of a shared Nordic nuclear branch culture. For example, some interviewees from the Loviisa power plant thought that because of their reactor type they have stronger connections to certain other countries than Sweden. An interviewee from a Swedish plant answered the question "Is there a common branch culture within the Nordic nuclear community" as follows:

> "Yes there is. Much because of the Nordic, particularly Swedish, nuclear power plants are tightly coupled to the Swedish industry, ABB or ASEA ATOM. So it does exist, but there are also, as I see it, very big branch differences. From a technical point of view there are similarities, especially concerning the boilers. But then there are actual cultural differences. The Finnish plants, for example, are tightly connected with the conventional industry and have got short lines of decision. There they don't talk so much about consensus decisions. This creates, at least in theory, very high efficiency. One can possibly sometimes wonder if it is not going too fast. But you still have to acknowledge that the Finnish nuclear power has got very high availability factors and they have got a high safety level, so all in all it seems good. Sometimes, during many many years, there has been a desire within the Swedish nuclear power to take up some of the advantages with Finnish decision making, it should be faster: how come Finland has got so short outage periods and so on. And one can of course state that the Swedish and the Finnish character/culture play a big part in this. It is not that easy, and not even possible in some situations, to transfer the Finnish way of working. Exactly what the reason is for this I don't really have an opinion about. But one has for sure tried to take on to the Finnish way of working without really succeeding, I would say. But I still believe that the Swedish, more thoughtful way, is good."

Still, when discussing the nuclear branch in Finland and Sweden further, most interviewees pointed out forms of co-operation between the countries. They also emphasized the similarities in the goals and requirements the organizations in the Nordic nuclear field have to deal with and tried to describe a certain "Nordic nuclear mindset". For example, a representative of STUK emphasized that despite many differences the safety work in Finland and Sweden has a similar foundation:

> "Well, of course now, perhaps I can best compare these authorities, SSM and STUK. The foundations are, or goals for the work, are surely exactly the same. Like the use of radiation, prevention of harmful effects of radiation and, a kind of basic thing to that is that the licensees are responsible for it. It is, I think, the same in Finland and in Sweden. And that in its part creates this similarity in the operation and culture. … If you think of the safety of the plants, the starting point and the requirements are very similar. Or the level of safety. The difference isn't so big as it is between some other countries."

The interviewees from Posiva strongly highlighted the tight co-operation, shared goals and common challenges between Posiva and its Swedish sister organization SKB:

> "SKB is our most important partner in co-operation. We have almost everything alike, the plans, technical plans are alike and geology is the same, so it's natural that we then have the most in common…"

It was also mentioned that in many countries government organizations are taking care of the nuclear waste. Posiva and SKB are both jointly owned by the nuclear power plant operators. The development of nuclear waste management issues was considered by many as being ahead in progress of almost all other nuclear countries.

The similarities between Finland and Sweden were most clearly manifested when the interviewees were asked whether there are some things or areas of knowledge that every one working in a nuclear power plant should know. Most of the interviewees immediately acknowledged that there exists some kind of "nuclear mindset" that each and every one working in the nuclear domain should share. However this mindset or general branch knowledge was hard for them to make

explicit or describe in detail. This is how one representative of the Finnish authority talked about the issue of a nuclear mindset in general:

> "Well at least you have to understand that you're working in a nuclear power plant and what it means. It should already be in, like, in your scheme of things that you're not there just casting concrete but you're casting concrete to a nuclear power plant, so that your scheme of things is somehow oriented to working in a nuclear power plant area or in a nuclear power plant. Of course, in order to understand it, you have to know something about why it is so special. It should be made clear for everyone that radiation is involved and radiation is deadly if it's not controlled. And from that, the understanding about working in the nuclear branch or in nuclear power plant surroundings or in a nuclear power plant should be on one's mind … Now we are talking about even the helpers that pick up trash from the construction site or things like that, so that if they see some kind of a deviation there, they bring it out because they know that some deviation can be significant from radiation safety point of view. So every one should understand this much, should have an understanding about safety, about what is the thing that we are dealing with and what is the threat to you and to the environment and to the safety of people."

A certain Nordic mindset or orientation towards nuclear safety was evident also when the interviewees contemplated the similarities between the countries. A representative from the Finnish industry described the similarities in the following fashion:

> "Maybe this kind of quite honest way of working, that… This I would say is similar with the Swedish. And taking of responsibility also, taking of personal responsibility is typical. That's also visible at Germany. But what I have seen the Americans and the French, so they have a little bit different way of working then. It is more like supervision. … [The honest way of working] shows when we have problems we report those problems, we tell that we have these kinds of problems. In many countries this does not happen. And this shows, for example we are very diligent in reporting, to WANO for example."

One characteristic that a few interviewees considered as separating the Nordic countries from some other nuclear countries was the perceived reluctance of the personnel to follow the rules strictly, but on the other hand to take personal responsibility for safety more than was perceived taking place in many other countries. A representative from the Swedish industry discusses the characteristics of the Nordic nuclear branch culture:

> "A: I think you have to start from another perspective, such as is there a certain Nordic culture that separates us from others? And I'm certain that is the case. So, in Sweden and in the north we are not tremendously dependent upon instructions and rules. In some other countries they become almost paralyzed if there aren't any rules. I believe that we even from a branch perspective are more different as northerners than we are as nuclear power personnel in how we are, no matter if we are talking about running a nuclear power plant, working on a paper mill, or whatever, and that "water divider" is, I believe, much stronger than Swedish culture versus Swedish or Nordic culture,
>
> Q: But from that water divider, as you say, is how the Nordic culture originates?
>
> A: Yes, I believe it is wrong to define it as one or it's obviously so that there is a branch culture as well. … But I believe the big divider is something that is a Swedish or a Nordic way of being versus central Europeans and so forth. .. If you would consider some Swedish deficiencies, so to say. Swedish cultural deficiencies compared to how an international standard in the branch are… we are not dependent upon, or don't need, instructions, and we don't really like to use instructions if we aren't unsure of what or how to do something. And this leads to, that it is much harder to make people to really bring an instruction, use an instruction in every work task. Adherence to rules is not, I would say, very important for us as Swedes, or Nordic people. As long as you don't challenge safety, in one's own opinion, then one considers it to be good enough. And as long you don't challenge my safety, then I don't interfere with how you are doing – I would say that is also something typically Scandinavian. … At the same time we, unlike most others, well if it would only be a defect, then it would never work, so as an opposite pole, there is something else, and that is that we have a strong sense of personal responsibility. One does actually take responsibility for the situation even if one doesn't follow rules, one doesn't behave in a stupid way. And this is probably all good, at least to 98 -99 %, but then there are a few that have a bad judgment… and it is somewhere there where the problems begin…"

Some interviewees emphasized that due to high sense of personal responsibility and high competence the instructions do not have to be so detailed in the Nordic countries as in some other countries. This applies also to the instructions that are given to contractors, some of the interviewees say. Some worries were expressed about the contractors understanding of the hazards of nuclear power and the safety significance of their work. These worries were expressed by the regulator, power companies and also the waste management organizations. The issue could not be explored further within the scope of this project, but it was selected as a theme for the continuation work (see the conclusions section of this report).

5.2 What differences exist?

Many interviewees pointed out the differences in the political environment toward nuclear power that has existed in Finland and Sweden. As was already pointed out in the quotes at the history chapter (Section 3.4), at the beginning Sweden had a strong domestic manufacturing industry in the nuclear business whereas Finland was dependent on foreign suppliers. Some interviewees argued that the decline in the political acceptability of nuclear power has also led to a decline of competence in Sweden. This is evident in the challenges of the big modernization projects where both the suppliers and the power companies have had problems with competence, claim the interviewees.

STUK representative thought that the differences between nuclear power plants had more to do with differences in company culture than in national branch culture, which in his opinion was rather united:

> "Q: If we think of the way the plants are managed and operated, are there more differences between Finland and Sweden or between plants within these countries?
> A: I'd guess that nowadays, when these companies are so integrated, I mean they almost all work in Finland and Sweden, expect for TVO, so there are more of these operations models that are connected to the traditions of the company. Between companies, there is a huge difference for example between Fortum and TVO in their organizing and organization and in their so called set of values. In my opinion, there can be amazingly big differences. It is partly because the other one is from the west coast and the other one is from the east coast, so there is also a visible difference in these ways. And then this old tradition, if we talk about nuclear power, so working with the Russians has affected an awful lot of Fortum's activity. … and then again TVO's co-operation with ASEA Atom has affected the way TVO's organization works, just as much. So yes, I think there aren't so big differences between these countries, but then again there are more [differences] between these companies, yes, there still are these traditional differences. They of course are also evening out, because the personnel is changing pretty fast everywhere. These ways of working are also becoming more alike."

Even though there are differences within both countries, several characteristics were found that separate the Finnish nuclear industry from the Swedish industry. First of all, the interviewees perceived a difference between Sweden and Finland in the way the co-operation between plants and nuclear safety authorities is arranged and thus how the safety of the plants is regulated. Secondly, the interviewees perceived differences in the way research activities are organized in Sweden and Finland. Thirdly, decision-making styles were considered different between Finland and Sweden.

Authorities

A representative of a Finnish power plant described the difference between the regulators in Finland and Sweden in a way that seemed to represent the majority opinion in Finland:

> "…this authority thing is a bit different there in Sweden, than what it is in Finland. In Finland the connections seem pretty tight. There is a rather continuous dialogue with the authority and the documents are circulated very widely for approval. In this sense I got the impression that this Swedish method is … such that the power companies have their own inspections and the authority then monitors … that the procedures are followed, and the

> monitoring is kind of happening from above … I don't know if this is an accurate impression, but this is the impression I have."

Swedish interviewees had a similar impression. A representative of a Swedish power company described the difference this way:

> "A: I have seen enough and know that STUK's approach is a bit different and they have a bit different relationship between the licensees and the authority in Finland, really. And, so if you compare with the situation in Sweden, the Swedish authority work has, over time, become more and more formal and formalised… and structured, so to speak. Yes, this is a significant, rather considerable change that has happened during the course of the years."
> Q: Has the Swedish view changed more towards some American, or what is the direction they have moved towards?
> A: Yes, don't know exactly if it has approached the American way, but it absolutely has moved, we have shifted away from the Finnish way of thinking, in other words away from having an inspector present that had a certain mandate, to approve certain things, so this is eliminated. All the approving is handled, so to speak, in Stockholm and it is more formal handling there with approvals. It is the same with the plant modifications. In the past the inspector could write an approval on the spot after you had gone through the modification. Now one has to formally send papers and approve them. And then this handling of the security issues has also been a rather special case, one could say. For example, they want to approve subcontractors that come to the plant. I think this is close to detail handling that doesn't yield a thing."

Another representative from the Swedish industry was asked to elaborate on his previous comment that there were differences between the authorities in Sweden and Finland:

> "A: Yes, there are some differences. The strict authority, but still very strong collaboration between the authority and licensee, is uniquely Finnish. It is strict, very tight, and it is based upon trust. It is very much based on persons, a stability in the staffing. … You can see that when they have a problem at some plant, they sit down, then after a while they agree upon the safety consequences and then they act according to that agreement - on an effective way. That way of approaching problems does require a very different competence high up in the different leading positions. The Finnish system is based upon high competence all the way up to the leading positions of the company. Maybe we are prioritizing other competences for leaders in Sweden and that is why we could not apply the Finnish system – it is not possible. We must have other ways, based upon other patterns. So it is not possible to just take it on [the Finnish system]."

There were some differing interpretations on the authority relations. One experienced representative from the Finnish industry shared his thoughts on regulatory work at Sweden and Finland that differed from the majority opinion:

> "Swedish and Finnish do have some differences, in that the Finnish way of working is more autonomous. And this kind of, one takes own responsibility for things, but then also the regulator does not necessarily want to give that, so the regulatory activity is such that is tries to oversee everything. In Sweden the regulator is more like a partner in cooperation. It is more watching than prescribing. … The Finnish way is closer to the American way, where the regulator is supervisory, strictly supervisory."

When a representative from the Swedish industry was asked to compare STUK, SSM and NRC, he did not agree with the previous interviewee completely:

> "Well, each one of those three have a rather different way of working, so one probably can't group like that. But it is obvious that STUK is part of a branch / industry. I think many people in Sweden believe that STUK is not as tough as SSM, but that is all wrong. But STUK is part of the production process, and a part of making nuclear power work. And that is not how SSM looks at itself. SSM has, I would say, solely an auditing/verifying and "pushing for safety" role. But then one is one part of a part of the production process, and one part of making nuclear power work. And that might be a risk too, or I would rather say, already has to a large degree contributed to the problems the Swedish nuclear power is in today. And I believe one can generalize upon this: the cases I know about, where the authority is not part of making the whole business work, it doesn't work well. Take the situation in northern Germany, which is a brilliant example. NRC is another brilliant example. When they had the opinion that they should only deal with auditing safety and nothing else, and had no responsibility of making the branch/industry work, then the American nuclear power didn't work very well either."

The representatives of both authorities also agreed with the idea of SSM and STUK having different approaches to controlling the safety of the plants. When discussing the history and development of nuclear power in Finland and Sweden, some possible reasons for the different regulatory authorities were found. A representative of STUK described the difference and possible reasons for it as follows:

> "There is probably some kind of historical background here, for how these ways of working have developed. With us they started developing from the Loviisa plant, from the regulation of the Loviisa plant. There was this foreign plant supplier, that you maybe didn't fully trust and you wanted close monitoring. On the other hand, in Sweden, there was this domestic well-known, trusted plant supplier, so the ways of working formed on the basis of that. Well, now Sweden has had a bit parallel development to us, so that they have developed some rules of their own, but then this regulation of the plants, there they don't go nearly as far into the technical details as we do. So they, they sort of emphasize the power company's own inspection activities more. They watch very closely that inside the power company there is an independent inspection. And the authorities, the role of the authority isn't emphasized that much. And they emphasize the responsibility of the power company. Here with us, on the other hand, there are these expressed fears like whether it is possible to inspect that much, so part of the responsibility sort of shifts to STUK in this sense, so it is this, like the flip side in this issue. Of course we say that we don't have the responsibility [for nuclear safety], but still we inspect much of the plant. You can't just simply say what is right and what is wrong, these are just chosen solutions. There are authorities that do inspections even less than they do in Sweden, for example. This British authority, it doesn't really inspect anything."

Interviewee from SSM described the difference as follows:

> "We have understood that STUK has more people; they also have more people that have worked as designers and more people that make calculations – this means that they take more samples and make more their own calculations. We as regulator are not doing this – we have neither the people nor the calculation programs. We are working at a rather high administrative level. But I also think that the regulator in Finland has a tendency to take over the responsibility [from the plants]. The operators give an impression of having the responsibility. Because the way they organise themselves, the owner has taken a position of responsibility but the operators do not always have the ability take this responsibility so they tend to slide responsibility away to the regulators – so, it is positive that they can control and review details – here we try to run it so that the owner takes full responsibility."

In summary, the Finnish authority is regarded as having a more interactive and dialogic way of working than the Swedish authority. According to the perceptions of the interviewees, STUK is working more closely together with the power companies than SSM, which is considered more formal and distant in its practices. Opinions on the competence at STUK were positive by both Swedish and Finnish interviewees. STUK was considered as quite detailed-oriented in its focus and some considered that this focus shifts responsibility away from the power companies. SSM was considered as being sometimes unsure and unpredictable in its decisions. Still, many interviewees noted improvements at SSM in the recent years. Many interviewees considered the different regulatory styles as the largest difference between the nuclear cultures in Sweden and Finland. Some were hesitant to talk about shared Nordic branch culture due to these regulatory differences.

Decision making and way of working

The interviewees also elicited some national differences in the way everyday activities like decision making and management are carried out in the nuclear power organizations. For example, some of them pointed out rather stereotypical differences between Sweden and Finland in the process of decision making, as is illustrated by this representative of a Swedish power plant:

> "And then if you think of this kind of cultural things more, … the Finns have a tendency not to talk so hell of a lot, but to make a decision and then do it. … Whereas a decision in Sweden is a sort of sketch of what somebody thinks should be done, someone liable, and then you look how, no, now I'm exaggerating. But there is such a cultural difference …"

A representative of STUK described the same kind of differences in decision making as follows:

> "I think it would be terribly hard all of a sudden just to change our system and the national system to a Swedish-like system. It would be an enormous problem. We are not used to it, everyone would become agitated already in less than an hour from all that conversation [laughing], everyone would be wondering, what are we sitting here for, can't anyone decide a matter as simple as this. That is, I took part in few of these Swedish gatherings and they are of course kind of educative for a Finnish person, sort of unnerving gatherings, when you feel like, like the answer is there now but why doesn't anyone say it aloud."

Differences between Finnish and Swedish decision making styles were also highlighted by an interviewee from Posiva:

> "Well if you think about our sister organization, SKB, I guess our basic thinking is pretty much the same, there are no big difficulties in that as such, in working with them. But especially in some of these questions the decision making, there are these differences there, maybe. Yes it, here in Finland if we have decided something we tend to stick to that decision and, in Sweden people value this consensus, like you should reach mutual understanding in things first before you make any decisions. Nonetheless we are now maybe, I'm not saying that we clobber decisions but we say that it is maybe such an organization anyway the idea as such is that some things are decided by someone, if there are differences of opinion then somebody makes it anyway and nobody feels bad about that. It isn't necessarily made in his own interest, but most people start from the fact that this is how it was agreed, that a certain organizational hierarchy takes care of the decision making. Whether it is good or bad."

A Swedish interviewee condensed the difference in cultures into the following story:

> "Well I can give you an illustration: If there is a seminar or something of that kind – the Swedish speaker tells about how he would solve a problem and that he has a project going on and other plans and thoughts. And then the Finnish speaker talks "we have not thought very much about it but this is what we will do" – then it becomes clear that they already have done all the things that the Swedish talk that they will do. They have a simpler hierarchical system – very hierarchical but it is accepted, it is not so much talk and not so much deliberation. They say they shall do it and really do it, but it can be based on rather shallow assumptions."

One Finnish interviewee offered the following anecdotal description of the key national differences:

> "There are differences and some of the differences are quite stereotypical, they are related to these typical characteristics of Finnish and Swedish organizational cultures. As someone has said, in Sweden time is a resource, in Finland it is a constraint. For us a schedule is something that we have to hammer everything into it, in Sweden they think that time you can always have more, if not the other resources."

In a summary, there is no clear agreement on a Nordic nuclear branch culture. There are some differences that many interviewees perceive between the Finnish and the Swedish nuclear industries. The Finnish management style was considered more hierarchical but at the same time clearer and stricter than traditional Swedish management. The Finns were perceived as more action oriented than the Swedes. There seem to be more cooperation between the regulators and operators in Finland but also a tendency that the regulator in Finland focuses more on the detailed technical issues and thus perhaps tends to take more responsibility in a subtle way. Manning resources are not considered sufficient for such detailed work at the Swedish regulator and the regulators also show differences in competence profiles.

5.3 National culture as one of the differentiating variables?

As described in chapter 5.2, several of the interviewees said that the difference between Sweden and Finland with regard to nuclear safety issues could probably be traced back to differences between national cultures. An in depth discussion regarding national culture is not within the scope of the present report, but some small comments about the issue, departing from four of Hofstede's cultural dimensions (Hofstede, 2009), are in order. For comparison, some data is also presented for France, Germany and USA.

The aim of Hofstede's study was to study how values in the workplace are influenced by national culture. There are four dimensions which are of special interest here: Power Distance Index (PDI), InDiVidualism (IDV), MASculinity (MAS), and Uncertainty Avoidance Index (UAI).

- The dimension of PDI represents the extent to which the less powerful members of the organization accept and expect that power is distributed unequally.
- The dimension of IDV represents the degree to which the individuals are integrated into groups.
- The dimension of MAS represents the distribution of roles between the genders. On conclusion Hofstede is indicating that the masculine pole means that one is very assertive and competitive, while the other pole, feminine, means one is very modest and caring.
- The last of the four dimensions, UAI, deals with the society's tolerance for uncertainty and ambiguity. It indicates to what extent the members of the society feel either uncomfortable or comfortable in unstructured situations. Uncertainty avoidance cultures thus try to minimize the possibility of novel, unknown, and surprising situations by strict laws and rules, safety and security measures, and a belief of a "absolute truth". The uncertainty accepting culture are more tolerant of opinions different from what they are used to; they are more tolerant of opinions different from what they are used to, try to have as few rules as possible and allow many currents of "truths" to coexist.

Below the quantitative results for Finland, Sweden, France, Germany, and USA are presented. The differences between Finland and Sweden are then briefly discussed.

Table 1. Comparison between cultural dimensions (Hofstede, G. 2009)

Dimension	Finland	Sweden	France	Germany	USA
PDI	28	27	72	30	36
IDV	68	68	77	62	97
MAS	20	3	48	61	58
UAI	52	28	90	60	41

The two first dimensions, PDI and IDV, are very similar between Finland and Sweden, and are thus not of interest for explaining differences with regard to national culture. The last two are, however, of more interest. Finland is more masculine oriented than Sweden (but much more feminine oriented than France, Germany, and the USA). Finland is also more oriented towards uncertainty avoidance than Sweden. Some tentative conclusion based on these differences could be that the Finnish culture, to a greater extent than the Swedish culture, values strong decision making (is more assertive). Another conclusion is that the Swedish culture, to a greater extent than the Finnish, is more comfortable in living with uncertainty – and might to a larger degree accept that different opinions are raised within the organizations. These results are in line with the differences uncovered in this study, especially concerning the more hierarchical decision making at the Finnish nuclear organizations.

6. Key content issues in the Nordic nuclear branch culture

6.1. The roles of the various players

The main players of the Nordic nuclear branch were typically summarized into three categories: industry, regulator and technical support. Some informants pointed out other stakeholders such as the police, plant site municipalities and the government. A few mentioned contractors as one important player in the Nordic nuclear field. Some interviewees divided the industry into two subgroups: the plant licence owners and the company shareholders. It was pointed out that the interests of the plant owner and the company shareholders do not always necessarily coincide. Still, in issues that relate directly to nuclear safety there are no conflicts of interests according to those interviewees that discussed this issue. A more challenging issue from safety point of view was the joint ownership of the plants and the competition legislation that prevents the owners from discussing issues together. The forbidding of discussion between competitors does not necessarily always promote nuclear safety. A STUK representative felt that there were changes going on in regard to the main players of the Nordic nuclear branch:

> "It is quite easy [to name the different actors in the Nordic nuclear branch] since we don't have actual nuclear manufacturing here. So what we have is power companies, technical support organizations or research institutions and then the authority organizations. So there is not much of anything else in the Nordic countries I guess, since ABB doesn't manufacture anything anymore. Of course you can say that there are always subcontractors, that there are actors that supply some components to nuclear power plants, there are lots of them, of course, valves, pressure vessels, things like that. And they are coming to the market more and more apparently because if there are new nuclear power plants coming to Finland, necessarily there will also be manufacturing infrastructure transferring here, it is a sure thing."

The core task of the **regulator** was considered quite harmoniously as guaranteeing and supervising that the power companies fulfil their responsibilities in issues related to nuclear safety. One interviewee however considered regulator's role more as a neutral party who is able to share information between the industry parties:

> "Well, I'd guess that the task of the regulator is to supervise that we do the things right and that we do the right things. That's where it should focus in my mind, when sometimes it feels like they go deep into the technical issues, which is not… of course it should supervise that we have the technical competence and our processes are functioning. But the ultimate technical bend, that should be with us and with our equipment supplier or plant supplier and so on. Then we are doing the right things, and the regulator is no doubt also a good benchmark on what is required elsewhere in the world and where the nuclear power is going … bring those requirements and thoughts, a bit like 'have you noticed that this country has done that' and so on. Of course the power companies cooperate through WANO, but of course commercial legislation too hinders the cooperation. In safety issues we can talk whatever we want, but in some for example modernization projects and such, there are commercial aspects involved, so you do not necessarily discuss them so much."

A few interviewees explicitly raised **research organizations** as a key player in the nuclear branch. A representative from the Finnish industry described the key events that have shaped the nuclear safety culture:

> "From the Nordic countries and elsewhere from the world, this operating experience that we have got, they have been … usually they are negative operating experiences that further the development. Then research is another thing that should not be forgotten. It has led to practical applications. Let's take handling of severe accidents; there a lot has been achieved specifically with research."

Interestingly most of the interviewees from the power companies or from the authorities did not explicitly mention **radioactive waste management** (RWM) organizations as actors of the nuclear branch at all. Representatives of RWM organizations themselves also seemed to position

themselves and their organizations somewhere on the margins of the nuclear branch. It also seemed that the position of RWM organizations in the branch varies depending on the state of the public discussion concerning the use of nuclear power. The RWM organizations are sometimes understood as part of the branch and sometimes not. An interviewee from Posiva reflected on this issue:

> "…it is obvious that if we are there alone just cleaning up afterwards, then we are executing this environmental mission, when on the other hand if there is this rising industry, then we are, we are necessarily seen as a part of that industry, like it has been now again lately. And it has been seen that, because if you want to build new nuclear power plants, then the waste things will also have to be in order. Yes, these have been coupled together with each other again lately, more clearly than maybe ten years ago, when the mindset was much more like that the waste needs to be taken care of anyway, that even though the nuclear power would otherwise, power plants would otherwise go out, there is enough to do with the waste. The operational environment has changed in that sense."

Based on the interviewees it seems that even though the RWM organizations are largely dependent on the power plants, they don't necessarily share their core task. Thus the challenges they face in their operation are also different from the challenges of the power plants and nuclear safety authorities. The above cited representative of Posiva described this difference in challenges faced:

> "…this educational aspect, that has been this big concern elsewhere, especially of course for the authority in Finland also, whether the plants can be taken care of properly and if the personnel is ageing and there aren't new people coming, then this similarly hasn't been a challenge because most of the personnel here doesn't need directly … or their educational background is something else than this nuclear power education, since there is not much nuclear technology. You can say that there is this criticality problem, but otherwise, of course you have to know something about radiation, but otherwise it is pretty much this environmental technology and it has nonetheless been on the upgrade, also earth sciences have always prospered in Finland, there is, you can even say that there is surprisingly lot of education and training in earth sciences. So in that sense we have not been worried about that side so much as maybe in the sense that if the nuclear industry is faring badly, then we are in a stiffer situation when it comes to resources, financial resources, so it's clear that if there is no future in sight, then everybody's use of money is taken more critically and strictly than if this was a rising industry, so then it does reflect to us too in that sense."

Besides the main players the interviewees also recognized some outside actors or organizations that had a strong influence on the branch. A representative of STUK described these influential actors or partners in co-operation as follows:

> "Of course the government, the ministries come to mind. So these authority organizations that are by our side, the ministries. We don't actually have anything else here, are there any… Of course we have many people issuing statements then, if you are writing some papers, so there is the Ministry of the Environment, Ministry of Social Affairs and Health, these sorts of actors. But they are ministries in general, the Ministry of Employment and the Economy and others. Then of course the Prime Minister's Office is one of those, that always drags itself every where with us. It is in certain situations, when we talk about alert situations then, then we have to be in touch to that direction also. And rescue service organizations of course, they are in the Ministry of the Interior's side and there are these municipal fire departments and all. These are of course such actors that are connected to our nearby organizations also, with who we are dealing with. And the police, of course, in a sense that there are security issues."

Another interviewee from STUK contemplated on the same outside interest groups like this:

> "Then there are of course many interest groups, if you think of these placement locations, then we deal with them a lot, with their rescue services, because contingency work is a very essential part. And with the police, because security arrangements are important, and we do have direct contacts to different police organizations. But they probably don't still see themselves as nuclear branch organizations. From our point of view they perhaps are, but they hardly think like that themselves. And they probably don't see themselves belonging to any kind of nuclear community. But these interest groups, if you think about it for a while, there are a lot of them."

All in all, it seems that the roles of the key players, namely the industry, authorities and technical support, have not been strictly defined. There are also players that do not fit straight into any of the key roles, such as RWM organizations and consultants.

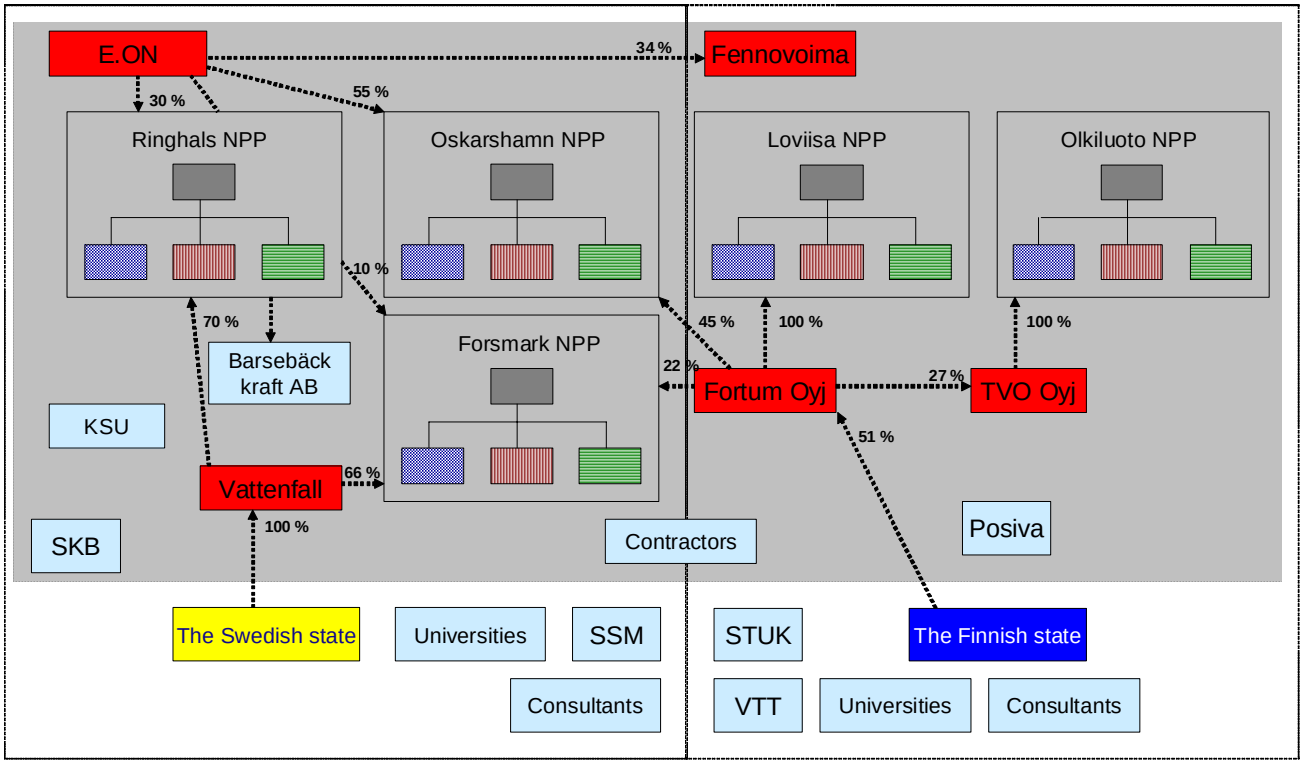

Figure 5. Illustration of the key players of the nuclear industry at Finland and Sweden. The illustration shows the power companies and their shares of the power plants. The percentages of ownership have been rounded to the nearest full number. For clarity's sake, only the ownerships for the power plants are shown, not for the nuclear waste organizations, KSU or government organizations (VTT, universities). The ownerships have been checked from the company web pages on 15.12.2009.

Figure 5 illustrates the nuclear branch culture domain in Finland and Sweden based on the interviews and literature. There are five operating power plants and four major owners. The power plants have four main functions – maintenance, engineering, operations, management - that sometimes seem to share more similarities across the organizations than with the other functions within their own organization (cf. Rollenhagen & Westerlund 2007; Reiman et al. 2005). Furthermore, both states have a large ownership of the power companies; the Swedish state completely owns Vattenfall and the Finnish state is the majority owner of Fortum Oyj.

6.2 Information transfer institutions in the Nordic nuclear branch

Based on the interviews, there are several institutions in Sweden and Finland that can be called information transfer institutions of the Nordic nuclear branch. These institutions are often not seen as a part of the actual branch, and are thus not all depicted in figure 5. However, they act as "glue" between the power plants, passing on and transforming experiences and ideas back and forth between the power companies and their plants and thus unifying and changing the branch safety culture. They have a role as carriers as well as modifiers of the nuclear safety culture.

The most often mentioned information transfer institution in the interviews was **contractors**. As one Finnish interviewee put it:

> "Common denominators [for the Nordic nuclear branch] are, of course the contractors that work for the plants mainly during the annual outage. … often the contractors work both in

> Sweden and in Finland. They circulate in all these plants. They are like common actors. … they in a way then see things and we then have contact with them and they bring their own ideas from there."

There were also a lot of challenges connected to the role of contractors in the Nordic nuclear safety culture. The role of contractors is tackled more closely in Section 7.

The **media** could also, by definition, be seen as an institution that transfers information or "carries the culture" between Nordic nuclear power plants. For example newspapers and TV companies filter and interpret the happenings of power plants. In their communication nuclear safety aspects are often emphasized. However, in the interviews with the power company representatives the media was mentioned as having a rather minor effect on the Nordic nuclear branch culture. It seems that there is a shared unwritten norm within the power plants about how to talk about the media. The interviewees from the power plants often described the media in a cautiously negative manner, belittling its importance. They did not explicitly identify the media as an information transfer institution. Nonetheless, the media appeared to act as a counterforce for them, creating preconditions for their actions, communicating the limits of the actions for them somehow – transferring information about how far they can go. The people at the power plants seemed to follow closely on how the media treated them and the other Nordic plants and from that they seemed to make conclusions about the boundaries of their action. An interviewee from a Finnish power plant described the role of media as follows:

> "All that we do often attracts attention, pretty great attention, even though we ourselves can in a sense be aware of it, if we know the matter better, can think that it is not… We don't necessarily feel that it is that significant, but it has its news value anyway. They want to make news out of anything. I don't know if it has that much effect [on the branch], but is something that is always in mind here."

The same attitude was echoed by an interviewee from a Swedish power plant:

> "…the media is not really a powerful mover, it is just, it is just a punishment if you don't take care of things. So it is not any prime mover otherwise than, it is of course a much stronger means to get the operation permit suspended."

Another Swedish interviewee from the industry spontaneously reflected on the general attitudes toward nuclear power by the society at large, and how these may affect the way things are done at the industry:

> "If you look in the mirror you can see that nuclear power has been much questioned. Those who work with nuclear power believe in nuclear power - that goes with a lot of them. They are in any way much determined in their conception. They supervise the technology, and have, I believe, a rather pervasive point of view that this is sound technology, a good way of producing electricity and so on. And that is not a drawback but there is, of course, another side. Nuclear power has been questioned under such a long time, in so many aspects in so many ways so that if you in many ways say yes to nuclear power and defend yourself against an outer enemy. Those who are against nuclear power In my opinion, this might lead to a situation where one is closing the eyes regarding those deficiencies that the technology really does have and that one, as a group – contractors, operators, and authorities - deals with questions/issues that you given another climate probably would deal with in a totally different way."

The authorities emphasized the significance of the media in shaping the nuclear branch safety culture more than the representatives of the power companies. The authorities in Finland also thought that media's effect on the branch was getting stronger and stronger. Some of them thought that the power companies should act more openly towards the media and the public. One of the interviewees from STUK described it like this:

> "A: It [the media] has affected us of course, from the very beginning. It is clear that we have to be very transparent and traceable in our work. And our doings, decisions; those procedures have to be easily arguable from the point of view of safety. But this interest that the media has, it has sort of strengthened this conception even more, in our part. And I think it has been merely good that they have had this interest and it has encouraged our way of working to become more open and more traceable and more transparent and maybe also more active towards the public. The situation has, for a long time, been such that the interest hasn't been too great and… The activities have just been going between

> this smaller group. But now, when there is this interest, you have to think about your actions in a slightly different manner, so that some very simple things like writing a decision, that they have to be written in a way that some others besides the power company that the decision is addressed to, can work it out, so that you can show what has been done there. And it is merely a good thing that…
> Q: Yes, many of the STUK's documents are public any way, most of them?
> A: Yes, in principle everything, but of course it can be considered case-spesifically whether they are or not. And in this aspect I am expecting that the power companies have to become more active towards the public. And the fact that we are more active and more open and bring these things more into the open leads to that. In the end I would like to see it as a goal that the power companies would have to take more responsibility that belongs to them, from their actions and from their openness and activity to come out if something happens. As it is, I think things are going in a good direction."

Also another representative from STUK mentioned that communication to the public is a topic of discussion between the regulator and the power companies – how to communicate events to the public.

Besides the above-mentioned information transfer institutions, the significance of **personal contacts** and informal connections in transferring the culture also came up in the interviews. There are many individuals that have worked in other plants or know personally someone working in a foreign plant. For example in a case of an event/incident, these personal relationships are seen as an important source of information and a way to learn. Many consider them better than the official ways of exchanging event information in order to learn. Personal contacts to similar types of power plants around the world were considered important for learning especially about new phenomena and fault mechanisms. These contacts allow a quicker way of getting information than the official channels, and they used to make sure that one gets the information that one considers important.

6.3 Development of the Nordic nuclear safety field

The history of the nuclear field was briefly tackled in Section 3 of this report. From the interviews it was evident that a lot of development has happened over the years at the Nordic nuclear community. Most interviewees considered the branch as having a positive and even exciting start lasting through the 60s and the 70s, with a clear decline in the 80s and 90s, and finally with signs of a hope of a new renaissance showing up in the 21st century. Many interviewees pointed out that the fact that no new nuclear power plants have been constructed and taken into operation since the 80s has had a negative influence on the field. This has manifested in terms of people not wanting to get into the nuclear field as well as in general stagnation of competence. One interviewee commented the prospects of future as it looked at the time of the interview:

> "In the recent years there have been signs of a different kind of development and maybe, who knows, there is some kind of a new renaissance, and new enthusiasm also. It is visible in training and research and development this, if there is a vision for future, that attracts other activity around it. And it is, if one looks some five to ten years back, this field was withering away, only the waste was to be left behind and that's what we are dealing with in the future."

The main events that according to the interviewees had shaped the nuclear field were all negative; the accidents at Three Mile Island and Chernobyl were the most significant of these. A representative from the Finnish regulator described the influence of various international and Nordic events on the Nordic nuclear safety culture:

> "TMI 2, the accident at Harrisburg, was a significant event in Finland. And it was perhaps even more significant in Sweden. In both countries severe accidents were seriously considered after that. In Sweden they made significant policy definitions on what they have to do at their own plants. One can say that Finland and Sweden were really forerunner countries. And quite independent of each other, of course there were a lot of discussions, but it cannot be claimed that Swedes copied what we did, rather they proceeded at least in phase with us, with their FILTRA and other concepts. These filtered containment venting systems were built. The event was taken very seriously, and a lot of good development

> work was done. Surely many other countries reacted too, but I do not know any other than Finland and Sweden that so concretely started to develop their plants. Well then there was in 1992 the problem with the clogging of the sumps at Barsebäck. It was internationally a very significant event. They have at the reactor two types of safety valves, ones that blow directly into the condensation pool, and others, at least at that time being, were so called direct blow valves that blowed into the upper drywell of the containment. That kind of valve opened and the blow hit some pipe and broke a lot of thermal insulation material loose from it. This material badly clogged the suction strainers of the emergency cooling system. Well they eventually survived that, there was no catastrophe, but it was a lesson for the whole world. Even though all did not want admit it for a while. After that event there has been huge research on the behavior of the suction strainers when they have debris in them. The sumps at Loviisa were replaced a year or two after the event. Some changes were made at TVO too. And some other countries started activity making changes at their plants, but then there were also those coutries that only studied the issue but did not really improve the plants in any way. One could say it took 10, 20 years before we were in the situation that all the plants [in the world] had been fixed. There was a lot of international cooperation involved, meetings, and it developed into an almost scientific discipline of its own, sumppology. It was a big issue. And the Swedes brought it very actively into international awareness, this event and what they had done afterwards. And we also reacted swiftly and strongly. The next big Swedish event was the Forsmark electrical disturbance in 2007 [refers to the event in 2006]. And in that case too one can say that the Swedes handled it very well internationally. They brough it well into international awareness, arranged a big international seminar on the topic during the following spring, and several work groups have been established based on the seminar that still conduct further examinations on the topic. In both of these cases they [the regulator] contacted us and we had close cooperation with them when they were making decisions."

Another interviewee remembered the discussions that followed the Three Mile Island accident on the suitability of nuclear power for private ownership:

> "I am old enough to remember the Three Mile Island accident and that brought some original discussions on the … private and state ownership, then it was discussed, whether nuclear power is suitable for private ownership or not, and there was a larger consequence that it was wanted that the Finnish state has a large enough part-ownership, as it now has. So the accident affected thinking quite much back then."

Some interviewers pointed out that the standards and requirements have changed during the years, toward stricter and stricter requirements. On the other hand, some informants argued that the power upgrades have been possible partly because the original design basis of the safety critical equipment had been so conservative.

It was pointed out that the construction work of the nuclear units in the 70s was very different in terms of safety attitudes and competence requirements than e.g. the construction of OL3. The planning and construction of new nuclear units in Finland has created pressures for development at STUK. The interviewees noted that the regulations of STUK are undergoing a major revision and the inspection activities of STUK will in the future probably decrease. The representatives of STUK were of the opinion that the most significant components in terms of nuclear safety will be inspected by STUK also in the future. That means that STUK is not abandoning its role as a regulator and a testing institution, but rather rearranging its priorities.

A Swedish representative described the development of the Nordic nuclear field as progressing through three stages:

> "The first stage was the under-staffed authorities, and in that situation the constructors/suppliers, and the operators took, in a responsible way, on the task to despite that situation construct and operate the nuclear power plants in a very safe manner. There were, anyhow, a tradition within the Swedish authority system which led to that one didn't go all wrong when introducing this technique. It was characteristic and also combined with certain over-conservatism towards the safe side. When one felt uncertain one acted toward strong/safe, and this is something we have been gained upon during a long time in the Swedish system. In the next phase, the power companies wanted to

> become independent of the contractor/supplier and the work with gaining all necessary information, building up their own resources and relations to other than the main contractor/supplier in order to be able to run the plants. And they actually succeeded quite well at this, party because the main contractor/supplier had a rather open attitude regarding letting go of the information. So, one wanted to be independent – one considered that to be useful. What they at that time didn't realize was the need for big scale modernization. It is possible that they realized it, but that they believed that they would be able to build up their own competence. But there I believe they were wrong, and we can see that now - there was a lot of knowledge that disappeared, and it also disappeared from the main contractor/supplier. So, the consequence of this was that one lost competence and knowledge which should have been better preserved. The third phase is that the authorities has got a grip of themselves, so to say, and want to steer up, the regulations, and I would say that they have done that in a very good way – they should be complemented. And as I interpret it, this was pretty much because of the people who were at SKI at that time."

It seems that the basic technology and the first years of operation (and maybe also the construction phase) have formed the backbone for the organizing and management of the given plant. These principles have shaped the safety culture of the plant. They have changed slowly by e.g. regulatory concerns and emphases, incidents at one's own or some other plant, and changes in personnel, especially at the management level. For example, an interviewee from the Swedish industry explained the differences that have formed in the organizing and management of the Swedish plants from an historical perspective:

> "Forsmark was very focused on production. Forsmark had economy as a leading star and productivity, and during the first years they were immensely successful. They managed to prove to themselves and others that it was a good concept. Ringhals I and II had a lot of difficulties in the first years. They had 50 scrams the first years. There wasn't a chance to reduce the departments of operations. Then we found out, during the reorganizations, that it was a damned strength for operation readiness verification, maintaining written procedures and so on. Then, Ringhals has two technologies, BWR and PWR. So it has been that sort of changes as well."

The development of the Nordic view on safety has progressed in parallel to the nuclear field in general, with first the technical focus enlarging into an emphasis on human factors and finally organizational issues. Many considered this change a rather profound change in the focus of attention.

6.4 Current challenges in the Nordic nuclear field

Co-operation between regulators

SKI (now SSM) and STUK have always had quite tight co-operation and according to the interviews it has been strengthened during the recent years. This is how a representative of STUK described the signs of tightening co-operation between SSM and STUK:

> "A: Then at the Nordic level the thing [learning from incidents] goes mostly so that there are shared plants, similar plants and a common interest to keep them in good condition, so that's how it normally goes. And we also have a certain form of co-operation with SKI. We have these regular meetings with its operational safety group from time to time and we exchange thoughts and experiences, so it is in my opinion an awfully good forum, information is spread then and we get, we also strive for somehow defining common ways to react to things. At least at the moment it has, in my opinion, proved to be a rather useful system. Then we of course have traditionally had information exchange on this process and automation and electricity side, with the corresponding people in Sweden, between SKI's head office and there in the design level. And of course we are sort of support organizations for each other.
>
> Q: These regular meetings, are they a new procedure or has it been for a long time…?
>
> A: It has evolved slowly here from, let's say from a small beginning, then it has been perceived to be quite a useful thing. Now we have also in the upper level these, in fact we had the very first meeting a few months ago, that was perceived as terribly important, that we have these shared meetings, where we can sort of change opinions on these big issues and try to find even shared ways to deal with them. Then of course, what the Swedes emphasized there is that, now that they are apparently starting some kind of reassessment

> and different plant's re… There are, you know, a few plants that indeed are not worth keeping in service for many more years, so modernizing them will very soon become topical for them. So then of course, when there are actual projects that are starting, then our co-operation will surely take new forms. It's not worthwhile to do the same things twice. When we know how it has been done and how they would be better off, then we are better off telling it to them [laughing]."

Another informant from STUK mentioned that SSM is not technically as strong as STUK, and as such they seek help from STUK concerning some technical issues. An example of concrete help was the Forsmark 2006 incident when STUK borrowed an electrical expert to SSM since at that time they did not have experts in that field. Some interviewees considered the development of STUK's regulatory style as being too detailed and control-oriented. For example, according to an interviewee from a Finnish power company:

> "This Finnish regulations has gone on a different trajectory compared to elsewhere in the world. We have difficulties in building such a plant in Finland that would satisfy the Finnish regulator, since that kind of a plant would not sell anywhere else. It is too expensive for others. … The regulator has taken for itself the role of a testing institution [in the building of the new plant], for what they do not have the competence or the resources. … They have been able to carry it out in some modernization project here. But now suddenly they have the entire plant and all the equipment have to be licensed at the same time, inspected, and all the tricks carried out, that leads to the shortage of resources."

Co-operation between the Nordic power companies

More efficient co-operation between the Nordic plants was perceived important by the interviewees in order to further develop the nuclear safety of the plants. However, some of the interviewees also pointed out that working together as a common Nordic front is not self-evident. The issue seems rather sensitive for many reasons, mainly because the companies are competitors in the electricity market. This sensitivity might partly explain the general scepticism expressed towards the whole idea of shared nuclear branch culture. One representative of a Swedish power company answered to the question about shared branch culture by an historical account:

> "There has been a shared branch culture. But I believe it is fast on its way to disappear. There was something called - "the Swedish model" – which was Nordic; Sweden and Finland. And the Swedish model was characterized by a rather intimate collaboration between the three parties; Contractors/suppliers, Authorities, and operators/licensees. It was effective - at least when it existed. We would not have managed to take the nuclear power plants into operation; these are small countries, Sweden and Finland, if we wouldn't have had this interaction. That culture has now been party replaced with a formalistic attitude that sometimes is almost confrontational between all these three parties. Not only between operators and authorities, but also between buyers and sellers. And between sellers/suppliers and the authorities – that contact doesn't exist today – and that is a shortcoming."

One of the Swedish power company representatives pointed out that it was a right moment in history for asking questions about a shared Nordic safety culture. He – as well as a few other interviewees – referred to the HUSC-network (Human Performance and Safety Culture) that had been working towards strengthening Nordic co-operation in the area of nuclear safety culture for a couple of years.

> "A: I think that the questions are posed at the right moment of time. We have worked quite a lot with these questions and we are certainly not finished and we need some kind of collective culture, it is just a question of, and talking together between plants, on which level. I'm maybe not so enamoured when they talk about, or use, consultants for training our personnel in, or our suppliers, in safety, I would prefer that we'd do it ourselves, but then we might need some help. Whereas I'd like to see that we present training material and things like that in a shared alignment. What will come out of the HUSC-work, that I don't know, for it is [names a person] who is involved in it, now it has been a bit messy. The person who had it at our organization has quit. And then it hasn't been easy at all to get the work going on again. As usual, they perhaps try to pull it to somewhat different directions. It is a bit hard to get representatives, for us also.

Q: And it concerns, and to get continuity here, I think, so that you don't change the representatives too often.
A: No, because I think that this here is very sensitive, partly because historically it hasn't been so easy to work together in these kinds of forums. So it is not like something that is given, it is a lot of work to get there. This is one thing anyway. And the job is not so much appreciated. So the questions are posed at a right moment of time, that's what I think.
Q: I would have gotten other kinds of answers four years ago.
A: Yes, I wouldn't have understood the questions."

One representative of STUK expressed same type of hopes and concerns with relation to Nordic co-operation concerning the exchange of operating experience:

"We haven't succeeded in these… We have events that recur in Finland that have already happened in Sweden and what has happened in Finland recurs in Sweden. So it is not, we haven't succeeded in this in all respects. So this, I don't know what the situation is in Finland with the Olkiluoto people, but the Forsmark electricity disturbance in 2006, TVO had already done changes to prevent that kind of electricity disturbance that happened in Forsmark, so in Olkiluoto it wouldn't have been that significant. Well, the information hadn't been successfully communicated to Forsmark, that it would be worthwhile to do it like this so that you would maybe avoid disturbances. And this of course isn't the only one. But of course there are areas where there has happened a lot. The insulator problem was one case where information was communicated. And of course the Forsmark electricity disturbance also led to a thorough examination of these electricity system plans in Finland. It has become better now, in my opinion, especially between the plants and authorities, this communication of information about these events so that last year's fractures in control rods that happened in Forsmark and Oskarshamn, information about them was communicated very fast. … But I would say that on the power company side there is especially a need to strengthen this. But, they are bit of competitors, or not maybe even just a bit… So how much does that prevent them from communicating this information?"

Organizing of research and assuring competence in the nuclear field

The historical differences have also affected the current organizing of nuclear related research at Finland and Sweden. This is how an interviewee from STUK described the differences in the organization of research activities:

"A: Well, this organizing of research activities is of course one big issue [that separates Finland and Sweden]. There were these research reactors at Studsvik, and there was some kind of research activity going on around them, but they are also run down. And at one point they were in a pretty bad shape, these research activities in Sweden. There were lots of these small consulting firms that got financing from the authority for doing some small simple things. But they of course became aware of the problem and started to develop this nuclear technological research also at KTH and they have advanced some what in that, not like VTT of course, but there is still something, something of their own at the moment.
Q: What do you think, why are these research activities organized differently? Is it partly the same question that there has been this domestic plant supplier that has developed and maintained the know-how in Sweden?
A: It might be that it has had an effect on this, that they haven't seen a great need for this. And on the other hand, maybe in the authority side, they haven't seen a great need for a sort of technical support of their own, because they haven't wanted to go so far on the other hand, into details. So yes, it has very much been because there was ASEA Atom that delivered the plans and analyses and that was all that was needed. For one reason or another, they [the power companies] haven't felt a need to create a readiness to independently analyse different things. This is what they don't have. Yes, it probably has something to do with this historical background and here again the situation was quite different from the very beginning. The reason for why we have been so smart here and have come up with this centralized, on the other hand centralized and then again also decentralized way of handling these research issues, I can't really say, because it has happened so early."

The challenges of assuring competence were raised especially in Sweden, but also in Finland Connected to the institutional arrangements at the nuclear community a Finnish representative contemplated the competence challenges:

> "Actually what I see as a problem for all these organizations at the moment is that we all eat from the same load. And if the organizations are all growing, then at the moment, there aren't plenty of these experts around, so we sort of take employees away from each other. Then of course VTT is always this sort of lowermost organization, so that when these new experts are grown there, which I think is also one important task for VTT, to raise new experts, then the continuity of the research is always a bit shaky. Sometimes there is, sometimes there is not, and then… Of course from our point of view it is not a very nice thing. We would hope that it would be uniform quality all the time, the quality of the research. But it is of course terribly hard to organize in this kind of system, you can't tie anyone down to the turf, so to speak."

Some people also discussed VTT's funding and financial base and contemplated how committed VTT is to maintain know-how in the nuclear domain. For most interviewees the research issues were not in focus however.

Understanding the significance of one's work and the nuclear hazards

Overall, many informants considered that the recent incidents have emphasized the need for deeper and wider understanding of the various accident mechanisms of the power plants. A Finnish interviewee was asked whether the incidents indicate some kind of a latent weakness in the Nordic safety culture:

> "No, I would not go that far in my conclusions. Of course, there is this Forsmark incident [in 2006], TVO's incident last summer [refers to the "flywheel incident" described in Section 3.5] and then this Swedish incident two weeks after that, that all are connected to the electricity side, so there is something to think about there, I mean like what is there in the background. Is there something specific, something Nordic, like is there something specific that is connected to the designing in the old ASEA Atom or does it have something to do with the fact that they have been trying hard to raise power capacity in the Nordic plants? Because in these incidents that happened last summer, these flywheel generators[6] of the main circulation pumps, had a significant role. And they were needed there because the power capacity was raised. Yes, there is reason to think about these things and their background. At least you need to think carefully if someone still tries to raise power capacity, so that then all things would be really profoundly looked through, what they might mean."

The last comment is also related to issues of life-cycle management and the additional challenges that ageing plants can bring both to the power companies as well as the regulators. Furthermore, operating experience was considered an area that requires more focus and improvements as well as consideration of risks from various external events.

A representative from STUK contemplated whether there are areas where the understanding of hazards or risks is deficient at the power plants:

> "Very comprehensive risk analyses are done for the plants … but somehow the plants are still able to surprise us, for example what happened at TVO last summer [2008], the electrical disturbance [where the flywheel generators failed], that opened our eyes in a new way, to think about electrical disturbances and their significance. … Of course everyone understands that the safety of these types of plants depends on electricity. But these kinds of events make the fact concrete. That it can really be vulnerable, the power supply. There can be these external, events originating from outside the plant, that have an effect on the inside. … There have been some weather phenomena that have made us think a bit differently. Weather anomalies, in the recent years we have contemplated, especially concerning Loviisa, these oil accidents at the Baltic sea. Common to these events is that the plants are not so isolated from the outer world. Yes, maybe there is a bit of a new emphasis on things. Surely they consider these issues at the plants also, but how deep it has gotten through to the personnel, probably not very deep. It does not mean that they would be very vulnerable in this regard, but maybe there is a slight change in our way of thinking.

[6] Flywheel generators act as safety systems in case of failure in electricity supply to the pumps. The mass inertia stored in the flywheels is transformed into electricity by the generator and used as a direct power supply for the pumps. In strict technical terms the systems installed at the Olkiluoto 1 and 2 reactor units are not flywheels, but rather rotating motor-generators acting as flywheels.

> Q: So you consider that the plants master the phenomena connected to the core process and the fuel well?
> A: Well they do have learned it quite well during the last 30 years. And these operating plants in Finland have been improved all the time based on risk analyses. Primarily the internal activity of the plants. ... In a way it goes naturally that first you improve the most obvious and easily fixable things and then you slowly move toward the more difficult things. So what comes next. All the time this, human and organizational performance, the uncertainties in that, TVO had quite a lot of incidents last year and that's why we asked them to reflect on their activity, especially their decision making ... and they made this, they called it safety culture review. ... In a way behind all this there are the risks associated with human and organizational activity. That one emphasizes wrong issues in decision making. Thus, we have two new trends, external events and human and organizational factors. Because the internal [technical] processes are quite well understood already."

Quite a few interviewees commented the challenges associated with contractors at the nuclear power plants. A representative from the Swedish industry described the challenges as follows:

> "For our own employees I believe we have a good package, and we let the employees take their time to come into the company. They can take on more and more responsibility successively and so on. But a contractor that enters the company takes on a few short courses with some simplified test of knowledge. If this contractors works mainly in non nuclear industries, we will not be able to influence that person very much, neither regarding knowledge nor culture. What we sort of "thrive" upon in this case is that the contractors that comes here for the first or even the second time have an enormous respect for nuclear power as such. But those contractors that are here for lets say the 75th time during a 15 year period, they lose that respect at the same time as they bring with them cultural values from, lets say the forest industry… And in this case I believe that we will not reach an adequate level of insight. And then there is an another aspect in this, which might be a bit Swedish, and that is, as Swedes, we like to think ourselves, to have our own opinion about what is going on… and I often notice that people sometimes focus on the wrong issues, since they don't have a correct overview of the process. I ran into a situation last year when everything under the sun were stirred up because of a minor problem. This led to that other, more important issues maybe could not get the attention it deserved. So it is probably just to make a point that a deep knowledge regarding the overall process is not possible to develop for all employees – it's just not realistic. That's why you are forced to, I think I have learned that when encounter a sort of "stupid issue", you just have to clench one's teeth. You can't put it aside, if it is a principally correct behaviour, but which has just in this case led to the wrong direction, then just live with it."

Next we look more closely at the role of the contractors in the Nordic nuclear industry.

7. Contractors' role in the Nordic nuclear industry

7.1 Contractors in the Nordic nuclear field

In the period just after the nuclear power plants in Sweden and Finland were commissioned, there were a few fairly large contractors involved at the nuclear industry. For various reason these contractors became less important with regard to the maintenance and operation of the plants for quite a long time. The importance of contractors has, however, increased during the last years, primarily due to new build and modernization projects. As of today, there have been problems in reaching the capacity factors and project goals in many modernizations – problems which have been attributed to inadequate contractor management. The decreased capacity factors are not necessarily connected to decrease in safety culture, i.e. there could be situations in which a stop of production is a good sign of safety culture. One obvious example could be when a situation has arisen which means that the safety level due for some reasons has dropped close to what is acceptable. But, to our mind this is not the case regarding the availability problems related to new build and modernization. These problems in managing contractors, sometimes concerning among other things design and construction issues, could according to our minds sometimes be quite clearly connected to safety culture issues (see also STUK 2006). The interviewees were of course often well aware of the importance of the contractors regarding nuclear safety issues, but as will be evident below, the opinion about how the safety culture issues should be addressed varies between the interviewees.

Overall the interviewees discussed issues related to contractors mainly when they were specifically asked about them, with two major exceptions. First, contractors, and especially AB Atomenergi (later merged with ASEA to become part of ASEA ATOM) as a plant supplier, were mentioned by many when discussing the shared history of the Nordic nuclear field. It was pointed out that the fading out of ASEA ATOM resulted in a huge amount of one-man consulting companies in Sweden. Many of the consultants were experienced people, but already close to retirement age. Little by little they stopped working and this led to a lack of technical support for the regulator and the industry. At the same time the licence holders' were seeking to become more independent from the plant supplier by developing their in-house competence. A Swedish interviewee described the situation as follows:

> "This is one of the bits we have lost in Sweden. The safety was once driven by ASEA Atom. When there was a continuous development of new plants then one learned what the previous mistakes were. And this was also driven by that one did see new market possibilities. But when the development stopped and they became very dependent on the big customers' they also became very "customer oriented" with respect to reactor safety issues. Then something was lost, and therefore we now sit in this vacuum".

Second, when asked about the common players of the Nordic nuclear branch culture, some of the interviewees raised contractors as one of the key players. A few pointed out that in Finland the number of subcontractors - especially in industrial manufacturing - is growing because of new construction projects. Some perceived that contractors might have a role in the experience feedback within the nuclear industry, see next section.

There were different views on the basic mechanism or premise that the power plant should utilise to guarantee the safety and quality of the work done by contractors (see also Figure 6). For example, there was a difference between people relying on trust and people relying on control and supervision. An interviewee in a Finnish power plant discussed the issue in the following manner:

> A: Well, subcontractors, when they come for example to work during outages or any other time, they have a right to move at the plant and work according to our instructions and work permits. Of course in practice under our supervision, but how they work and do they follow the instructions, that counts. And the attitudes … during the outage, we have

> systems on-line at the same room where they work, it is imperative that they follow the instructions. They work in the … almost same manner as the regular staff.
> Q: So do you mean that they also then have the same responsibility for nuclear safety as regular staff?
> A: Well … I do not know if it is exactly the same, but they do have the same instructions. Of course they have to work under our supervision, but one has to understand that when we for example have a foreman who has many people under his supervision, the starting point has to be that the people working at the plant follow the instructions. Everyone has the responsibility to follow the instructions. We have to start from the fact that we trust people.

Another type of opinion was given by this interviewee about the responsibilities of the contractors as well as the main mechanism of assuring safety:

> In fact, I don't think contractors have any other responsibilities than to follow the specs they have gotten, so these requirement specifications and quality assurance specifications, it is connected to this quality assurance business. And in fact the contractor or this main designer, main organization has to make sure that the contractor has the right preconditions for manufacturing the product. In fact our job is just to see that this is really how it is, that the right requirements, it is of course all about this controlling of requirements and it is a part of this requirement control procedure that this main contractor or main actor uses. So they have taken contractors into consideration there, so that they'll be having the right input so that they can get the right output out from there. …it is mostly a job of the main contractor, main actor to make sure that things go as designed. … The key word is always this, that the control of the requirements is done in such a strong way that everyone involved understands the machine, that they are unambiguous all these things and they are transferred to the head designer as such, so that there is no room for interpretation and they are easy to understand, so that this subcontractor… When it is an organization that doesn't necessarily even work for the nuclear industry, it has to get the specs, in order to produce the product.

Some of the specific challenges and worries brought in the interviews and the email survey concerning contracting were related to the following issues:

- The challenge of assuring that contractors have enough nuclear specific knowledge. This requires also more specialized training and information exchange than is currently given. Information should be better tailored to the needs of the contractor's work.
- The balance of how much the power company should train and educate the contractors versus how much the company should rely on enforcing strict rules and instructions for the contractors.
- The short time frame for the contractor's visit at the plant site (e.g. during the outages) makes it difficult to establish a dialogue and provide the necessary information
- The effectiveness of training. How effective the current training programs are in getting the necessary information to the contractors? How could they be improved?
- Cultural and language difficulties with foreign contractors
- Mismatch between supplier's and the plant's interests
- The effect of competition on information exchange and experience feedback.
- Need for different approaches for new and old contractors.
- Distribution of responsibility in long supply chains
- Lack of competence on both customer's and contractor's side
- Balance with regard to cooperation between customer and contractor versus the need for a clear cut between customer and contractor due to responsibility issues

It was also pointed out that it is important to give the contractors good prerequisites to adhere to rules and instructions. These prerequisites include time, training and supervision of work. The power company must itself act as a good example.

7.2 Major roles for contractors

The term Contractor was mainly used in the following three ways:

1. Organizations that manufacture and/or deliver hardware products to the plants (machine parts and systems, maintenance hardware etc)
2. Organizations that manufacture and/or deliver software products (computer programs, method descriptions etc).
3. Organisation that deliver services such as engineering resources, test and qualification, analysis, maintenance, installation etc.

The different types of contractors are not mutually exclusive - a manufacturer of hardware may deliver software and consultant services for installation, maintenance, analysis etc. Thus, we need a more refined framework for identifying the variety of roles that the contractors in the Nordic nuclear industry have. Next we will look at the contractor roles we have identified during the course of this study.

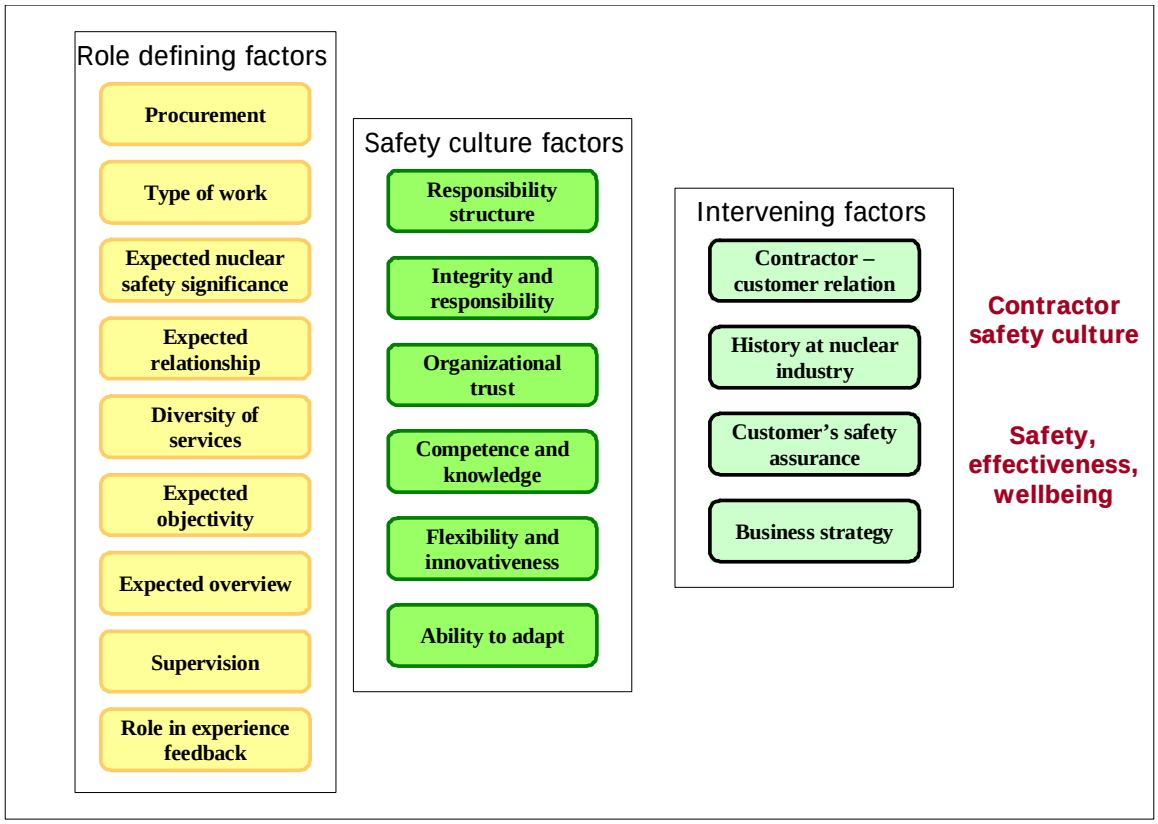

Figure 6. Illustration of the key role defining factors, safety culture defining factors and intervening factors related to the contractor safety culture in the Nordic nuclear industry. Intervening factors were considered in Section 7.1 and the safety culture factors will be described in Section 7.3.

The **procurement** practices and procurement strategy relates to the way the power company runs their business. This refers to all the practices of bidding and making contracts. The procurement issues are probably one of the most important factors when it comes to safety in the new build and modernization projects. The reasons for this opinion are that the procurement sets the stage regarding for example the cooperation and dividing of responsibilities between the customer and the contractor as well as the design of the processes for quality assurance. The contract also gives a possibility to evaluate if the resources that the contractor formally intend to put in the project (i.e. the price tag) is reasonable given the amount of work that are expected to be done. From safety point of view, the unwanted situation would be that the planned resources are not in balance with

the required resources, a situation which possibly would encourage the contractors to cut some corners.

The second factor deals with the **type of work** that has been contracted. A basic differentiation can be made between products and services. However, contractors increasingly offer both services and products as a combined service business. The work also varies by its duration. For some tasks the contractor comes for the outage, whereas some tasks might continue for months (or years as is the case with plant construction). Location of work can be considered a sub role of the type of work, and can be considered as a description from either a process or physical point of view. The location as understood from a process point of view can vary from the sharp end (close to reactor or the production technology in general) to blunt end (design work, office work in general). Location as understood from a geographical point of view describes were the work is done, on site or far away from the site. Given these two characteristics, one can thus describe different kinds of work. As an example, when we are dealing with manufacturing of safety critical components, the work is very sharp end in type, but can happen far from the plant site. Connected to location is the issue of the degree of occupational hazards and radiation that is present at the work location. Occupational safety issues and radiation can have an effect on the way of carrying out the work and should also be included in considering the type of work.

Expected nuclear safety significance separates contractors that work with tasks having low nuclear safety significance from the more safety-critical contractor work. The nuclear safety significance is defined as "expected" to remind that the issue is about what type of tasks are allocated to the contractor and not what the contractor does outside of the intended role. It also reminds that not all safety impacts of the work are necessarily understood in advance, even by the plant personnel. For example, the safety significance of contractor work can also be indirect, e.g. a consultancy or research job that has an effect on a long time frame; with a non-linear causal influence to the nuclear safety. Examples of direct safety impact would be tasks related to fuel handling, critical safety systems or manufacturing of the pressure vessel.

The third main role concerns the **expected relationship** with the contractor. In some cases the power company only needs the contractor for a specific task without any long term plans for cooperation. Long term partnership contracts are becoming one of the strategic options for, e.g. outsourcing certain functions to a company that will provide the service for the power company. **Diversity of services** refers to the contractor's field or fields of specialty. That means, does the contractor work only in the nuclear area, in other safety critical domains, or in any domain (or, for example, all kinds of manufacturing irrespective of the industrial domain). **Expected objectivity** refers to the type of the contractors work from the perspective of alignment with power company's interests and implicit goals. The contractor can be signed in to execute specified order acting under the interests of the power company. Another possibility is that the contractor is from the start supposed to conduct an independent (safety) review irrespective of the client organizations interests or implicit goals. Both roles have their challenges in terms of client-contractor collaboration as well as requirements for the contractor's safety culture. **Expected overview** means the extent to which the contractor is expected to have knowledge of the plant situation, plant configuration and the overall context of where the contract work is supposed to take place. This can vary from the contractors executing their own task without knowing the context or having a good situation awareness of the other relevant tasks currently in progress at the plant as well as the overall condition of systems, structures and equipment. **Supervision** refers to the degree that the plant supervises the work versus the contractor supervising its own work. Finally, **role in experience feedback** refers to the degree that the contractor is involved in learning from experience at the plant. This can also refer to contractor's role in the Nordic nuclear safety culture overall. As

mentioned in Section 6.2 about information transfer institutions, contractors could potentially act as information carriers between the power plants. This potential has not been fully realised by the nuclear industry, or the contractors.

7.3 Requirements for a good contractor safety culture

Most of the interviewees agreed that all contractors have to understand the significance of their work including the possible negative consequences for plant safety if something goes wrong. This applies to all kinds of works done at site or somewhere else. This simple and understandable basic principle is made complex by the issues of responsibility for nuclear safety. The interviewees were asked what kind of responsibility the contractors have for nuclear safety:

> ”at the end of the row it is us, that is the NPP organizations that are responsible for this – maintaining the nuclear safety. So in this case the contractors don’t have any responsibility. At the same time, they of course do have some kind of responsibility for the quality in the work they perform, independent of them being contractors of technical issues, components, investigations or whatever might be the case. And, it is easier to control (steer) safety if you deal with contractors that have got a good attitude and good culture regarding these questions (nuclear safety, safety culture), compared to dealing with contractors that doesn’t consider this to be their questions to handle, or doesn’t have any interest in this questions at all. So, hey way I see it, from a very strict perspective, I believe that they do not have any responsibility for anything else than the quality in what they deliver, that they deliver what has been agreed upon, that is according to specifications. That, I would say, would be the strict way of looking at this.

Figure 6 also depicts some of the relevant contextual factors that are salient for contractor safety culture. Responsibility structure refers to the division of labour and accountabilities inside the contractor organisation but also between the contractor and the client. An interviewee from the Finnish regulator discussed the issue of the role and responsibilities of contractors:

> The subcontractor of course has a responsibility to do the work in a competent manner, but that’s where it more or less ends. But then the situation is of course different when we think of the subcontractors of the plant supplier. Then there are also many kinds of… The plant supplier’s biggest subcontractor Buick that constructs the buildings, they also of course have significant responsibility for the execution that it is done according to instructions and contracts. But again to our direction, to our direction TVO that supervises Areva who supervises Buick, is responsible. These are very long these chains and how the responsibility shifts. But the subcontractor of course has the responsibility and probably the things the subcontractor should do are written in the contracts but the standards in the contracts should then be right, set in a manner that fulfils all nuclear safety requirements, this instrument… This responsibility, distribution of responsibility, it’s a really difficult question when there are these long supply chains. But this is how it precisely is, the question is: who is responsible to whom. … But there is of course no clear answer and I don’t know if it is the right question to ask if the thing goes according to formalities or how we could make them feel responsible about nuclear safety. Then we are closer to safety culture. Like matter should rather be approached from there than through some formal responsibility definition.

All in all, whatever the formal responsibility structure is, the integrity and sense of responsibility of the contractor has without a doubt a huge influence on how work is carried out in practice. The issue of integrity and sense of responsibility came up in many interviews when the interviewees considered the role and responsibilities of contractors in assuring nuclear safety. For example, the following representative of a Finnish nuclear power plant discussed the issue of what kind of responsibility contractors should have for nuclear safety:

> A: […] yes, their [subcontractors’] role is pretty important but what about their responsibility? I have to think about what it means, if they can really have responsibility for nuclear safety, like in the end the responsibility is with the licence-holder, but… Of course they have responsibility for their own work, that they do it well, but … The role there is really such that the subcontractors have to adopt the… when it is good enough, lets say this safety thinking, that he knows that now we’ll work according to these demands and it requires certain know-how. We have to know how to, we need to take them into consideration in our activities that… It won’t hurt if they use the same know-how than in

> other industries. That might be sort of good, but… I hope that when they come to work here with us, we are able to pass them the information that this is now like, that they can't do things in the same bungling way than they possibly do somewhere else, now without blaming any industry now, but anyway, I think we can say that we like, this industry takes more than many other industries. Even though there are demands in many other industries as well, but this is… You sort of have to know what can happen if something goes wrong in a technical sense as well. It has to like be there in the background. Then you also understand how to work…

The same issue manifests when talking about the role of contractors in fulfilling the requirements set by the licence holder. The following interviewee starts with an attitude that the role and responsibility are simple as the licence holder bear solely the nuclear safety responsibility but realises fast that the issue is in reality more complicated:

> A: It is quite simple, I guess, the role and the responsibility… They have to do the work that is ordered from them according to the requirements that are set. And responsibility for safety is always within the licence-holder. So the licence-holder needs to be sure that the contractor does its work so that the safety level of the plant is maintained. But of course the contractor is… in order to be responsible, one has to know what he is dealing with. …
>
> Q: You said that it is quite simple that the purchaser or the responsibility of the subcontractor is to do the work according to requirements. So how, I mean the definer of requirements here is then this…purchaser. But if the requirements aren't adequate or sufficient concerning nuclear safety, then is it still the responsibility of the subcontractor to do it according to the requirements?
>
> A: That's a good question. In principle it probably is … licence-holder is responsible and sets requirements that wouldn't maybe be… let's say that according to safety requirements. The contractor knows that they could do better and especially so that the safety requirement is fulfilled. Yes, a responsible contractor would of course do it so that they would guide the licence-holder like: "by the way, you don't fulfil this requirement, this has to be changed". An irresponsible contractor would maybe not do this because he would do it cheaper, the solution that fulfils the requirements that the purchaser has set. But the responsibility is within the purchaser and in Finland it is the licence-holder. And they have to know what requirements have to be fulfilled when it comes to safety. They can't land it on the contractors …

Competence and knowledge are essential in any good safety culture, but in terms of contracting certain special demands arise from the fact that there are many companies involved and the knowledge requirements – or deficiencies – are not always easy to recognise beforehand. An interviewee described the challenges of a modernization project from the point of view of competence management:

> In the [acronym] project, the power upgrade project, quite a lot of deficiencies surfaced afterwards in both turbine and reactor side quality assurance, that components had to be sent back to repair and modify at the site. … I think for the big components that are replaced very seldom, generator, the inside of the reactor, I think it is a sign if these are let come at the process, that components have to be send back afterwards, [it is a sign] that there has not been enough competence [at the power plant] to supervise the process well enough, or give good enough specifications. Maybe all big components that are seldom replaced suffer from the fact that there is not enough experience at one's own organization. And maybe one of reasons is also the long supply chains. These components [at acronym project] for example have been manufactured in many places all over the world. It is clear that it is more challenging to manage the whole the more players there are. But some kind of golden middle road should be found, one cannot demand that the power company has complete deep knowledge of a component that is replaced at an interval of 20-25 years. It's impossible to ever build an organization that knows everything.

A couple of interviewees pointed out that there should be different requirements for contractors that work at site and contractors that manufacture products off-site. For contractors working at site it was perceived important that they follow the rules and procedures laid out by the power company. The requirements that can and should be placed for e.g. component or system suppliers are much more diffuse. Some were of the opinion that the power company cannot require that the supplier adheres to any specific practices or procedures, that only the quality requirements of the final product can be specified. In a related matter, others commented on the insufficiencies of contractor

audits in guaranteeing high quality products. Few comments addressed contractors working with design issues, however.

When the interviews comment on the safety culture with regards to contractors, it seems to us that they most often associate this with contractors performing actual installation/construction work at the plants. But it is quite seldom that the contractors' design departments are mentioned in relation to safety culture discussions. The above observations are also supported by our, albeit limited, experience with some of the Nordic safety culture projects aimed at increasing the contractors' safety culture awareness, since these mainly address areas related to installation and construction issues.

Related to interviews with the customer with relation to the contractors design departments are the issues of trust versus control and supervision mentioned early in section 7.1. It seems that there are some examples of customers starting of with a good portion of trust, a trust which after some time decrease in favour of an increased awareness of the need or control and supervision. Trust as an explanation of nuclear fuel mishaps can be found in relation with the incident at Paks. One of the interesting results of the investigation was that the Hungarian Atomic Agency placed too much trust in the technology and knowledge of the French Framatome company (currently called Areva), and they did not investigate the drawings provided by the company deeply enough to find out the fatal design flaw in the cleaning equipment (Framatome designed, produced, and used the equipment). (IAEA 2003).

8. Conclusions and discussion

The results of this study were twofold. First, the study gave insight into the nature and evaluation of safety culture in the nuclear industry. It illustrated that the concept of nuclear safety is all but clear and there is a wide variety of views on matters that are considered important for nuclear safety. The study however showed rather coherently that people in the Nordic nuclear branch see such psychological states as motivation, mindfulness, sense of control, understanding of hazards and sense of responsibility as important for nuclear safety. However, there were different conceptions on *how* these dimensions of safety culture affect nuclear safety.

Secondly, the study gave insight into the characteristics of Nordic nuclear culture. The differences in safety cultures in Finland and Sweden were uncovered in the study. In addition to the differences, the study pointed out historical reasons for the development of the nuclear safety cultures in Finland and Sweden. It was pointed out that the industry in Sweden has been driven by the strong supplier whereas in Finland the regulator has had a more active role. However, both of the approaches have been changing in the recent years. All in all, the cultural differences inside the Nordic nuclear field stem from many factors: national culture, company / owner culture, regional / province culture, occupational culture (maintenance, operations, engineering), organizational or unit culture. These cultures are partly overlapping and in addition to them the type of the power plant (BWR, PWR) creates certain constraints and requirements for the development of safety culture at the given unit.

Co-operation between Nordic nuclear organizations was viewed as valuable from safety point of view. The interviewees described different initiatives that were going on at the time of the interviews in order to tighten the co-operation. However, co-operation was also found to be challenging. Comparing or integrating ways of working is difficult because of the deep-rooted differences in the working cultures. The issue of Nordic co-operation is also rather sensitive in the sense that the Nordic companies – even though partly co-owned – are competitors in the electricity market.

Although at a general level the safety performance of the Nordic nuclear industry has been good there have been some incidents at the Nordic nuclear power plants. These incidents have shown that there exist deficiencies in understanding of certain technical phenomena as well as deficiencies in management and operation of the power plants. These incidents have raised discussion on the concept of safety culture and consideration on what good safety culture means at the Nordic nuclear power domain (see also Svahn, 2009). In the next two Sections the issues of safety culture and the idea of a shared Nordic nuclear safety culture are discussed further from a theoretical point of view.

8.1 Safety culture

Usually the concept of safety culture is framed as the beliefs, attitudes, values, and behaviours that members of a group share with respect to safety. Thus, safety culture is typically conceptualized as people oriented (beliefs, values, behaviours) rather than context oriented (Rollenhagen, 2010). Safety culture thinking is of course contextual in the sense that the beliefs, values, attitudes and behaviours are assumed to have a contextual direction toward various objects. The beliefs, values, attitudes and behaviours with respect to safety are also often analyzed with reference to e.g. subcultures, wider organizational culture, branches and other contextual matters. However, the focus in safety culture thinking is rarely on how the technological context itself shapes values, beliefs, attitudes and behaviours or how the context affects the suitability of the different beliefs and behaviours in terms of their safety effects. Criticism that safety culture risks to become a catch-all popular concept for human factors and not really something that concerns the context has been heard (Hale, 2000; Guldenmund, 2000; Pidgeon, 1998; Reiman & Oedewald, 2007).

Many theories of organizational culture remain at their root individualistic, conceptualizing culture in terms of individual perceptions and conceptions. The emergent and social nature of culture eludes scientific definition and operationalization. In the concept of "safety" culture an additional confusion is created by the varying focus on either society or organization; culture is used sometimes to refer to societal level phenomena, sometimes to organizational level phenomena and sometimes to phenomena that are postulated to occur at the both levels. Often the level is not made explicit. A third possible level of analysis of culture is that of institutions. Many models of an ideal safety culture seem to imply an institutional focus, but it is seldom made explicit. Still, safety culture in terms of e.g. IAEA's (1991) conceptualization is no more an organizational level than a societal level phenomenon. It transcends both organizations and societies, creating a transnational safety culture institution (in fact similar in nature to IAEA itself).

The question in safety culture research and in the concept of safety culture in general is **how much of system safety does the safety culture of the organization explain, and what is left unexplained**? This question is a matter of definition and it can be argued that the crucial aspect is to acknowledge the limitations of the concepts that one is using. If one is using a narrow (yet perhaps more precise) definition of safety culture as shared attitudes and norms, one must acknowledge that this concept explains only some part of system (nuclear) safety. However, if one enlarges the definition of safety culture into a metaphor for the organization, the concept gets more imprecise but in theory it explains a larger variance of system safety. The challenge then is to operationalize the concept into measurable variables.

Rollenhagen (2010) has pointed out that statements about safety culture often imply a moral stance even though ethics is seldom explicitly tackled in the safety culture models. Furthermore, competence is an issue that has been poorly defined and evaluated in safety culture work. The term competence is associated with formal qualification, knowing, understanding and doing the right thing. The rapid development of technology and organizational models highlight the competence issues as crucial for safety culture. Thirdly, safety culture models seem to have a limited view on the interaction between individual behaviour, group values and organizational structures and processes. Institutionalization of values and beliefs as enduring and taken-for-granted social structures is a key mechanism of safety culture development.

Most theories of safety culture speak about the importance of management commitment to safety but they do not further analyze what this implies in terms of moral attributes. To be committed to safety means to take a stance in moral issues since there are always competing demands facing management. In a choice between production goals and safety a manager may take different positions depending on moral issues, such as: following a rule or policy, following a rational calculation weighting different values against each other, or following a virtue of care and prudence. Another path of reasoning associated with moral issues concerns collective virtues – a concept rather recently discussed in moral theory. Safety culture with its focus on shared attitudes and values has often had a focus on collective virtues but seldom with an explicit focus of what this really implies in terms of the "right attitudes".

One of the main problems is that morality is implicit rather than explicit in many discussions and decisions concerning nuclear safety. In particular, it seems that an implicit moral of collective virtues are often implied. This echoes a previous time when individual operators were seen as guilty for accidents when they in fact acted reasonably within the constraints imposed by the contextual features of the present situation. When safety culture is used as a collective moral virtue, there is often an implicit moral dimension lingering in the background. Statements such as "the organisation

must develop a safety culture" could be understood as members in the organisation having the wrong attitudes and behaviours because they lack moral concern for safety – but are we then not back on the old track of searching for guilt? When talking about culture, guilt is transformed into organizational level. Still the question is one of moral attribution: Under what conditions an organization instead of the individuals in the organization can be labelled as immoral?

8.2 Assuring safety culture among contractors

This study gave implications that on the one hand subcontractors can bring new ideas and improvements to the plants' practices, but on the other hand the assurance of necessary safety attitudes and competence of the subcontracting companies and their employees is considered as a challenge. The requirement to assure safety culture of the subcontractors has been highlighted by IAEA in their recent documents for the design and construction of new plants (IAEA, 2007). Also national nuclear safety regulators have been active in this area in Finland and in Sweden. The challenges in the OL3 construction project have revealed that the current management systems in the nuclear industry do not necessarily provide sufficient means to manage multinational projects (STUK, 2006). Subcontractor management can not rely solely on the contracts, procedures and supervision. There is also a need for the development of a safety mindset and safe working practises among the subcontracting networks as well as for development of tools to evaluate the quality of the current safety mindset. HSE (2009) has emphasized the need for the power companies to act as "intelligent customers" toward contractors. This means that "the management of the facility should know what is required, should fully understand the need for a contractor's services, should specify requirements, should supervise the work and should technically review the output before, during and after implementation". The concept of intelligent customer relates to the attributes of an organisation rather than the capabilities of individual post holders. According to HSE (2009), the key question in terms of nuclear safety is if the licensee can retain adequate and enduring control in practice of the nuclear safety risks of work carried out on its behalf by the contractor? This control is achieved by a combination of licensee's technical competence and understanding of the work, its management arrangements, its relationship with the contractor, and, its assurance of the contractor's own management arrangements.

A confusion of different types of safety is a common challenge in safety management (Reiman & Oedewald, 2008, 2009). Occupational safety issues are often emphasized with contractors. Nuclear safety may not be the main focus of contractors whose primary field of operations has a strong focus on occupational safety (e.g., construction industry). Thus, the contents and meaning of safety may be interpreted differently by the contractors than the power companies. Safety culture can be associated with guaranteeing occupational safety, whereas in the nuclear industry it has traditionally been associated with the control of the risk of external release. Also, most previous subcontractor studies analyse occupational safety issues (see e.g. Choudhry & Fang, 2008; Jaselskis et al., 2008; Larsson et al., 2008; Dingsdag et al., 2008; Mayhew et al., 1997). Some studies have looked at contractualisation on a generic level (Jensen & Rothwell 1998; OECD/NEA 2002; Bier et al. 2001).

Correct design of the components in the power plants is of course vital for nuclear safety. Yet, there are several examples of erroneous design made by constructors related to both new build (for example the initial automation designs of OL3) and various modernization projects in Sweden. One example of challenges with regard to the modernization projects were mentioned in the section 7.3. If the erroneous designs are found in conjunction with the various tests performed before start-up, i.e. operation readiness verification, the consequences will be "only" economical. But if the faulty design is not identified there might be potentially seriously latent "errors" installed. Given the complex environment and sometimes hard to find design faults it is of course important not only to

have good processes, for example like quality assurance, but also to have a supporting safety culture established within the constructors design organization.

Current challenges of the Nordic nuclear industry are of a very special nature. Major modernisations and new power plant projects are carried out at the same time. Subcontractor companies have increased their interest towards the nuclear business but the competence and experience in the field is varying. The power companies have been developing safety culture training and assurance programs, but so far these have been targeted mostly at the sharp-end workers. One big question is the role of safety culture in the contractors design organizations. It seems to us that this is an area which has probably to a large degree been neglected in the safety culture discussions that de facto are taking place between the customer and contractors. It is our strong belief that this is area should be emphasized in future research and development activities around the concept of safety culture (cf. Rollenhagen, 2010).

8.3 Emerging issues

The Nordic nuclear branch culture proved to be an elusive concept. The historical development of nuclear power in Finland and Sweden has had a lot of similarities and there has been tight co-operation yet at the same time differences in political climate have turned the development for a long time on different tracks. Now that nuclear power is again a viable option at both countries, there are other challenges for shared culture. Multinational energy companies as well as standards and best practices created by international nuclear organizations such as IAEA, WANO, NEA or INPO do not have Nordic roots. The globalization is a challenge that has both positive and negative possibilities for nuclear safety.

Even though the interviewees were sceptical of the whole idea of a shared Nordic nuclear branch culture, they seemed to share many common **experiences** with interviewees from other organizations, both foreign and domestic. For example, the interviewees from different organizations had similar kinds of tasks to take care of. They also had similar everyday challenges, like dealing with the subcontractors in a safe way or adhering to rules and procedures in a flexible yet safe manner. The organizations also had many formal and informal forms of co-operation both inside the countries and between countries. It can thus be argued that the Nordic nuclear organizations had a common social structure, even though not every individual in these organizations was directly involved in this structure. Besides the shared experiences, the interviewees also seemed to have many shared **beliefs and interpretations**. For example the interviewees believed there was an essence in the nuclear branch culture that was the same in both countries. According to the interviews this essence centered on the knowledge of and attitude towards radiation and safety. Another similarity that was brought out was the sense of personal responsibility and de-emphasis of strict adherence to instructions prevalent at the Nordic nuclear power plants. Some of the interviewees spoke Finnish and some Swedish. There were nevertheless signs that suggested that they had a shared **language** when it comes to safety related things. This is if you think of a language as a way of speaking about certain things or as a system that steers what can be said out loud and how you can talk about certain things. Also the concepts that were ambiguous for the informants were same in both countries; the definitions of nuclear safety varied as much in Finland as in Sweden and significance and contents of responsibility were given various interpretations in both countries.

The criteria of good nuclear safety presented in Figure 3 are most focused on stability and maintaining the safety level. There are not many criteria that deal with change and innovation. Even the ones that focus on change management do so more from the point of view of avoiding the negative consequences of change than embracing the potential that change can bring. This has

connections to the requirements of a good safety culture. Should the concept of safety culture emphasize more issues such as innovativeness, change and even a certain amount of risk taking? There are no ready made answers to that. Rollenhagen (2010) has compared the differences between so called “innovation cultures” and “safety cultures”. The degree to which the concept of safety culture can be developed to incorporate the need for innovation and change as well as trade-offs between safety and production goals, is an interesting future research question.

The results of this study highlight the fact that nuclear power is not isolated from its environment, society affects the industry and industry has an effect on the society. There are many actors, organizations or institutions that are not necessarily part of the branch, but nevertheless have an important impact on it – possibly even more important than the members of the branch typically realize. One of the most influential outside actors is media. The role of subcontractors was also recognized as more and more important in shaping the nuclear culture (see Section 8.3). In terms of nuclear safety and indicators of nuclear safety it is interesting to note that most of the indicators selected by the interviewees focused primarily on the internal issues at the power plants – except for top management commitment. Of especial interest is the perceived nuclear safety significance of contractors. There have been plenty of challenges in dealing with long supply chains, and when directly asked the interviewees and the email survey respondents considered contractors as having a significant role in the nuclear power industry. However, when evaluating NPP safety no mention of contractor management was made (see Section 4.1). Does this mean that contractors are not considered so significant for nuclear safety after all? Or is the contractor work considered outside the power company’s influence? Or is this an issue that needs a better focus in future; developing indicators and improvement tools for how the power company is managing its contractors in terms of assuring nuclear safety?

9. Utilization of the report and recommendations

The results of this study can be utilized for many purposes. This report can be used to assess and inform stakeholders coming into the nuclear field. This means, for example, using the report or its contents as an introductory text for newcomers into this field. Another way of using the results is to evaluate how well new personnel and contractors know the unique characteristics of the Nordic nuclear field. For nuclear people outside Nordic countries this report can be used to reflect their own practices and attitudes toward nuclear safety against those presented in this study. The following recommendations can be made for the Nordic nuclear industry:

- The role of knowledge and understanding in a good nuclear safety culture has to be emphasized. Safety management activities should aim at increasing understanding of the safety significance of one's work, the inherent hazards of the work as well as the basic concepts concerning one's work and safety. Motivation is linked to understanding; motivation without good understanding makes the work efforts misdirected whereas understanding without adequate work motivation reduces the effort one is willing to put to utilize one's understanding.
- There have been incidents at the Nordic nuclear power plants that have shown deficiencies in understanding of certain technical phenomena as well as deficiencies in management and operation of the power plants. The root causes and the potential common contributing factors for these incidents should be considered in-depth and perhaps some of the past incidents should be re-analysed from a human factors and safety culture perspective.
- The concept of nuclear safety is all but clear. Since the conception people have of nuclear safety directs their attention and improvement efforts, it is recommended that people reflect on their definitions of nuclear safety and openly discuss what kinds of issues are important for maintaining high nuclear safety. The models and views presented in Section 3 of this report can be used as a starting point for that.
- Mindfulness and constant development of one's understanding and work practices is crucial for nuclear safety. One must remain humble in that there can be something that has not yet been recognized and that one's knowledge is not perfect. Nuclear power organizations are recommended to develop ways for maintaining open and critical discussion concerning their ways of working and level of understanding.
- There are certain inherent challenges in the nuclear domain concerning the psychological characteristics of work, such as the locus of work motivation (safety, efficiency, rule compliance), responsibility for one's own work and wider moral responsibility and rule following versus autonomy. These challenges stem from the nature of the work at a nuclear domain and they cannot ever be completely solved. Rather a balance has to be found between different kinds of solutions that all have their positive as well as negative effects.
- The increased use of subcontractors has raised challenges as well as opportunities. Contractors can act as information carriers between the power plants and contribute to experience feedback process. On the other hand, management of contractors is a special function that the power companies need to pay closer attention to. Assuring the competence and integrity of the subcontracting companies is demanding, and it also needs clarifying the knowledge requirements of different types of contractor work. Furthermore, an increase in dialogue between contractors and a power company is needed (the contract formulation, communication practices during the work, follow up routines, experience feedback), as well as clarification of the different safety culture requirements of different contractors.
- The study reminded about the challenges of benchmarking between Finland and Sweden or between any country and culture in fact. There are plenty of things that should be considered before implementing solutions from one Nordic country to the other. This should act as a

reminder that benchmarking, or even evaluation of practices, between national cultures has its challenges even in countries so close as Finland and Sweden. Benchmarking between significantly different cultures, such as United States and Finland or Sweden, is even more problematic.

- At the same time, more effort is needed in learning from operating events at other power plants to avoid similar incidents from recurring. Methods are needed to extract human and organizational lessons that can be generalized from the events and applied at other power plants. Also, methods are needed to assure that technical lessons are shared and utilized.
- Finally, the history of the Nordic nuclear safety branch has shown that decisions made at the various institutes in the field including the political, economic and educational arenas have (unintentional) consequences that might become visible only years (or decades) later. It is very important to maintain a long term focus in all activities at the nuclear field.

To conclude, a good safety culture requires a deep and wide understanding of nuclear safety including the various accident mechanisms of the plant as well as a willingness to continuously develop one's competence and understanding. An effective and resilient (Hollnagel et al., 2006) nuclear safety culture has to foster a constant sense of unease that prevents complacency (Hollnagel & Woods 2006, p. 356; Weick & Sutcliffe, 2007) yet at the same time it has to foster a certain professional pride and a feeling of accomplishment to maintain work motivation and healthy occupational identity. Safety is a dynamic non-event and thus it requires constant and never ending work to achieve. This work is often visible only in terms of absence of accidents yet the quality of the work itself denotes the presence of nuclear safety. This report has described some of the developments – successes and failures – at the Nordic nuclear industry as well as the challenges that lie ahead.

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Appendix A: The interview questions

The questions posed in the interviews were as follows:

Background questions:

- What do you do / what is your position?
- How long have you worked in this position / organization?
- What other positions you have had?

General questions (think about the Nordic nuclear field in general):

- What is nuclear safety? How do you define the concept?
- Is there such a thing as a shared branch culture in the Nordic nuclear field?
- Who are stakeholders of that culture? (*IF "no branch culture"*: who are the main shareholders at the Nordic nuclear field?)
- What is the core task of the regulator?
- Are there other groups that significantly influence the branch that are not actually part of the branch?
- From a historical perspective, how has the Nordic nuclear branch formed? What are the most significant situations or events that have shaped the culture?
- What kinds of issues concerning nuclear safety are negotiated from time to time in the community? Who typically gets the upper hand?
- In what kinds of nuclear safety related issues do the subcontractors have a special role or some responsibilities?
- When you think of the way the plants are managed and operated are there more differences between national plants or between Finnish and Swedish plants? (For example safety management principles and operating philosophy. In your view, do these differences affect safety? How?)

Safety culture dimensions (think about the nuclear power companies):

- If you had the task to assess the strength of the nuclear safety at a specific nuclear plant, what things would you consider?
- How can personnel affect nuclear safety positively? what characteristics / abilities are required from them in order to achieve this?
- How does organizational structure affect safety?
- Are there some issues or themes that everybody who is working in a nuclear field has to know or adhere to?
- What kind of role does work motivation play in improving nuclear safety? Is it necessary for the personnel to value safety?
- What is the responsibility of an individual in connection to nuclear safety? How important is the personnel's sense of personal responsibility for nuclear safety? In what kind of situations is personal responsibility important?
- Do Nordic nuclear installations have sufficient resources and other prerequisites to carry out their work as safely as reasonable? Are there areas or tasks where control over ones work has been a challenge?
- How much should each and every one working in the nuclear branch understand about the hazards that are related to production of nuclear power? Are there situations were understanding of hazards is more important than in other situations?
- How does the plant's life-cycle (planning, construction, operation, decommission) affect the requirements of a good safety culture?
- There have been several events in the Nordic power plants during the last couple of years (Forsmark incident in 2006, control rods at OKG in 2008, quality problems at OL3 construction site). What have these events taught about the nature of safety culture in the nuclear industry? Has anything changed? How effective is joint learning concerning nuclear safety in the Nordic nuclear field? Are the procedures, routines and practices examined critically enough in the branch?

Title	Nuclear Safety Culture in Finland and Sweden – Developments and Challenges
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Affiliation(s)	1 VTT, 2 RiskPilot AB, 3 KTH
ISBN	978-87-7893-311-9
Date	February 2011
Project	NKS-R / MOSACA
No. of pages	61
No. of tables	1
No. of illustrations	6
No. of references	52

Abstract

The project aimed at studying the concept of nuclear safety culture and the Nordic nuclear branch safety culture. The project also aimed at looking how the power companies and the regulators view the current responsibilities and role of subcontractors in the Nordic nuclear safety culture as well as to inspect the special demands for safety culture in subcontracting chains. Interview data was collected in Sweden (n = 14) and Finland (n = 16) during 2009. Interviewees represented the major actors in the nuclear field (regulators, power companies, expert organizations, waste management organizations). Results gave insight into the nature and evaluation of safety culture in the nuclear industry. Results illustrated that there is a wide variety of views on matters that are considered important for nuclear safety within the Nordic nuclear community. However, the interviewees considered quite uniformly such psychological states as motivation, mindfulness, sense of control, understanding of hazards and sense of responsibility as important for nuclear safety. Results also gave insight into the characteristics of Nordic nuclear culture. Various differences in safety cultures in Finland and Sweden were uncovered. In addition to the differences, historical reasons for the development of the nuclear safety cultures in Finland and Sweden were pointed out. Finally, results gave implications that on the one hand subcontractors can bring new ideas and improvements to the plants' practices, but on the other hand the assurance of necessary safety attitudes and competence of the subcontracting companies and their employees is considered as a challenge. The report concludes that a good safety culture requires a deep and wide understanding of nuclear safety including the various accident mechanisms of the power plants as well as a willingness to continuously develop one's competence and understanding. An effective and resilient nuclear safety culture has to foster a constant sense of unease that prevents complacency yet at the same time it has to foster a certain professional pride and a feeling of accomplishment to maintain work motivation and healthy occupational identity. The report gives several recommendations for further developing nuclear safety culture in Finland and Sweden.

Key words

Safety culture, human and organizational factors, safety management, contractors, evaluation

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