CHALMERS

The Evolution of Regulatory Approaches in Nuclear Power Oversight

A comprehensive analysis and comparison of Sweden, Finland Canada and USA

Master of Science Thesis

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MASTER'S THESIS 2014

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Abstract

Nuclear oversight is a subject that is increasing in importance and has today reached a point where it is perhaps the most affecting factor for the nuclear power industry. The main purpose of this project was to investigate and compare the different types of factors that affect the oversight and safety priorities of nuclear regulators. Further, the idea was to get an understanding of in which direction the regulatory work has changed, how it will change and what the complications of that might be. The report is based on literature studies together with 18 qualitative interviews with experienced utility- and regulatory personnel in Sweden, Finland, USA and Canada. The obtained result indicates that there is currently an ongoing harmonization of the reactor safety requirements taking place, especially in Europe. This harmonization is driven by a number of large international organizations with IAEA, WANO and WENRA being the most significant. The countries that will be most affected by the harmonization are the ones that deviate most from the rest. All of the respondents in this study confirmed that the work associated with regulatory compliance will increase. Many also predicted that the increase in compliance would reach a level where the financial incentives associated with nuclear power generation are gone. Since many countries today have reactors that are getting close to their operational lifetime, their power industries and governments will soon stand before a crossroad whether to invest in new nuclear or not.

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Preface

This master's thesis was performed during the spring of 2014. It was developed and designed by ourselves from concept until finish. This idea for a project was mainly chosen because of the large impact that nuclear oversight has on the industry and because no similar study had previously been performed as a master thesis. A comprehensive study was chosen due to personal preferences.

This study would not have been possible without the assistance from our supervisor Anders Nordlund, Ann Berg at Vattenfall and Jan-Anders Svensson at E.ON. For this we are very thankful. Also, we would like to thank ÅForsk, Vattenfall and E.ON for the financial support that made this study possible.

We would also like to say thank you to all our interviewees who have contributed with time and knowledge. The most interesting part of our project has been taking part of your experience and opinions.

Gothenburg Sweden, September 2014
Björn Arkborn & Alexander Engström

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1. Introduction

Due to the potential risk of nuclear power, regulatory agencies are used to assure that the power plants live up to present nuclear safety regulation. Depending on cultural aspects, traditions, economy and more, the approaches of the regulatory agencies can vary with country and time. Current globalization, such as for instance The European Union, raises demands for regulatory conformity. This regulatory conformity will most likely affect the evolution of the regulatory work and the approaches used for oversight. Following and trying to predict the development of regulatory approaches will be of great importance, both for the regulatory agencies and for the utilities.

Besides from national political situation and the electricity price, the nuclear oversight is likely the factor that affects the industry the most. The nuclear safety regulation and the ability of the industry to comply with the requirements have a direct impact on the economy of the utility. Thus, this provides a large incentive to follow and try to predict the evolution of the oversight.

The world's nuclear fleet was mainly built during the mid-60s to the mid-80s. With an initial technical life-time of 40 years (in many cases extended to 60), the end of the plants' operational time is closing in. For the nuclear power countries this means that the decision whether to replace the plants with new nuclear or some other energy sources must be taken in the near future. The costs associated with increased regulatory pressure together with low financial margins and other affecting factors are likely to cause nuclear countries to replace their reactors with other sources of energy. Many of these sources will contribute to the release of more greenhouse gases.

1.1 Main purpose

The main purpose of this project was to investigate and compare the different types of factors that affect the oversight and safety priorities of nuclear regulators. Further, the idea was to get an understanding of in which direction the regulatory work has changed, how it will change and what the complications of that might be. The report is based on literature studies together with 18 qualitative interviews with experienced utility- and regulatory personnel in Sweden, Finland, USA and Canada. The following subjects were treated in this project:

- How cultural, historical and organizational differences in different countries lead to differences in nuclear oversight.
- How international organizations affect the nuclear oversight in the analyzed countries.
- The interviewees' perception regarding the direction of the evolution of the regulatory work.
- What the regulator's areas of priorities are based on.
- How the regulators and the utilities self-assess the efficiency of their work.
- In what direction the regulatory work evolves and how this will affect the nuclear power plants in the future.
- What factors that affect the evolution of nuclear power plant oversight in the analyzed countries.

1.2 Delimitations

This study is delimited to only analyze and compare the nuclear oversight within reactor safety of Sweden, Finland, USA and Canada. The following oversight aspects were not considered:

- Security of the nuclear power facility.
- Handling of radioactive waste from nuclear facilities.
- Emissions to the surroundings during normal operation of nuclear power facilities.
- Decommissioning of nuclear power facilities.
- Control of radionuclides and non-proliferation at the nuclear facilities.

2. Background

This chapter is divided into two major sections; Nuclear power development and International organizations working with nuclear related matters.

2.1 Nuclear power development

This purpose of this section is to give the reader sufficient background information about the history of nuclear power with extra emphasis put on USA, Canada, Finland and Sweden. The knowing of how and why nuclear power was developed in these countries is central in order to be able to understand their differences as well as to make predictions about their future. The focus is kept on the most important aspects of nuclear power as well as the events that have steered the development of each country's nuclear authority.

2.1.1 Nuclear power development in USA

Two years after World War II ended in 1947, the United States Atomic Energy Commission (AEC) was created. This civilian federal agency was appointed for the management of the nation's nuclear programs, i.e. both military protection and the development of peaceful uses of the atom. [1] Due to the realization that the same commission should not promote and regulate nuclear power, the AEC was in 1974 divided into the Nuclear Regulatory Commission (NRC) and Department of Energy (DoE).

In 1953, the U.S. president Eisenhower proposed his famous "Atoms for Peace" program which drastically reoriented the research efforts from military purposes to electricity production by the disclosure of the nuclear confidences. [2] The speech which was addressed to the United Nations in New York, came to be the turning point for the nuclear era. The background for the speech was the Cold War and the nuclear arms race. By accepting the assistance and co-operation from the U.S. in the peaceful uses of the atom, the countries would also need to submit to international nuclear activities control for non-proliferation of nuclear weapons. Eisenhower had the belief that diversion of resources from weapons to power reactors could lead the world to peace instead of war as well as provide electrical power to the economic development worldwide. [3] To back up his words, Eisenhower declassified all the sealed documents of the Manhattan Project that were not related to bomb production, making the information available world-wide. [2] He also proposed the establishment of an international atomic energy agency that would work to promote the peaceful uses of nuclear energy and work against non-proliferation. In 1957, this proposal became reality through the establishment of the International Atomic Energy Agency (IAEA). [4]

The commercialization of nuclear reactors started in the late 50's and in the beginning of the 60's. In America, Westinghouse designed the first commercial PWR and General Electric the first BWR, both using enriched uranium as fuel and light water as coolant and moderator. From the start of the commercialization, the reactor constructions and the number of granted permits in the U.S. were very quick. More than half of U.S. today approximately 100 reactors were built during a 20-year period. [2]

From the late 1970's to about 2002 the nuclear power industry was experiencing some decline and stagnation. Many reactor orders were cancelled and few new were ordered, mainly because of strong public resistance. [5]

2.1.2 Nuclear power development in Canada

Canada started its nuclear program immediately after World War II using knowledge from the Manhattan Project, which Canadian scientists were a part of. In 1947, a 10 MW research reactor, named NRX (Nuclear Reactor Experiment), came online at the nuclear research complex at Chalk River, Ontario. The reactor was heavy water moderated and light water cooled run on natural uranium. [4]

In the 1950s, Canada lacked the heavy industry necessary to build the reactor pressure vessels for the PWR and BWR. Furthermore they had a strong desire to avoid the cost of uranium enrichment. These two factors, amongst others, lead to the development of the Canada Deuterium Uranium (CANDU) reactor. The characteristics of the CANDU reactor differ somewhat from other reactor designs. First of all, it has no pressure vessel. Instead, the heavy water moderator is contained in a low-pressure tank and the fuel is enclosed in small high-pressure zirconium tubes, placed in the tank. The zirconium tubes conduct heavy water which is fed to a secondary loop-system containing ordinary water. The secondary loop is then used to produce steam and in the end, electricity. [4]

Canada today has NPPs in operation on four sites, Pickering, Darlington, Bruce and Point Lepreau. The Pickering and Darlington sites are run by Ontario Power Generation, a public company owned by the province of Ontario. The reactors on the Bruce site are operated by the privately owned Bruce Power and the single NPP located in Point Lepreau is operated by the provincially owned NB Power. [6]

Control and regulation of nuclear power in Canada was from the beginning handled by the Atomic Energy Control Board (AECB), answering to the Canadian Parliament. The AECB was established in 1946 under the Atomic Energy Control Act, under the declaration that nuclear energy is of national interest. The control was obtained by a comprehensive licensing system in cooperation with other federal and provincial government departments, such as health and environment. In 2000, the AECB was renamed and became the Canadian Nuclear Safety Commission (CNSC). [7] [8]

During the mid-80´s to the mid-90´s the Pickering NPP suffered a series of incidents of different magnitude, ranging from fuel damages to a failure of a fuel channel, along with attendant partial contamination of containment. The AECB was so concerned with the declining performance of the licensee that it shortened the operating licenses from two years to six months. In order to stop the deterioration, the utility Ontario Hydro requested assistance from U.S. experts to assess the plant and to develop an improvement program. The review team rated the Pickering station as “minimally acceptable”, relating the deterioration to retirement of experienced staff, weak leadership and decentralization of nuclear operations. Another significant point was that the utility never really shifted from an engineering and construction organization to an operational and maintenance organization. As a response to the review, Ontario Hydro shut several units down in order to being able to focus on improving the status of the remaining ones. Due to implementation of the wide-range improvement program and other improvement efforts, the performance of the utility increased, which eventually led to the permission to restart some of the shutdown units. [9]

2.1.3 Nuclear power development in Finland

The development of nuclear power in Finland was mainly motivated by three factors. First was the wish to avoid reliance on import power, second the high electricity price and third the need to increase electricity production for the growing industry after World War II. [10]

In 1942, President Risto Ryti signed the Act on the Technical Research Centre of Finland and VTT (fi. Valtion Teknillinen Tutkimuskeskus) was thereby created. At first, VTT's research focused on military purposes and civil defense. In the mid 1960's VTT was Finland's largest research institute with 26 laboratories and more than 400 scientists. The first nuclear reactor in Finland was the FiR 1 research reactor in Espoo. This came into operation in 1962 and was administered by VTT. Today VTT is the largest applied research facility in northern Europe. [11]

In 1958, the Finnish Radiation and Nuclear Safety Authority STUK (fi. Säteilyturvakeskus) was established under the name Radiation Physics Institute (SFL, fi. Säteilyfysiikan laitoksena). However, the name STUK was not established until 1984. In the beginning, STUK was a small institute of radiation physicists that worked primarily with radiation protection related to hospital equipment. In 1965, the preparation work for nuclear power oversight in Finland started. The U.S. AEC was chosen to draft the initial guidelines and regulations for the Finnish model which STUK continued to develop to fit their needs. Today STUK also functions as an expert organization in the entire field of radiation and nuclear safety.

In 1965, the state-owned energy company IVO (fi. Imatran Voima) sent out a bid to ten potential suppliers for the construction of a nuclear power plant in Finland. The plan was to purchase a fully operational plant based on financial calculations. However, it was soon clear that the construction of a nuclear power plant was a huge undertaking that could not be achieved solely on financial considerations. The political climate as well as the trade relations had to be taken into account. In 1969, the Council of State decided to purchase Finland's first nuclear power plant from the Soviet Union. In 1998, IVO and Neste Oy (a Finnish national oil company) merged and became Fortum Cooperation. [10] Today Fortum besides owning Loviisa, has shares in Oskarshamn NPP, Forsmark NPP and Olkiluoto NPP.

In 1969, 16 Finnish industrial and power companies together founded TVO (fi. Teollisuuden Voima Oy). A year later, the board of directors of TVO decided to build a 600 MW nuclear power plant and in 1972, the Swedish company ASEA-Atom was chosen to deliver. The planning of an additional reactor started in the 1970's and the application for decision was made by IVO and TVO in 1985. However, due to the deteriorated public opinion after the Chernobyl accident in 1986, the government together with the industry chose to abandon the project. [10]

In the year 2000, TVO submitted to the government an application for a Decision-in-Principle to build fifth nuclear reactor, in accordance with the Nuclear Energy Act. The Finnish government approved the construction of a new plant in 2002 and the next year, TVO made the decision to invest in a new reactor at the Olkiluoto nuclear power plant. The construction began in 2005 after the Finnish government granted the construction license. The original plan was that the reactor should begin commercial operation in 2009, however as of 2014, the construction is still not finished due to several reasons. [12]

In 2010, the Finnish government gave a positive Decision-in-Principle to TVO for a fourth reactor at Olkiluoto and to the Finnish company Fennovoima, to build one or two reactors in the north of the country. [13]

2.1.4 Nuclear power development in Sweden

During the 1950s, the technical development of the use of nuclear power was very quick. The Swedish government was strongly determined to develop its own nuclear energy program to ensure national energy security. With nuclear power, the politicians saw the opportunity to end the heavy oil dependence (approximately 75 percent of the energy came from oil at that time) and at the same time spare the remaining rivers from hydro power exploitation. [14]

In 1956, the parliament approved the law which gave right to extract atomic energy in Sweden (1956:306, Atomenergilagen). This new law required a special regulating agency to make sure that the law was obeyed and to issue permits. This agency was named The Delegation of Atomic Energy (se. Delegationen för Atomenergifrågor). [15] The same year, the Reactor Siting Committee (se. Reaktorförläggningskommitten) was established in order to assist the delegation in matters concerning the safety at the atomic plants. As a response to the Atomic Energy Investigation of 1966 carried out on behalf of the Ministry of Commerce, it was decided that the agency's resources should increase and that the division of roles between state and industry should be clarified. [16] This lead to more employment at the agency and in 1970 – 1971, the agency had about ten employees. In 1971, the delegation was given new mandate which included following the development of nuclear power, especially nuclear safety, as well as the control of nuclear fuel (i.e. safeguarding). Three years later, the agency changed name to Swedish Nuclear Power Inspectorate (SKI, se. Statens Kärnkraftsinspektion) and was at the same time given further mandate and more resources. At this time SKI had about 25 employees and the employment increased with about ten per year up to 1981. [15] Today, SKI and Swedish Radiation Safety Institute (SSI), previously working under the Ministry of Environment, has joined together and become Swedish Radiation Safety Authority (SSM). SSM is today the sole authority regarding everything concerning nuclear and radiation in Sweden.

In 1968, the Nuclear Liability Act (1968:43) came into force which regulated (and still regulates) the responsibilities associated with a radiological accident. Two years later in 1970, the Non-Proliferation Treaty comes into force and Sweden formally abandons its nuclear weapons program and the heavy water reactor system. [17]

To the beginning of the 1970s, there was more or less political consensus in Sweden about continued investments in nuclear power. However in the mid-70s, a more restrictive attitude started to take form where the risks associated with the handling and final disposal of used fuel was heavily emphasized. The future of nuclear power was questioned, and after the political tumult that arose from the Three Mile Island accident in 1979, the parliament decided to have a referendum about the future of Swedish nuclear power. As a result of the referendum, the 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. [10]

In 1984, the parliament adopted the Act on Nuclear Activities (1984:3) which particularly focus on the safety of nuclear operations, non-proliferation and nuclear oversight. Three years later as a response to the 1986 Chernobyl accident, the parliament accepted an amendment to the law which prohibited any construction, calculations, orders or other activities with the

intent to domestically build a nuclear reactor. The law was in force until 2006 when it was abolished since it was considered to inhibit the research and development of nuclear technology in Sweden. [14]

January 1st 1996 the Swedish electricity market was deregulated. This was preceded by a proposition from the government where the goals of the deregulation were presented. According to the preposition, the possibility to choose would increase for the consumers, and the pricing of the electricity would become more efficient. The reason for the previous regulation of the electricity price was to prevent that the market dominance of the electricity producers would lead to uncontrolled electricity price increases. The main goal of the deregulation was consequently to increase the competition on the electricity market. [18] Since the deregulation in 1996 the Northern electricity price has fluctuated heavily. This fluctuation is due to a number of reasons, such as production versus demand, water levels in the reservoirs used for hydro power, coal prices, taxes and more. [19] Regardless of the reason, these fluctuations have led to poor conditions for large investments in the power production industry.

In 1997, the parliament accepted the government proposition of a sustainable energy policy which meant that the two reactors in Barsebäck should be prematurely shut down and that the final phase-out date 2010 should be removed. A year later as an additional step for the phase-out of nuclear power, the parliament accepted the Decommissioning Act (se. Avvecklingslagen) which gave the government the authority to decide when the license of an operating a nuclear reactor should cease. This right was exercised on the reactors Barsebäck 1 and Barsebäck 2 that were shut down in 1999 and 2005 respectively, mainly because of their inappropriate location. [14]

In 2009, the governing parties agreed that nuclear power will have an important role in Sweden in the future. With the increased focus on climate change, nuclear power is one of the few energy sources that fulfill the requirements of the carbon dioxide emissions. The agreement enabled further power up-rates of the existing power plants and the possibility to replace existing reactors with new-builds as they reach their economic lifetime. In 2010, the decommissioning act and the new-build ban are abolished. At the same time the parliament decided that the damage claims in case of an accident should be raised. [14]

There are currently 10 nuclear reactors in operation in Sweden; 3 PWRs and 7 BWRs distributed at the nuclear power plants Ringhals, Oskarshamn and Forsmark.

2.1.5 Highly affecting events and accidents

This section will give a brief introduction to four events/accidents that have had a large effect on the evolution of the nuclear power oversight in the world.

2.1.5.1 The Three Mile Island accident

In 1979, the Three Mile Island nuclear power plant in Harrisburg, PA, experienced a partial meltdown which released a small amount of radioactivity to the surrounding area. Several independent studies showed that the average dose to about 2 million people were only about 0.01 mSv (corresponding to 1/6th of a full set of chest X-rays). [1] Despite the insignificant damage, this event came to have a huge impact on the already infected debate whether to continue nuclear development or not; not only in the U.S. but in several of the western nuclear nations. As a consequence in the U.S, the Institute of Nuclear Power Operations (INPO) was

formed by the U.S. nuclear electric industry the same year. The analysis of the accident made it clear that it was necessary for the risk assessment to include human factors as well. Human Reliability Assessment (HRA) was then introduced as a compliment to the Probabilistic Safety Assessment (PSA) in order to calculate the probability of human failure. [10]

2.1.5.2 The Chernobyl accident

Seven years after the Three Mile Island accident, a full core meltdown and a huge explosion occurred in the Chernobyl nuclear power plant in northern Ukraine. An enormous amount of radioactivity was released to the atmosphere and spread to a large part of Europe; close to 5 million people were exposed to high levels of radiation. [1] This event turned the worldwide opinion against nuclear power well into the 21st century. Most post-accidents-reports pointed out that human- and organizational factors were the main cause of the accident. In the INSAG-1 (International Nuclear Safety Group) "Summary Report on the Post-accident Review Meeting on the Chernobyl Accident", the term "Safety Culture" was mentioned for the first time. It was at that time defined as:

> *"That assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receives the attention warranted by their significance."*

Today, Safety Culture has numerous definitions. The western regulatory authorities quickly required a proper Safety Culture for the nuclear power plant organizations and some nations even included it in the law. [10]

Another important lesson learned after Chernobyl was that nuclear accidents do not respect country borders and that it is of every nearby country's best interest to maintain a high level of safety at the nuclear power plants. This is most likely one of the reasons for the large amount of international organizations working with these matters.

2.1.5.3 The attack on the World Trade Center

Another big event that came to have significant effect on the nuclear power oversight was the 2001 attack on the World Trade Center in New York. Terrorism took on a whole new meaning and President Bush raised the concern of terrorist acquisition of weapons of mass destruction. He announced that any extremist radical "able to produce, buy, steal an amount of highly enriched uranium little larger than a single softball" could produce a nuclear weapon. [1] The terrorist threats immediately led to tightened security of the nuclear power plants around the world. The impact this had on the industry varied between countries depending on how much security they already had.

2.1.5.4 The Fukushima Daiichi accident

The Fukushima Daiichi accident in 2011 was the largest nuclear accident after Chernobyl. A major earthquake offshore the Japanese coast created a 15-metre high tsunami wave that disabled the power supply and cooling of three Fukushima Daiichi reactors. The three reactors suffered core meltdowns and the accident was rated 7 on the INES-scale. Four reactors were severely damaged during the accident and large amounts of radioactive material were released to the surroundings, leading to evacuations. [20] After Fukushima, the European Council decided together with its nuclear advisory group, the so-called European Nuclear Safety Regulators Group (ENSREG), to launch comprehensive risk and safety assessments of all EU nuclear power plants. [21] These assessments are referred to as "Stress tests". The Stress tests

are mainly based on specifications provided by Western European Nuclear Regulators Association (WENRA) and cover extraordinary triggering events such as earthquakes, flooding or other initiating events potentially leading to multiple losses of safety functions. The accident has also led to stricter nuclear regulations in many countries. [21]

2.2 International organizations working with nuclear related matters

Since consequences of a nuclear accident do not respect country borders, the need of international organizations working with nuclear safety matters is obvious. These organizations often have different areas of foci, however some do overlap. As an example of this, IAEA can be seen as having a top-down perspective based on high level standards, while the work of WANO can be regarded as bottom-up, based on operational experience from nuclear operators. These organizations are today in some aspects overlapping and therefore in some areas competitive.

2.2.1 International Atomic Energy Agency

The International Atomic Energy Agency (IAEA) is an international organization created by the United Nations in 1957 that seeks to promote peaceful use of nuclear energy and to inhibit its use for military purposes. [22] As of January 2014, IAEA has 161 member states. For each member state the IAEA provide a series of services which aims to:

- Promote the uses of nuclear energy.
- Implement safeguards.
- Promote high standards for nuclear safety. [23]

For nuclear safety, which is area of interest of this report, mainly two services will be in focuses which are the Operational Safety Review Team (OSART) and the Integrated Regulatory Review Service (IRRS).

A significant part of the work of IAEA is the development, establishment and promotion of international standards and guides. The IAEA Safety Standards consists of Safety Fundamentals, Safety Requirements and Safety Guides, aimed to reduce the risks associated with nuclear activities and ionizing radiation. The standards can be seen as an international consensus regarding a sufficiently high safety level. The standards are developed to be applicable on the entire life of both nuclear facilities and related activities. A significant advantage with the standards is that they have been critically reviewed by many, this increases both their credibility and quality. The Safety Standards are also being reviewed periodically to assess needs for revisions based on new knowledge. [24]

2.2.1.1 Integrated Regulatory Review Service

The Integrated Regulatory Review Service (IRRS) is designed to strengthen the effectiveness of the national regulatory infrastructure for nuclear power, radiation safety, radioactive waste and transport safety. [25] This is accomplished with objective evaluations, or peer reviews, of the state's regulatory infrastructure with respect to certain standards and practices. These standards and practices allow variations between countries in many different areas, such as: legal and administrative systems, size and structure of the nuclear radiation protection program, financial resources, social customs and cultural traditions. [26]

The Swedish government requested an IRRS mission that took place in February 2012 at the headquarters of SSM in Stockholm. The IRRS mission reviewed the effectiveness of the

Swedish framework for safety within the competence of the regulator. Being close in time to the Fukushima accident, the regulatory implications of this was also assessed. In the review, the Swedish regulatory framework for safety was compared against the IAEA safety standards. The review resulted in 15 good practices, 17 suggestions and 22 recommendations. The review team found the requirements in the following areas to be insufficiently regulated compared with the IAEA safety standards:

- Reactor containments
- I&C-equipment
- Considerations for external events
- PSA (PSR)
- Safety classifications
- Fire safety
- Management systems
- Design of nuclear power plants

The review team recommended SSM to assess and modify the present regulations in order to make them clearer, more consistent and covering. [27] [28]

The Finnish government has also requested an IRRS review. In October 2012 the IRRS review team performed a review mission that took place at the STUK headquarters in Helsinki. The Finnish regulatory framework for safety was compared against the safety standards of IAEA. Information and experience were also exchanged between the review team members and the STUK counterparts in the areas covered by the IRRS. The review resulted in 10 good practices, 20 suggestions and 8 recommendations. Among the recommendations and suggestions, the IRRS team considered that STUK should enhance the effectiveness of their inspection activities by creating a formal qualification program for their inspectors. STUK was also recommended to clarify the process and make more use of unannounced inspections across the regulated facilities. [29]

Canada and CNSC have also been reviewed by the IRRS. The review was performed on request by the Canadian government and was carried out in May/June 2009. The review was aimed to compare the Canadian regulatory framework for safety with the IAEA safety standards and the relevant Codes of Conduct as an international benchmark for safety. The review resulted in 19 good practices, 18 suggestions and 14 recommendations. Some of the suggestions and recommendations given to CNSC regarded strategic planning programs for research activities to support regulatory decisions, ensuring that operating and technical support branches work together so that security measures do not compromise safety, and refining the existing plans for new-build. [30]

2.2.1.2 Operational Safety Review Teams

OSART is a human performance oriented review service of nuclear power operations. It is coordinated by IAEA and carried out by international experts. The review is normally carried out under an intense three week period whereby interviews are performed, plant workers are observed and document analyzes are carried out. The main purpose is not to examine the plant design, but rather to study the operation of the plant as well as the performance of the plant's management and staff. The OSART program broadly covers the following ten operational areas as standard review areas:

- Management,
- Organization and Administration,

- Training and Qualification,
- Operations,
- Maintenance,
- Technical Support,
- Operating Experience,
- Radiation Protection,
- Chemistry,
- Emergency Planning and Preparedness,
- Severe Accident Management. [31]

2.2.2 Western European Nuclear Regulators Association

On the 4th of February 1999, the heads of the nuclear regulatory authorities of the EU countries and Switzerland created the Western European Nuclear Regulators Association (WENRA) [32]. Today WENRA has 17 member- and 9 observer states. With a general aim of improving nuclear safety, the following objectives have been established: [33]

- Build and maintain a network of chief nuclear safety regulators in Europe.
- Promote exchange of experience and learning from each other's best practices.
- Develop a harmonized approach to nuclear safety and regulation, in particular within the European Union.
- Discuss and, where appropriate, express its opinion on significant safety and regulatory issues.

WENRA has launched two working groups to harmonize safety approaches used by nuclear regulators in Europe; the Reactor Harmonization Working Group (RHWG) and the Working Group on Waste and Decommissioning (WGWD). The purpose of these groups are to analyze and compare national regulatory approaches with the IAEA Safety Standards, identify any differences and propose a way forward to possibly eliminate the differences without impairing the final resulting level of safety. [33]

One of WENRA's major achievements has been the publication of a set of safety Reference Levels (RLs) for operating nuclear power plants in 2006. The RLs reflect expected practices to be implemented in the member states. Their emphasis has been on nuclear safety with primary focus on safety of the reactor core and spent fuel while nuclear security and radiation safety (with a few exceptions) have been specifically excluded. [34]

2.2.3 Committee on Nuclear Regulatory Activities

The Committee on Nuclear Regulatory Activities (CNRA) is an international committee that is part of the OECD Nuclear Energy Agency (NEA) made up of by primarily senior nuclear regulators. It was created 1989 as a forum for the exchange of information among regulatory organizations. CNRA's mission is to assist member countries in ensuring adequate safety of existing and future nuclear installations on their territory. This is done through maintaining and further developing the knowledge, competence and infrastructure to regulate and support the design, operation, decommissioning, waste management and construction of nuclear reactors. [35]

2.2.4 Multinational Design Evaluation Program

The Multinational Design Evaluation Program (MDEP) was established in 2006 as an initiative to develop regulatory approaches. These approaches are aimed to leverage the

resources and knowledge of the national regulatory authorities who are or will be tasked with the review of new reactor power plant designs. MDEP's activities are facilitated by OECD/NEA. The members of MDEP consists of national regulators from 12 countries, amongst them are Sweden (SSM), Finland (STUK), Canada (CNSC) and USA (USNRC). MDEP's main objectives can be defined as follows: [36]

- To enhance multilateral co-operation within existing regulatory frameworks.
- To encourage multinational convergence of codes, standards and safety goals.
- To implement the MDEP products in order to facilitate the licensing of new reactors.

2.2.5 Institute of Nuclear Power Operations

INPO is an American organization created by the American nuclear industry as a response to the TMI accident. Today INPO work with the industry in order to achieve the highest level of safety and reliability through:

- Plant evaluations
- Training and accreditation
- Events analysis and information exchange
- Assistance

INPO is a member of WANO. The organizations work together to share program resources and learnings. One large difference between the organizations is that INPO works with the regulator and WANO does not. [37]

2.2.6 World Association of Nuclear Operators

WANO is an industry non-profit organization consisting of nuclear operators all over the world. The main focus of WANO is to help their members to achieve a high standard when it comes to nuclear safety. WANO works directly with the operators, providing a professional network and five main services: [38]

- Peer Reviews
- Operating Experience
- Technical support and exchange
- Professional and Technical Development
- Communications

2.2.7 The European Nuclear Safety Regulators Group

ENSREG is an independent authoritative expert body created by the European commission in 2007. It is composed by international senior nuclear personnel from regulators and the industry. ENSREG's role is to help establish a common understanding of nuclear safety in the EU and to establish conditions for continuous improvements. ENSREG has lately had a large impact on the nuclear industry through the European Commission's adoption of their stress-test report. [39]

2.2.8 The European Atomic Energy Community

EURATOM is an international organization consisting of the member states of the European Union (EU). It was founded in 1958 through the EURATOM Treaty. The original purpose was to coordinate the research programs of the member states for a peaceful use of nuclear energy. Today, the treaty promotes the joint use of knowledge, infrastructure and financing in the nuclear energy area. Also, by the use of inspections assure non-proliferation and a safe nuclear energy. [40]

2.3 Periodic Safety Review

The Periodic Safety Review (PSR) is a tool for comprehensive safety review, performed by the licensee, which includes all the important safety aspects at nuclear power plants. It is also a way to ensure that experiences are properly handled and that new safety standards lead to safety enhancements at the plants. The PSR is carried out regularly, typically every ten years. In many countries the PSR is a prerequisite for the renewal of the license to operate the plant. [41] PSR is also by CNRA emphasized as a tool to ensure sufficient plant safety in Long Term Operation. [28]

3. Methodology

The overall work-flow of this study is illustrated in Figure 1 and described in more detail in the sub-sections of this chapter. The data acquisition comes solely from qualitative interviews with 18 respondents ranging from 1.5 – 3 hours plus 2 answered questionnaires. The analysis and conclusions are based on the given answers together with literature studies.

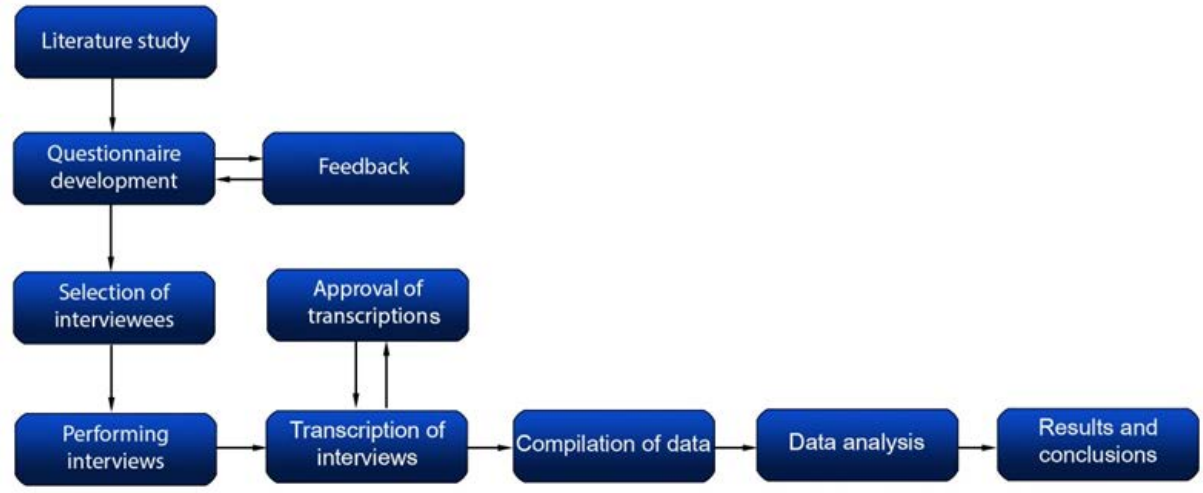

Figure 1. The work-flow of the methodology used in this project.

3.1 Literature study

In the beginning of the project, a literature review was performed in order to learn more about nuclear oversight, regulatory work and the factors that affects it. The literature reviewed mainly consisted of reports and studies by domestic and foreign regulatory agencies as well as reports from international organizations. As several studies in the vicinity of this projects scope already had been performed by SSM, information was both plentiful and easily accessible. [42] [43]

3.2 Selection of the interview questions

Since the result of the project would more or less solely be based on the data obtained from the interviews, much effort was put into developing relevant interview questions. The interview questions were derived from the questions defined in the purpose of the project. In order to verify the coverage of these questions, they were remitted to Vattenfall, E.ON and Chalmers. The questionnaires used when performing the interviews are found in Appendix A and Appendix B, for the utility and the regulator respectively.

3.3 Selection of the interviewees and countries

Similar to the interview questions, the choice of interviewees was understood to be crucial for the outcome of the study. The reason why owner or utility interviewees were preferred instead of licensees was that the former often have the long-term strategic outlook on the regulatory oversight and the compliance issues associated with it. Even though the licensees have the daily or at least more oft-recurring contact with the regulatory personnel or inspectors, their focus is more likely to be on present instead of future matters. Another important factor was that only owner representatives or utility personnel that had experience from interactions with regulatory personnel were selected. The last but not least important criteria when selecting interviewees, was that they had to have long experience from the nuclear industry. On average, the interviewees participating in this study had a nuclear experience of 28 years.

The choice of countries was based on several factors. Firstly, countries with regulatory models that in various aspects differed from the Swedish model were preferred. This was preferred to enable a comparison and the possibility to conclude the origins of the difference. With Finland and USA having a very detailed regulation and Canada having a moderately detailed regulation, this requirement was considered fulfilled. Secondly, two studies sponsored by the Swedish regulatory agency had already assessed a number of countries in a similar aspect. [42] [43] Choosing from these countries would provide valuable and easily accessible background information. All of the countries visited were part of these previous studies, fulfilling also that requirement. Finally, the availability of the countries as well as the possibility to make contact with the right people in these countries was decisive. Finland was quite easy getting contacts in, Canadian contacts needed some more efforts and contacts in the U.S. were very hard to obtain.

3.4 Performing the interviews

A total of 18 qualitative interviews were held ranging from 1.5 – 3 hours each, with a total interview time of about 37 hours. Additionally, two questionnaires were answered giving a total of 20 answered questionnaires. Table 1 shows the distribution of the interviews and the time together with the accumulated nuclear experience from all the interviewees. Most interview time was obtained in Sweden (42%) followed by Finland (30%), Canada (16%) and USA (12%).

At least one week prior to each interview, the questionnaire was sent out to the interviewee with a request to look through and prepare for answering the questions. The interviews were held in either Swedish or in English depending on the preferences of the interviewee. All the interviews were audio recorded for transcription.

Table 1. Number of performed interviews, the total interview time and the accumulated nuclear experience for each analyzed country. The parentheses show the number of answered questionnaires.

Country	Utility interviews	Regulator interviews	Total interview time[h/%]	Nuclear experience [years]
Sweden	6 (7)	2	15,5 [~42%]	248
Finland	4	1	11,3 [~30%]	124
USA	0 (1)	2	4,3 [~12%]	69
Canada	1	2	6,0 [~16%]	67
Total	**11 (13)**	**7**	**37,2**	**508**

3.5 Data compilation

All interviews were recorded into individual audio files. These were then transcribed into text documents in order to get the data more manageable. During the transcription, all pronounced information was transferred, without consideration of its relevance. Each interview required approximately 2-3 man-days of transcription. The resulting text document was reviewed and corrected by both interviewers in order to reach as high compliance with the meaning of the answers as possible. In this stage, English speaking interviewees were transcribed into English text and Swedish speaking interviewees were transcribed into Swedish text.

As soon as the interviews were transcribed and internally reviewed, they were emailed to the interviewees. The interviewees were requested to review their answers and to mark anything

that had been misinterpreted. The interviewees were also given the possibility to recant statements given. When corrections were requested, a new text document with the performed changes was redistributed for approval.

3.6 Data analysis

Since also the analysis was central to the outcome of this project, much effort was put into choosing a suitable method and implementing it. As the amount of information gathered was extensive, a clear structure of the analysis was necessary from the start.

3.6.1 Choice of analysis method

Many methods for analyzing qualitative data exist, one of them is known as content analysis. This method is used when the data has been gathered through interviews and/or observations. It is used as a procedure to categorize verbal and behavioral information, allowing it to be summarized, classified and tabulated. In this method, content can be analyzed on two levels, one basic level where little or no consideration is given to why or how things are said, and one higher level which is more interpretive, analyzing what may have been implied. [44] [45] With this study having data in both quantitative and qualitative form, a modified content analysis was used.

3.6.2 Analysis

Since the data contained both qualitative and quantitative data, two types of analyses hade to be made. For the qualitative data, a content analysis method was used. The method comprised of six major steps:

1. All the text was read through repeatedly in order to get a sense of the full picture.
2. Relevant sentences or phrases were extracted together with its context.
3. The extracted data was densified. I.e. unnecessary words were removed without damaging the important content.
4. The densified data was grouped into categories. The categories used were in this case already predefined in the questionnaire.
5. Representative citations for every subject were extracted.
6. Patters and deviations were looked for and commented on.

The implementations of the first five steps were quite straight forward since much work was already done by the structure of the questionnaire. Also, due to the extensiveness of the questionnaire, relevant information was abundant. Step six did however require a lot of effort. Finding patters and deviations for such vast amount of data was difficult and demanding. The comments should not only notice the deviations, but also contain an analysis based on all the information gathered during this project. I.e. information from literature studies, information from recorded interviews and information from un-recorded interactions/interviews. The latter also contained partial interpretation of what the interviewees may have implied, as the “higher level of content analysis” suggests.

Since the quantitative data for this questionnaire was only used as indicators of tendencies, no statistical analysis was made. Moreover, the results would not have been statistically significant due to the low population. The chosen method only accounted for the average value for every country, utility and authority. I.e. every quantitative question generated: 4 countries * (utility + authority) = 8 answers.

4. Results and analysis

This chapter presents the results from the findings together with an analysis where similarities and differences between the examined countries are discussed. The structure of this chapter follows the structure of the questionnaires in Appendix A and B, and is consequently divided into nine major sections:

- **Tradition, culture and organization**
  1. *How has the use of nuclear power been developed in your country?*
  2. *How is the regulatory oversight of reactor safety organized in your country?*
  3. *Can you identify any cultural characteristics that are affecting or have affected your regulatory model?*
  4. *At what degree has your culture and tradition affected the regulatory model that is used today?*

- **Organizational influences**
  5. *How large significance have the following (see* Table 5*) organizations and services had for your supervision (safety work)? How large significance do you think they will have in the future?*
  6. *Are there any organizations with perhaps associated services above missing which are of importance to your supervision (safety work)?*
  7. *To what extent do international organizations affect how the supervision (safety work) is conducted?*
  8. *Do you have any direct contact with other licensees where an internal exchange of information and experiences takes place?*

- **Relationship between authority and licensee**
  9. *Are there any neutral national forums where authority and licensee can converse?*
  10. *Describe briefly your relationship with the authority.*
  11. *What advantages and disadvantages do you from a safety perspective see with this type of relationship?*
  12. *From your perspective, what would an ideal authority – licensee relationship be like?*

- **Affecting factors**
  13. *Assess for each factor (in Table 10) how large significance you think it have had the last 10 years and how large significance it will have in the future. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very significant influence.*
  14. *Can you think of any other factors that affect the regulatory supervision and safety work? In that case, which are they and how large significance will they have or have had?*

- **Level of detail within the reactor requirements**
    15. *How detailed are the requirements that the authority imposes on the licensees?*
    16. *Why do you think that level of detail is preferred?*
    17. *Describe how the level of detail has changed. (If it has changed)*
    18. *If the level of detail has changed, what does this change depend on?*
    19. *What is your impression of this change in the level of detail? Has it had generally positive or negative consequences?*
    20. *Is there a risk that the changes in the level of detail affect the responsibility distribution?*
    21. *How do you think the licensee/regulator perceives this change? Do they want a higher or a lower level of detail?*

- **Harmonization**
    22. *(Regulator only) Does your agency work for an international harmonization of the reactor safety requirements?*
    22. *(Utility only) What advantages come with an increased international harmonization of the reactor safety requirements?*
    23. *What disadvantages come with an increased international harmonization of the reactor safety requirements?*
    24. *Do you get the impression that the nuclear oversight is developing internationally in any specific direction?*

- **Priority areas**
    25. *(Utility only) Do you know how the authority chooses its priority areas?*
    25. *(Regulator only) How does the authority choose its priority areas?*
    26. *(Utility only) To what extent is your work steered by the regulator‘s priority areas?*
    27. *Is there a neutral forum where safety priority areas can be under discussion with the regulating agency?*
    28. *(Utility only) Do you get the impression that the regulating agency often or seldom chooses the same areas of priority as you would have done?*
    28. *(Regulator only) Do you get the impression that the licensees often or seldom think you choose the right area of priority?*

- **Efficiency**
    29. *Is the efficiency of your safety work (supervision) measured?*
    30. *If efficiency is measured, how has the method of measuring the efficiency been developed?*
    31. *How do you work with increasing the efficiency of your safety work (supervision)? Is increased efficiency a high priority?*

- **General questions**
    32. *(Utility only) Are there any changes that you would like to see within the regulator's supervision?*
    32. *(Regulator Only) Are there any changes that you would like to see within your supervision?*
    33. *On a comprehensive level, do you get the impression that the regulatory supervision will change in the near future?*
    34. *(Utility only) On a comprehensive level, do you think your safety work will be affected by this change in supervision?*
    35. *(Utility only) What requirements do you think the licensees should have on the regulator?*

The reason why these sections were chosen is that they together give a picture of the characteristics of the nuclear oversight and its effect on the nuclear industry. Every section is divided into five sub-sections: Sweden, Finland, Canada, USA and Comprehensive analysis. The first four sub-sections present the answers to the questionnaire from the respective countries together with a brief analysis. Every section ends with a comprehensive analysis that compares all the countries and discusses the subject in general. Most emphasis is put on Sweden followed by Finland, Canada and last USA. This is mostly due to the gathered information distribution (see interview time Table 1) but also due to the main focus of this project.

4.1 Tradition, culture and organization

The purpose of this section was to get an understanding of how and why nuclear power and its regulatory model were developed and how it is currently organized. The respondents were asked to emphasize what they believed were the most important aspects and try to connect that with their country's cultural characteristics. The following questions were asked:

Q1. How has the use of nuclear power been developed in your country?

Q2. How is the regulatory oversight of reactor safety organized in your country?

Q3. Can you identify any cultural characteristics that are affecting or have affected your regulatory model?

Q4. At what degree has your culture and tradition affected the regulatory model that is used today?

4.1.1 Sweden

Most interviewees recognized that the Swedish nuclear power program was derived from the Swedish nuclear weapons program and that it was initially fully owned and promoted by the state. Most of the technology is developed in Sweden by ASEA-Atom, but the PWRs are originally from Westinghouse. Since most of the power companies from the beginning were state-owned, there was no real need to have a strong regulator. The fact that the private-owned power company OKG (Se. Oskarshamns kraftgrupp) decided to build nuclear power plants did not change this consideration. However, after international and national nuclear events and accidents (mainly TMI and Chernobyl), the government realized that Sweden needed a stronger authority. This led to a gradual increase of resources to the regulator for a very long time. The first construction requirements in Sweden were the SKIFS 2004:2 which became valid for all plants with a certain transition period. According to most respondents, this kind of approach has not worked very well. This is how one respondent commented on that situation:

> *"The authority thinks that the licensees have misinterpreted the regulations and the licensees think that SSM has underestimated the difficulties."*

The regulatory model used in Sweden was by the respondents characterized by the following:

- One national regulator (SSM) that is responsible for everything concerning nuclear.
- Certified bodies are used to a high extent. Mainly for non-destructive evaluation and review of design changes.
- The plant operators do not need licenses issued by SSM. Instead their education is regulated.
- There is a particularly high focus on self-assessment.
- Sweden has no site-inspectors or local offices; the oversight is fully coordinated from Stockholm. According to SSM there are mainly two reasons for this: Firstly it would require too much resource from such a small agency.

Secondly, the inspectors would come too close to the licensees whom the licensees can use to their advantage.

The Swedish culture was by many respondents recognized as particularly strong and very different from the rest of Europe and the world. The most important aspect that was recognized by almost every respondent is the cultural built-in trust that exists in Sweden. I.e. most of the authorities' regulations are constructed in such a way that they require a certain level of trust to be effective. Some respondents said that that this trusting relationship has some benefits but also some problems. The advantage is that it requires less follow-up (or oversight), both from the regulator but also within the utilities. Consequently, smaller authorities are required. The problem arises when orders are not executed accordingly and there is no one there to follow-up.

Another cultural characteristic closely related to the latter is the personal room for own decision-makings. I.e. all the way down the hierarchy, people has (to a much higher extent than most countries) the ability to question and modify an order. This is likely due to the perception that a better way of doing something may exist, and that orders seldom are considered literally. The opposite of Sweden in this aspect would be the United States, where people have almost no room at all for own decision-making. In the U.S., workers must follow prescriptive regulations and detailed operating procedures. There are however provisions for relaxing regulatory requirements and modifying procedures when such changes are justified. This cultural behavior can be both advantageous and disadvantageous and it raises high demands on good leadership. An easy solution to this problem seems to be to just increase the follow-up of orders. However the reality is a bit more difficult as questioning someone's work can be regarded as intrusive. Further it is often regarded as impolite of a manger to check on his/her staff. This is how one respondent commented on these cultural characteristics:

"Lack of follow-up is a very big problem in Sweden. This puts high demands for good leadership which Sweden also lacks. This is Sweden's biggest cultural problem."

Some of the industry respondents felt that the Swedish regulator historically have been lagging the industry and consequently have had a more reactive approach. However this changed in the 90s when the authority strengthened their position.

When the respondents were asked to quantify on a scale from 0 to 5 how much the Swedish culture and tradition have affected the regulatory model they answered on average:

Table 2. Effect of culture and tradition in Sweden

SSM	Utility
4,3	4,6

where 0 equals no significance and 5 high significance.

4.1.2 Finland

The Finnish respondents recognized that nuclear power was political from the beginning. The state owned company IVO was politically influenced to purchase Russian reactors while private-owned TVO had the possibility to choose vendors freely. Nuclear power was built because Finland had a fast growing industry after the war and a high electricity deficit.

The reactor regulations were at the time more or less adopted straight from the NRC. But Finland wanted their own expertise and their own guides so they developed the NRC-regulations to fit Finland. Due to technical problems that occurred during the construction of the Loviisa nuclear power plant, the regulator wanted more insight into how the equipment was manufactured. A representative from STUK expressed it like this:

> *"From the beginning, the regulator has had a tendency to supervise and to look into the details in order to be certain of the performance. This has affected the regulatory model and can be seen still today."*

The regulatory model used in Finland was by the respondents characterized by the following:

- STUK handles everything related to nuclear in Finland.
- Certified bodies are used, mainly for the inspection of pressure vessels. The use is somewhat increasing but it is currently used to a very low degree.
- STUK's continuous safety-assessment programs are so extensive that the licensees put most of their effort on compliance rather than self-assessment.
- The biggest self-assessment is the PSR, which is performed typically every 10 years. It is also required for license renewals.
- Quality-departments are not really used as of today. The Q-investigations are instead integrated in the operations. However, some respondents believed that Q-departments will come in the future.
- Site-inspectors are used. At the time there are 2 in Loviisa and 2 in Olkiluoto.

When asked for typical Finnish cultural characteristics, almost all respondents said that Finnish authorities typically have a very practical approach as opposed to philosophical. This is how one respondent put it:

> *"STUK asks practical questions which are fact-oriented. They are not particularly bureaucratic which is good."*

Furthermore, the Finnish way of doing things tend to be much more informal than in any of the other analyzed countries. The cooperation between the regulator and utility was by every respondent characterized as very close. It is e.g. not considered inappropriate in Finland if the regulator and utility become friends or go out to dinner together, as long as everyone pays their own bill. This would not be considered appropriate in many other countries. Informal meetings where approaches can be discussed and informal approvals for solutions can be given beforehand exist. According to one respondent, it is e.g. also possible to go directly from working at STUK to the industry.

When the respondents were asked to quantify on a scale from 0 to 5 how much the Finnish culture and tradition have affected the regulatory model they answered on average:

Table 3. Effect of culture and tradition in Finland.

STUK	Utility
5,0	4,0

where 0 equals no significance and 5 high significance.

4.1.3 Canada

Every Canadian respondent recognized that the Canadian nuclear program was from the beginning derived straight from the U.K. After the World War II, the U.S. took all the enrichment competence from Canada, but since they were very determined to have nuclear power, they developed their own program. The CANDU-reactor became the natural choice since it did not require any enrichment. And since Canada had, and still has, vast resources of uranium, no import was required. Nuclear power in Canada was at the time highly promoted by the government and it would not have been developed without their initiative. The CANDU-reactor was developed incrementally, i.e. every new reactor-version built was an improved version of the latter. Thus, the nuclear requirements have to be applicable for several types of reactors.

The regulatory model used in Canada was by the respondents characterized by the following:

- CNSC is responsible for everything concerning nuclear in Canada.
- Certified bodies are not used to assess the plants.
- Resident site-inspectors are used.
- Self-assessment is used to a high extent. This is how CNSC described it:

"Self-assessment is one of the cornerstones of our regulations. We do not go inspect the concrete but we make sure that they have a sufficient inspection program. However, if we believe that the licensee isn't telling the truth, we hire a third party to inspect or do augmented inspections or investigations, as necessary."

And this is how the utility described it:

"We use self-assessment but we do not share that with the regulator. They can take part of it if they really want to, but they usually do not. The idea is that they want to independently assess our program. We need to able to scrutinize ourselves without being worried about what we write down."

The Canadian culture has been influenced by many sources, but mainly from the U.K. When the respondents were asked what they thought was typically Canadian they replied that they are open, direct and transparent with no hidden agendas, very much like the Nordic countries.

They are also not afraid to raise issues if necessary. When it comes to the regulations there was a cultural shift in 2000 as a new Act and Regulations came into effect. Canadian plants were not performing very well, the regulator was taking more and more interest and Ontario Hydro, the name of the licensee at that time, contracted with U.S. nuclear plant management experts to help them improve. The new group made plant procedures much more prescriptive and consistent and applied them equally across all of their plants. The decision making process was tightened up, allowing less individual discretion to managers.

When the respondents were asked to quantify on a scale from 0 to 5 how much the Canadian culture and tradition have affected the regulatory model they answered on average:

Table 4. Effect of culture and tradition in Canada.

CNSC	Utility
4,0	4,0

where 0 equals no significance and 5 high significance. CNSC commented that they did not choose 5 because their regulations are based on the U.K. approach.

4.1.4 USA

There are a lot of important events that took place in the U.S. that have not only affected their regulations but the entire world's. A selection of the most important aspects that were highlighted by the American respondents follows: The Atomic Energy Commission (AEC) had a strong desire immediately after the bombings in Japan to show that nuclear power had value beyond killing people. So they began to heavily promote nuclear power, which continued on into the 60s. At the same time they were eager not to have an accident that could cause public concern, so they put a lot of emphasis on safety. However, eventually people started to question AEC's intentions, since many believed that promotion and regulation was contradictory. Because of that the AEC was divided into the NRC and DoE (Department of Energy), and since then the regulator has been fully independent.

> *"I think U.S. was first in the world to realize that you cannot have the regulator and promoter in the same organization. Some countries are just finding that out (after Fukushima)."*

A key turning point for the technology came in the late 60s when the full implications of the so called "China syndrome" became evident.

> *"That problem (the China syndrome) has pretty much steered the direction of the regulation and industry ever since. The decisions made from mid-60s to perhaps 1975 made the safety standards for the 1st generation of reactors. Mainly the AEC used the defense in depth approach, which is pretty much the same today all over the world."*

Eisenhower and his Atoms for Peace program played a very important role since it allowed the civilian industry to use the information.

The regulatory model used in USA was by the respondents characterized by the following:

- Everything concerning nuclear in USA is regulated by the NRC.
- NRC has 5 commissioners that are appointed by the president.
- USA use resident inspectors with the N+1 criterion, where N is the number of reactors. E.g. 2 reactors would require 3 resident inspectors.
- Certified bodies are not used in the sense that authority or work is delegated. But the NRC uses some guides and standards that are developed by others.
- Plants are required to have self-assessment programs and corrective action programs.
- NRC and INPO have a very close relationship, not like WANO and authorities in other countries.
- NRC license operators. The education is delegated to INPO who have very tough exams, but the NRC has the final exam.
- To change the nuclear requirements, the NRC has to make a cost-benefit analysis and present it to the utilities. This makes it quite difficult to make drastic changes in regulations.

When the respondents were asked to quantify on a scale from 0 to 5 how much the American culture and tradition have affected the regulatory model they answered on average:

NRC	Utility
4,5	4,0

where 0 equals no significance and 5 high significance.

4.1.5 Comprehensive analysis

It is obvious that both culture and events have had a large impact on the evolution of nuclear oversight in all analyzed countries. However, trying to differentiate single factors and their significance is very difficult.

In all countries the governments have had a central role for the promotion of nuclear power. Today, most governments try to stay out of the subject. However, there is no doubt that nuclear power still is and probably will be a highly political issue.

All countries except from Sweden prefer to have site inspectors. Both regulators and licensees are aware of the risks associated with such close working relationships but most interviewees agree that the advantages outweigh the disadvantages. This is how a representative from the NRC explained it:

> *"Resident inspectors are very important since they have a very good feel for the culture of the plant. They have always in mind that they are NRC staff and regulators, and they also act as ambassadors".*

When certified bodies are used it is often with the intent to relieve the work-load for the authorities in certain areas. The problem with this is that the bodies need to live up to certain expectations in order to keep their certification. Some Swedish respondents were concerned

about this since they felt that they tend to overdo their analysis in order to not risk their certification. Some would perhaps argue that overdoing is justified in the nuclear business, but according to many of the respondents (both regulators and utilities) it is not. Instead, overdoing lead to discontent and unnecessarily high costs and thus, wrongly prioritization of resources. This is how one Swedish respondent commented on this problematic:

"They (certified bodies) are tougher than they should be just so they can keep their certification."

The following comment given by a representative of the NRC summarizes quite well what most respondents thought about the cultural impact on nuclear reactor regulations:

"All nuclear regulation in every country is a reflection of their national culture."

Even though all analyzed countries have quite similar culture (compared to the rest of the world), there are still significant differences. These differences are to a quite large extent reflected on the countries' authorities and their regulations. When asked to quantify how much significance their own culture and tradition have had on their regulations, everyone agreed that is was very high (4-5). A low significance in this sense would imply that the regulations are adopted straight from another country.

Some respondents expressed their experiences regarding the susceptibility to influences related to the level of development of a culture. An important cultural characteristic that is more or less shared by all the analyzed countries is their belief that "their way of doing is the best possible way of doing it". This was regarded as typical behavior of highly developed countries. This behavior can be dangerous because people and organizations are reluctant to embrace new information and experiences; especially if they come from less developed countries. For less developed countries the opposite was said to apply; they typically embrace all new information and experiences, especially if they come from developed countries. This is how one respondent summarized this problem:

"Strong cultures are characterized by their inability to adjust to new ideas. This is a big problem since everyone has something to learn."

This issue was by another respondent considered as not only concerning the level of cultural development, but a question of safety culture.

4.2 Organizational influences

This heading aims at giving a view of which organizations that have the largest influence on both regulatory work and safety work. Emphasis will be on if this influence has changed in the past or will change in the future. The respondents were presented a list (see Table 5) of international organizations and services, they were then asked to weigh the past and future significance of the organizations. The following questions were asked (words in parentheses regard the utilities):

Q5. How large significance have the following organizations and services had for your supervision (safety work)? How large significance do you think they will have in the future?

Table 5. The list of international organizations and services presented in the questionnaire.

Organization	Service
IAEA	
	IRRS
	OSART
	PSR
WENRA (RHWG)	
CNRA	
INPO	
WANO	
ENSREG	
EURATOM	

Q6. Are there any organizations with perhaps associated services above missing which are of importance to your supervision (safety work)?

Q7. To what extent do international organizations affect how the supervision (safety work) is conducted?

Q8. Do you have any direct contact with other licensees where an internal exchange of information and experiences takes place?

4.2.1 Sweden

The following organizational significances were given by the Swedish respondents, subjectively weighting the impact from different organizations; see Figure 2 and Figure 3.

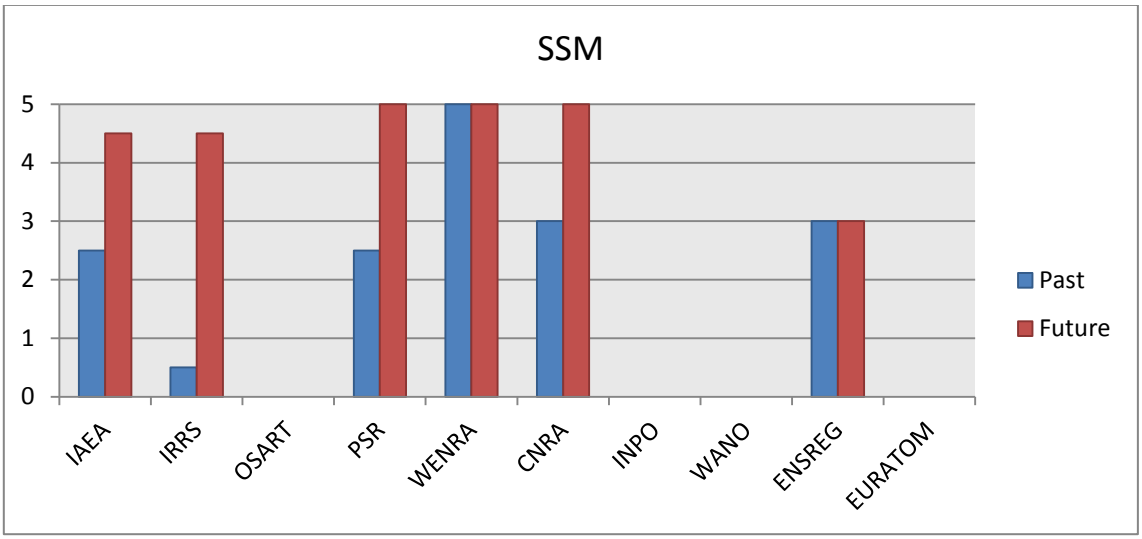

Figure 2. The organizational significances given by the Swedish regulator.

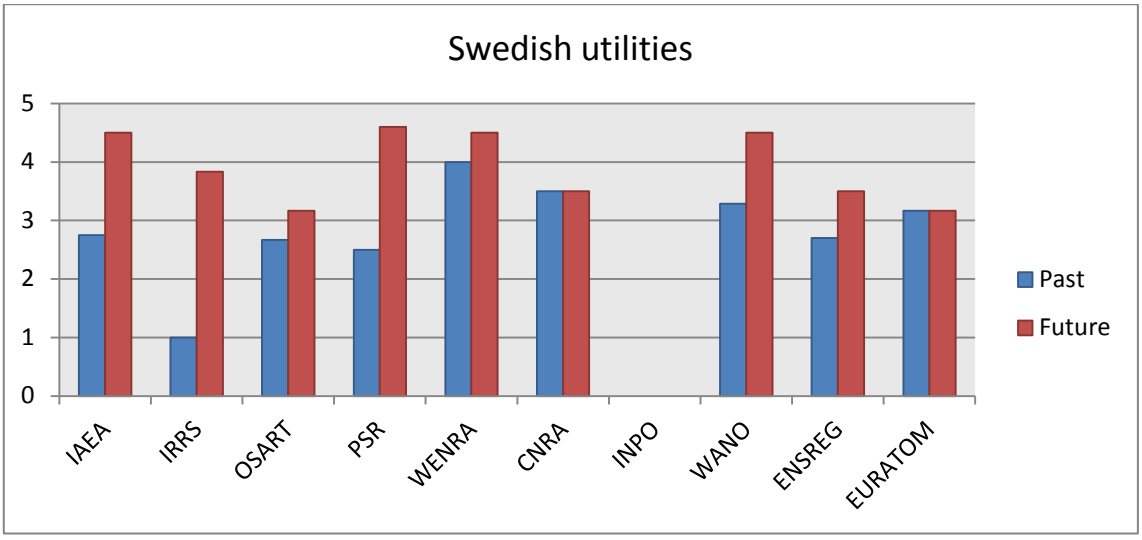

Figure 3. The organizational influences given by the Swedish utilities.

As can be seen from Figure 2, the organizations that have had the largest influence according to the regulator were WENRA, CNRA and ENSREG. As OSART, INPO and WANO mostly affect the licensees and utilities they were regarded as non-influential. EURATOM was regarded to have very low influence on nuclear safety regulation, but influential in other areas. The organizations that were predicted to increase their influence most were the IAEA with its service IRRS, and CNRA. WENRA was believed to stay at the highest level of influence possible even in the future. The PSR was predicted to increase and also get the highest level of influence possible, both due to aging as the Swedish nuclear fleet will go into LTO, and because of harmonization, partly through IRRS. Worth noting is that the total organizational influence on the regulator is increasing, with WENRA, IAEA and CNRA as the highest ranked organizations. One of the Swedish regulator respondents that were interviewed regarded being part of WENRA as very valuable, saying that:

"WENRA´s Reference Levels will have a great significance in the future."

The respondent also claimed that IAEA had not been used to a large extent earlier, but that their requirements are used a lot today. SSM try to keep the national requirements and adopt the best ones from IAEA. As the IRRS review is based upon the IAEA requirements, SSM will have to adapt in order to achieve compliance with the remarks given by IRRS 2012 [25].

The respondents from the Swedish utilities regarded WENRA, CNRA, WANO and EURATOM as the most influential organizations in the past (Figure 3). The only organization that was claimed to be non-influential was INPO, as they mostly are active in North America. When asked to predict the future significance of the organizations, WANO, WENRA, IAEA with its service IRRS, and ENSREG were believed to increase the most. The PSR was also believed to increase in significance, mostly due to aging of the plants. According to the answers, the utilities also believed that the total organizational influence on the safety work would increase. Some of the respondents felt that there were too many organizations influencing the nuclear industry and that it was difficult knowing which to follow. There were also opinions about competition between the organizations:

"WANO and OSART are strong competitors and there is a risk that OSART will not survive because WANO is improving so much."

All of the respondents said that the list of organizations and services included the most influential ones, but that there were others to add. The regulator emphasized the EU as an organization, as the EU-directives that handle nuclear safety must be adopted by the national regulation. This is believed to result in an increased control of the development in the nuclear safety area. Regulatory agencies in neighboring countries were also said to have a large influence, in this case STUK as the cooperation between the agencies is close. Also standardization organizations like IEC were mentioned to have influences.

The utilities named a variety of different influential organizations. Different Owners Groups were said to have large importance for the safety work. In Sweden, the BWR Owners Group, Westinghouse Owners Group and Nordic Owners Group were influential. One large advantage with the Owners Groups is that they enable international cooperation. Another important influence was said to be the Nuclear Energy Agency (NEA), especially the Working Group on Human and Organizational Factors (WGHOF), with its aim to improve the understanding and treatment of human and organizational factors within the nuclear industry. The Electric Power Research Institute (EPRI) has working groups on different technical areas that are quite influential according to the respondents. The IAEA/NEA Incident Reporting System (IRS) was also claimed to have significance, as every member state is obliged to report a number of relevant incidents every year. Also the Nordic nuclear safety research forum NKS (se. Nordisk KärnSäkerhetsforskning) was mentioned as having influence on the safety work of the utilities.

In the last question under this heading the respondents were asked to assess in what extent the international organizations affected how the supervision or safety work was conducted. The following significances were given, see Table 6.

Table 6. The respondents´ view of how much their work was affected by international organizations. 0 equals no significance and 5 equals very high significance

SSM	Utility
4,0	3,4

4.2.2 Finland

The following organizational significances were given by the Finnish respondents subjectively, weighting the impact from different organizations; see Figure 4 and Figure 5.

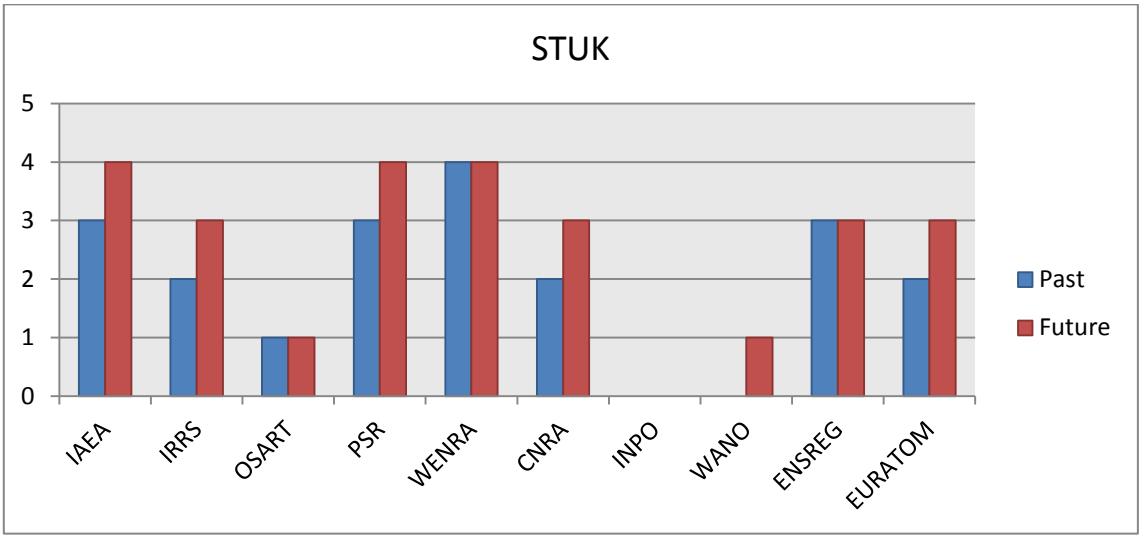

Figure 4. The organizational significances given by the Finnish regulator

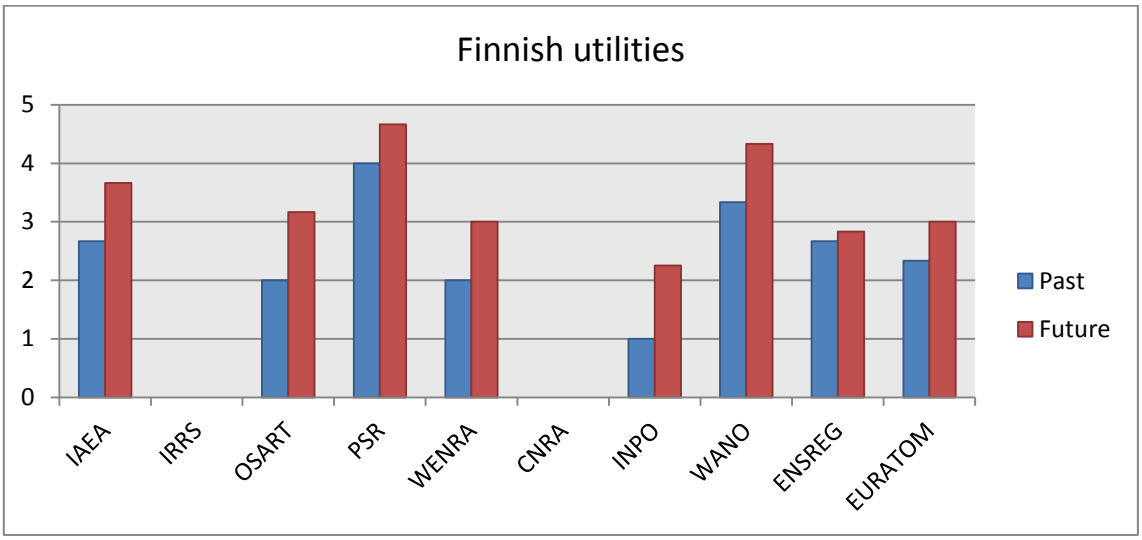

Figure 5. The organizational significances given by the Finnish utility.

As can be seen in Figure 4, the Finnish regulatory respondent regarded WENRA, ENSREG and IAEA as the most influential organizations in the past. The PSR was also regarded as significant for the oversight. INPO and WANO were said to have had no significance at all. The regulator´s view of the development was that IAEA, IRRS, the PSR, CNRA, WANO and

EURATOM would increase in importance. WENRA was believed to stay at a rather high significance. The significance of IAEA was described as:

"Some guides are taken directly from IAEA. STUK take part in the development as well. The guidelines have been very general, now they are getting detailed and functional."

The low significance of the IRRS was explained by that most of the remarks were pointed at the government, not at STUK. The answers indicate that the overall organizational influence will increase.

The Finnish utilities regarded the PSR and WANO as the most influential factors in their past work. In the future, the PSR, OSART, IAEA and WANO would increase the most. The reason for the large influence by the PSR is that it is part of the renewal of the operating licenses for the plants in Finland. Except from OSART, the utilities claimed that they had no direct contact with IAEA, only through STUK. The opinion was however that IAEA will increase as STUK refers to them more and more. The utilities considered influences as something that was important to be open to.

When asked for additional relevant organizations, the utilities considered VTT to be the most important one. VTT is used both as a consultant and technical research resource by both the industry and the regulator. The Finnish Safety and Chemicals Agency (TUKES) was also considered as influential by the utilities. Both utilities and regulator claimed that standardization organizations such as ISO, IEC and IEEE are important and used as references. The regulator also regarded the German Kerntechnischer Ausschuss (KTA) safety standards as influential on their work.

The Finnish regulator and utility were asked how large significance the international organizations had on their work, their answers are presented in Table 7.

Table 7. The respondents´ view of how much their work was affected by international organizations. 0 equals no significance and 5 equals very high significance.

STUK	Utility
3,0	3,0

According to the regulator, the influences from the international organizations increase as the organizations develop. One of the utilities stated the following regarding the influences from the organizations:

"The international organizations have a more implicit influence on us. We follow them although we may not always are aware of it."

4.2.3 Canada

The following organizational significances were given by the Canadian respondents, subjectively weighting the impact from different organizations; see Figure 6 and Figure 7.

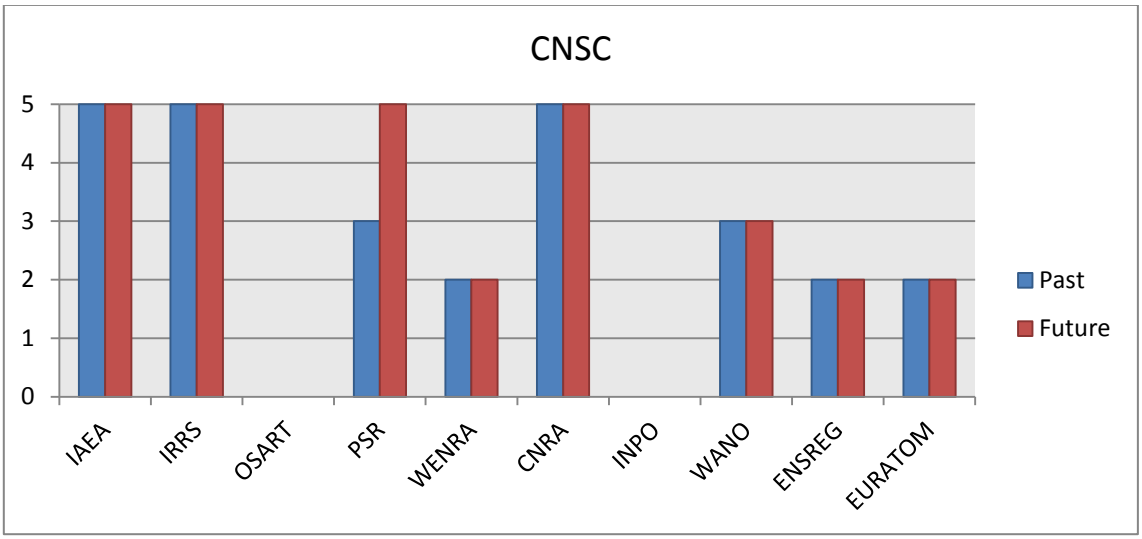

Figure 6. The organizational significances given by the Canadian regulator.

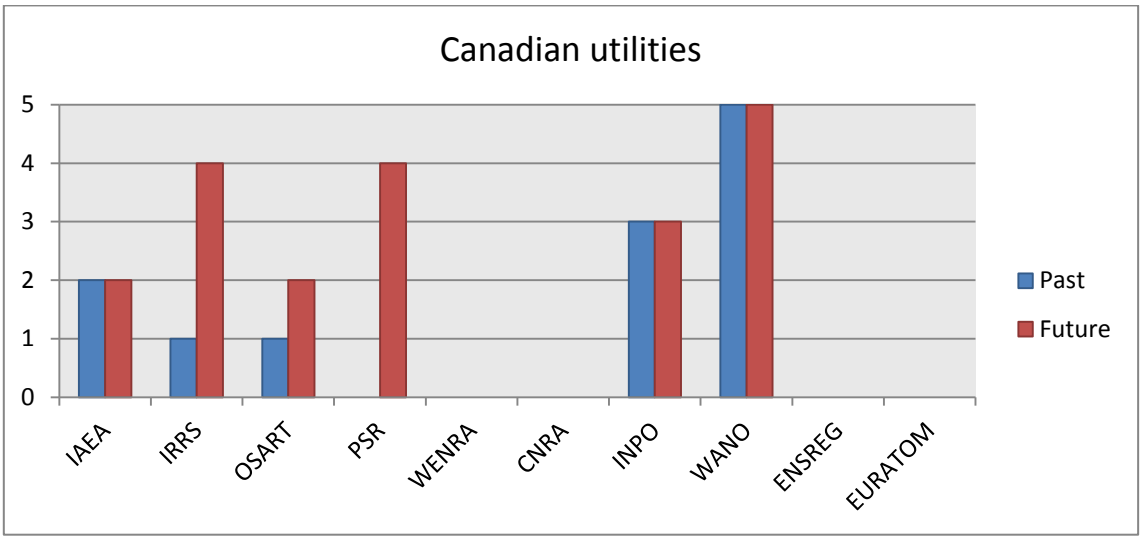

Figure 7 The organizational significances given by the Canadian utility.

As can be seen in Figure 6, the Canadian regulator considered IAEA, IRRS and CNRA as very influential both in the past and in the future. Other important influences in the past were WANO and the PSR, predicting that the latter would increase to the highest significance in the future. Noticeable is that INPO had no influence at all on the regulator, neither was any influence expected. The largest increase of influence was expected from the PSR. Although they were equally weighted, the regulator considered CNRA as the most important:

> *"CNRA is more important than the IAEA because it concerns only the developed countries. IAEA is an organization that must account for all the member states, even those without a sufficient infrastructure."*

As can be seen in Figure 5, the Canadian utilities regarded WANO and INPO as the only organizations that have had large impact on their work, giving WANO the highest significance. As for the future, IRRS, OSART and the PSR were expected to increase, with WANO staying as the most influential organization. The utilities considered IRRS and INPO as indirect influence coming through the regulator. When asked about the high significance of WANO, the utility responded:

"We stand up and salute when WANO comes. CNSC feel that we prioritize them higher but that is not true. CNSC is prioritized all the time while WANO is prioritized only on the rare occasions they are here."

Noticeable for Canada is that the utility expected influences from international organizations to increase to a higher extent than the regulator did. This does however appear contrary to the results of the survey where the regulator rated international organizations as having high influence.

When asked for other organizations and services that had impact on their work, both the regulator and the utility considered the CANDU Owners Group (COG) as the most influential. The regulator also thought that the importance of the organization would increase, saying that:

"The industry comes with one voice and talks to us."

Besides from interaction with the regulator, COG also works with technical solutions and information dissemination.

When asked for how large significance international organizations have for supervision and safety work, the Canadians responded according to Table 8.

Table 8. The respondents' view of how much their work was affected by international organizations. 0 equals no significance and 5 equals very high significance.

CNSC	Utility
5,0	4,0

This makes Canada the country that claims to have the largest influence from international organizations of the ones assessed.

4.2.4 USA

The following organizational significances were given by the U.S. respondents, subjectively weighting the impact from different organizations; Figure 8 and Figure 9.

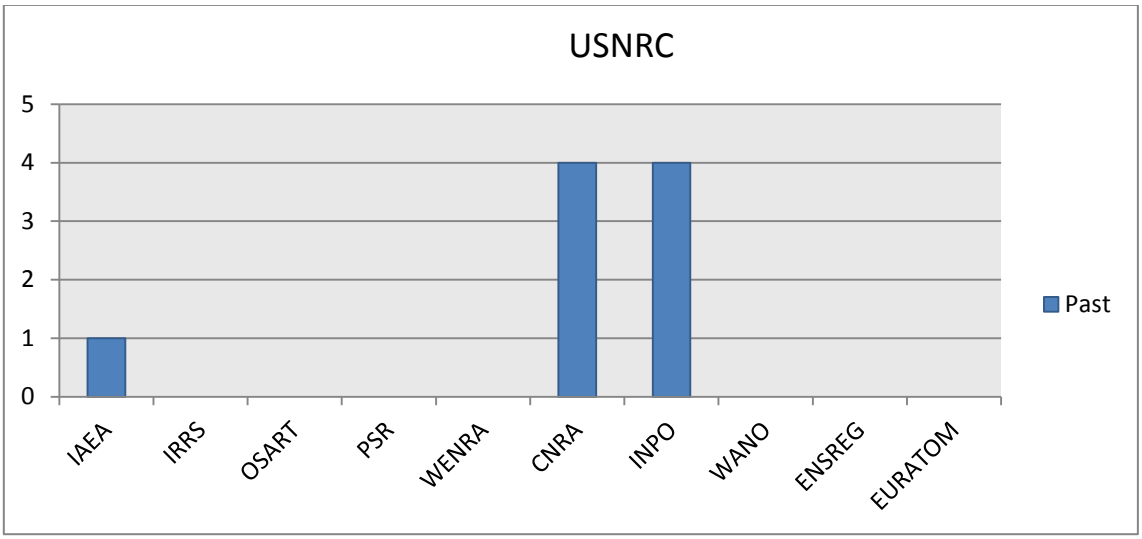

Figure 8. The organizational significances given by the U.S. regulator.

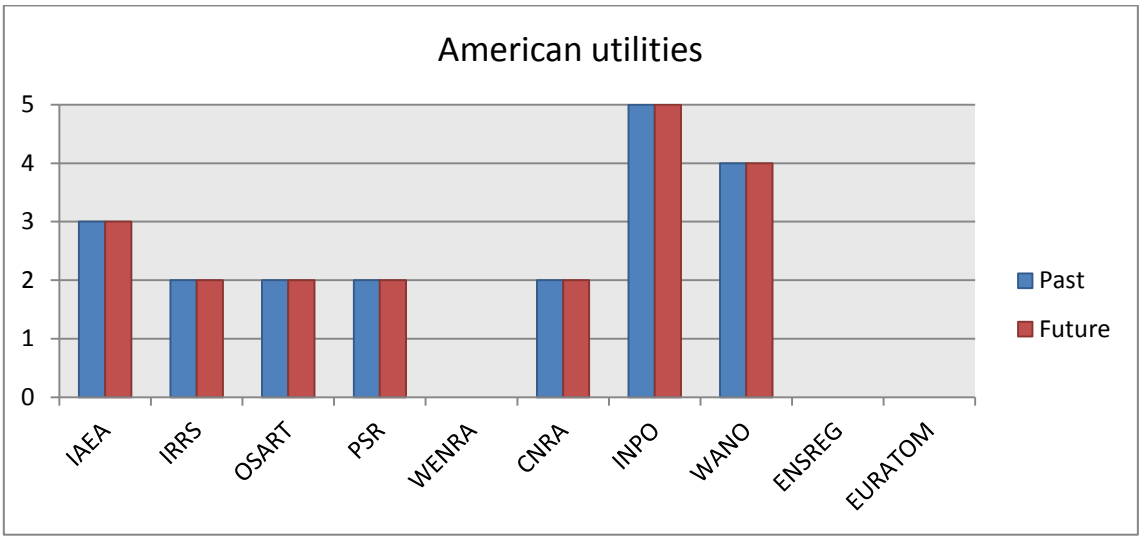

Figure 9. The organizational significances given by the U.S. utility.

As shown in Figure 8, only the past influence of the international organizations is shown. This is due to the respondents´ lack of insight in how these factors will develop. In the past, the U.S. regulator highlights both CNRA and INPO as important and influencing. INPO was even regarded as a complement to the NRC, having the advantage of being an industry group:

"It is much better if an industry group goes to a utility/plant and tells them what they are doing wrong than if the authority does it."

IAEA was considered less important, being a political organization while CNRA was regarded as more fact-oriented. As one of the regulatory respondents put it:

"I go to Vienna to teach and I go to Paris to learn."

The U.S. utility considered INPO, WANO and IAEA to have been the most affecting organizations in the past, see Figure 9. Noticeable here is that no increase of influence was expected at all, with all of the considered organizations staying at the same significance.
When asked for other relevant organizations affecting their work, both the regulator and the utility recognized the Nuclear Energy Institution (NEI) as being important. NEI provides technical support and reviews in specific technical issues. Furthermore, NEI also develops policies on key legislative and regulatory issues affecting the industry.

When asked to weigh the total influence from international organizations, the U.S. respondents replied according to Table 9.

Table 9. The respondents' view of how much their work was affected by international organizations. 0 equals no significance and 5 equals very high significance.

USNRC	Utility
1,0	4,0

Noticeable in the response to this question is the low amount of influence the USNRC claim to get from other organizations.

4.2.5 Comprehensive analysis

In Sweden there is a consensus between the regulator and the utilities that the overall organizational influence is increasing (Figure 2 and Figure 3). The regulator lists WENRA, CNRA and PSR as the largest influences in the future, closely followed by IAEA and its service IRRS. According to SSM, the impact of the organizational influence on the supervision was ranked 4, see Table 6. It is therefore reasonable that these organizations and services will have a large impact on the evolution of the Swedish regulation. This will most likely lead to increased harmonization with WENRA, CNRA and IAEA as the primary drivers. The focus on PSR is most likely a response both to remarks given in the IRRS review 2012 [25], and the fact that the Swedish nuclear fleet is aging. The regulator also highlighted the EU-directives, as they must be adopted in the national regulation, and are likely to result in an increased control in the nuclear safety area.

The Swedish utilities recognized the same organizations as the regulator, adding WANO and raising ENSREG somewhat. ENSREG was meant to increase, not only because of the stress tests, but due to an increased European cooperation. All of the utility respondents recognized WANO as very influential and rising.

In Finland, both regulator and utilities consider the organizational influence as increasing. The regulator regards IAEA and WENRA as the organizations that will have most significance in the future; also PSR will have large significance. The Finnish regulator does however regard influences from organizations somewhat less important than his Swedish colleagues, ranking it as 3, see Table 7. The Finnish regulatory model is however already more adapted to international standards, this is shown by STUK getting few remarks during the IRRS review. This makes it likely that the Finnish regulatory model will change in a lower extent, or at least more slowly than the Swedish.

The Finnish utilities ranked WANO, IAEA and PSR as most significant. As PSR is a part of their operating license renewal it has a direct importance. VTT was said to have a large significance, having an independent technical research and consulting resource was regarded as very valuable.

In Canada, the regulator considered IAEA and its service IRRS, CNRA and PSR to be most important in the future. As can be seen in Table 8, the Canadian regulator ranked the significance of organizational influence as 5 which is the highest amount in this study. The utility respondents in Canada predicted an increase of the influence from WANO, IRRS and PSR, which corresponds well to their European colleagues. The Canadian utility respondent ranked the total organizational influence as a 4, making Canada the country in this study claiming to get the most organizational influences.

The U.S. regulator respondents claimed to get the lowest amount of total organizational influences in this study, ranking it 1. CNRA and INPO were the only organizations that were regarded as influencing at all. Compared to all the other regulatory respondents, this is noticeably low. The utility respondents claim a much higher total influence, ranking it 4, which is above average of the utilities from other countries. According to the U.S. utility respondent, INPO and WANO were the most influencing organizations.

4.3 Relationship between authority and licensee

The purpose of this heading was to understand how the authorities and utilities perceived their relationship. Emphasis was put on what is good and what is bad and how well they were able to have constructive dialogs. The following questions were asked:

Q9. Are there any neutral national forums where authority and licensee can converse?

Q10. Describe briefly your relationship with the authority.

Q11. What advantages and disadvantages do you from a safety perspective see with this type of relationship?

Q12. From your perspective, what would an ideal authority – licensee relationship be like?

4.3.1 Sweden

How the respondents perceived the relationship between the authority and utility differed a lot between respondents in Sweden. Some were very satisfied with the current relationship and some were very dissatisfied. Overall for the utilities, the satisfactory level was by far the lowest amongst all analyzed countries. Exactly why that is, is difficult to say. However it is likely that the redaction of the regulations have had a significant impact.

When asked if there existed any neutral forums in Sweden, the respondents confirmed that no such forum existed. The forums that do exist are not neutral; the regulator and authority always have their roles. Furthermore many respondents were concerned that Sweden did not have a neutral expert organization as e.g. Finland's VTT. Such an organization would be very useful when the regulator and utility disagrees. Examples of non-neutral forums that currently existed were: SSM Conferences, Safety Manager Meetings, the Nuclear Technology Days and MTO-Seminars.

Many respondents from the utility were concerned that the communications has become too formalistic and that it is getting worse. Some argued that this increase is due to European influence and some that it is because of a decrease in regulator's technical competence. Typical comments about this subject were:

"If you lack nuclear power experience you will automatically become a formalist."

"The relationship is becoming more and more formalistic because of European influence."

"It is much better with an open dialog, but that requires technical competence. The technical competence has decreased dramatically at SSM."

Not all respondents shared this view of SSM. Some expressed the exact opposite:

"Our relationship works well. SSM has a lot of qualified employees, both managers and specialists."

"There is still a lot of informality, and it is needed."

"Overall, our relationship is open and close. Our communication is both single and bidirectional. You have to always be aware of the authority's regulating means."

As many of the respondents pointed out, the relationship is perceived very different depending on whom you ask. When SSM was asked how they perceived the relationship they said that it is exactly the way it should be and that it works well as long as everyone is aware of their roles. Many utility respondents agreed on the importance of being aware of your roles.

Some utility respondents were also concerned about the increasing number of injunctions that are handed out by SSM. They mean that this increase is not due to a decrease in performance but rather a change in how the regulator operates. This is how one respondent commented on the issue:

"We get injunctions all the time. If we send SSM an action plan of our intentions, we may get an injunction telling U.S. to do what we had already planned."

The problem with injunctions is that they immediately get top priority and hence steal priority from something else, perhaps with higher safety relevance. Therefore by writing injunctions the authority takes responsibility for which safety enhancements are most relevant. One respondent recommended that a solution to this problem could be some kind of grading scale on the injunctions. As of today all the injunctions have the same priority.

The deterioration of technical competence at the regulator was another reoccurring issue that the utility brought up. Some felt that technicians were replaced by jurist and behaviorists that knew nothing about the technical aspects of nuclear power. This has led to more bureaucracy and less dialog according to some respondents. A dangerous effect that lack of competence from a regulator might have is the lack of respect from the utility, which is something very undesirable for an authority. Having high technical competence was mentioned and emphasized as very important by several respondents in several of the visited countries.

When asked what an ideal regulator – licensee relationship should be like, the answers from the regulator were:

- A regulator should be independent.
- The regulator has his role and from that role the relation follows.

And from the utility:

- Mutual technical competence.
- In order to make decisions, regulatory sustainability and perspective is required.
- Understanding of each other's roles.
- Consensus about the most relevant safety issues.
- Communication of intentions.
- Juridical formalism should be avoided.

This is how one utility respondent summarized an ideal relationship:

"The ideal relationship would differ quite a lot from what we have today. The regulation should not be changed so much, it is pretty good the way it is. The plant design should not be changed as rapidly as we do today, the largest safety problems are introduced when major changes are performed."

4.3.2 Finland

In Finland the utility was overall pleased with the relationship with the regulator. They were particularly satisfied with the communication and their ability to have a constructive dialog. Moreover, the utility felt that the technical competence of the regulator was very high which they thought was a prerequisite for a good dialog. They also felt that STUK put a lot of effort in improving their organization and the relationship with the utility. This is how one respondent commented on it:

"STUK comes to the utilities once a year and asks us. about their work. They see us as their customers."

When asked if there existed any neutral forums were STUK and the utility can discuss different topics their answer was:

"Yes neutral forums exist. But we do not have one single forum; every topic has its own."

This comment describes quite well how the respondents perceived the situation. There seem to be many possibilities to have neutral discussions if desired and this question was not regarded as a problem. Some forums that were emphasized as very good by the respondents were the common training courses and management meetings. The management meetings occur twice a year and involve managers from the utility as well as managers from STUK. These meetings were very appreciated by the utility since they provide a good opportunity to discuss what works well and what does not.

Even though STUK has formally said that they do not give any oral approvals or approvals in advance, they can usually give some opinions. These opinions are much appreciated by the utility since it minimizes the risk of extra and unnecessary work. STUK can change their mind afterwards when they see the big picture, but this was not very common. Being able to give opinions and to keep a dialog during a project requires high technical competence and this was pointed out by the utility. One respondent commented on it like this:

"The perhaps most important thing with STUK is their technical competence. If you do not have that, you cannot make any decisions. It gets problematic if STUK becomes too bureaucratic since it creates unnecessary work."

When asked what an ideal regulator – licensee relationship should be like, the answers from the regulator were:

- The regulator must be clear and consistent.
- The regulator should focus on the most significant issues.

- The licensees should be willing to fulfil the requirements and to enhance safety.

And from the utility:

- Finland has an ideal relationship as it is today.
- Openness; a licensee should always be able to pick up the phone and call the regulator if there is a problem.
- Knowledge and integrity are important.

4.3.3 Canada

Both the utility and regulator in Canada were overall pleased with their current relationship. They both felt that the other part put an effort in helping each other. Further, both parties described their relationship as open, close and two-way. This is how the utility respondent described it:

> *"The regulator wants us to just pick up the phone and call if there is a problem, they do not want all of our communication to be formal letters."*

When the respondents were asked if there existed any national neutral forums they listed the following: CANDU Owners Group, the Canadian Nuclear Association, CNSC Commission Meetings, National Workshops and Conferences. This is how one respondent commented on it:

> *"There are lots of conferences where we chat without formal decisions. Here we are not afraid to speak up because they might ram it down our throats on our next licensing hearing. These meetings can be successful or not, they should however definitely exist."*

When asked what an ideal regulator – licensee relationship should be like, the answers from the regulator were:

- CNSC has an excellent approach in dealing with licensees and applicants as it is.
- CNSC is currently as open and transparent as possible.

And from the utility:

- Open
- Honest
- Trustworthy
- Consistent
- Good communication

4.3.4 USA

When one of the representatives from the NRC was asked about their relationship towards the utility, 4 important aspects were emphasized:

- Firstly, the regulator should have an arm's length relationship to the licensee. Arm's length meaning that the regulator should not be too friendly but at the same time not too harsh. The regulator is neither the enemy nor an adversary.
- Secondly, the relationship must be professional and not personal. It is hard to get personality out of it since the industry generally does not like regulators, and the regulator can get to a point where they think they are the police, which they are not.

"With a high level of technical expertise you can have a professional relationship and talk with any utility in the U.S. almost on an equal basis."

- Thirdly, the regulator must be firm but fair. Firm being finding out what should be the safety position or regulation and stick to it. Fair being not overdoing it, i.e. require things that go beyond the regulation just because you can.
- Fourthly, the dialog with the utility should be completely open on safety issues.

One of the NRC respondents stressed the importance of having well working neutral forums between a regulator and licensee. The biggest such forum in the U.S. is the Regulatory Information Conference which is held every year. This conference was described as extremely useful since it allowed non-adversarial discussions with the NRC and its licensees. Further was INPO's general conference mentioned as another such forum, however quite much more political.

When asked what an ideal regulator – licensee relationship should be like, the answers from the regulator were:

- The relationship must be professional.
- Nuclear engineering is a highly technical area which means that the discussions must be technical and the staff must be technical professionals.
- A regulator must be brutally self-honest and not worry about diplomatic issues.

And from the utility:

"The current relationship established between licensees and the USNRC is a positive one that has allowed the successful operation of over 100 nuclear power reactors in 31 states, operated by 30 different power companies."

4.3.5 Comprehensive analysis

Many interviewees stressed the importance of neutral forums, since it is very important to be able to speak your mind without authority repercussions. Of the visited countries in this study, Sweden is the only country where the utility interviewees have been very displeased with the situation in this area; especially when it comes to the lack of a neutral expert organization. Representatives from the NRC and CNSC emphasized the fact that it is very important to have forums were the regulator is not an adversary.

There is no question that an informal relationship introduces the risk of becoming "too good friends". The big disadvantage with this friendship is that the licensee may use it for his/her advantage. According to some utility respondents in more than one of the analyzed countries, this occurs occasionally. Typically the regulators are aware of this problem and it is up to them to keep sufficient distance from the licensee. Here it is important for both parties to be aware of their roles and further particularly important for the utility not to take advantage of the regulator when presented the chance. Examples of when the regulator had found out that the utility had tried to trick them were told by more than one regulator respondent. This is how one of them commented on this problematic:

> "*The moment a licensee play games they put their whole approach and integrity for questioning.*"

The big advantage with informal discussions and relationships is that it they lead to more trust from the utility which in turn lead to more honesty and openness as well as more constructive discussions.

4.4 Affecting factors

The purpose of this part is to give a view of which factors that have had and will have the largest influence on both regulatory work and safety work. Emphasis will be on if this influence has changed in the past or will change in the future. The respondents were presented a list of factors (see Table 10) and were then asked to weigh the past and future significance of the different factors.

Table 10. List of factors affecting regulatory and safety work presented in the questionnaire.

Affecting factors
Political situation
Fees, grants and taxes
Competence
Aging
New analysis methods
New-Build
Operations and experience feedback
Health-Safety-Environment (HSE)
Safety Culture

The following questions were asked:

Q13. Assess for each factor (in Table 10) how large significance you think it have had the last 10 years and how large significance it will have in the future. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very significant influence.

Q14. Can you think of any other factors that affect the regulatory supervision and safety work? In that case, which are they and how large significance will they have or have had?

4.4.1 Sweden

The following rankings of the given factors were made by the Swedish respondents; see Figure 10.

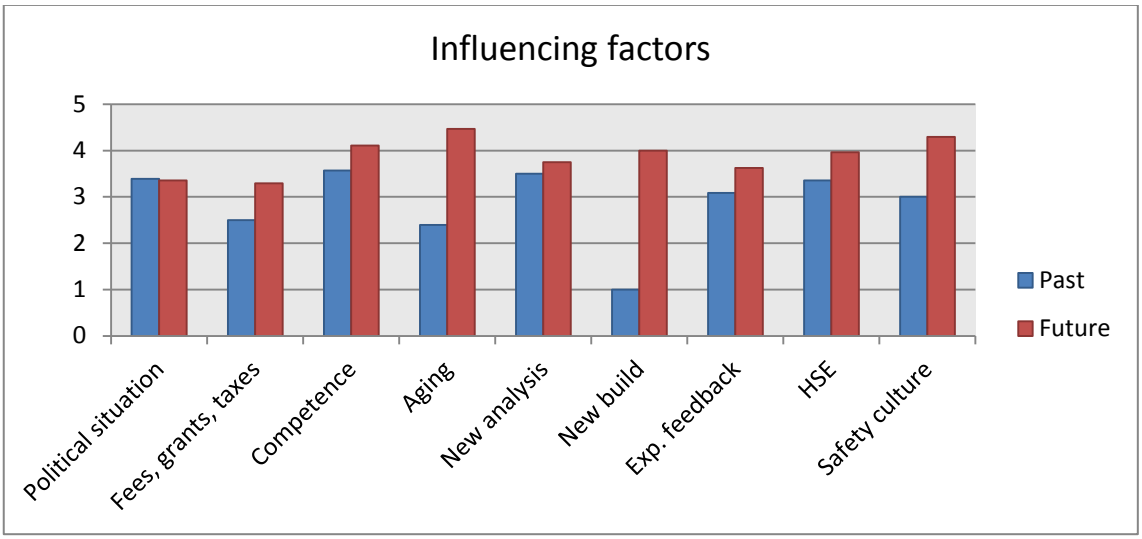

Figure 10. The significances of the affecting actors given by the Swedish respondents.

As the opinions on the affecting factors were similar (with a few exceptions) among both regulators and utilities they are presented composed in the diagram. Political situation was considered fairly stable whereas the others factors were increasing in various extents. With new-build as a current topic in Sweden, its increase was expected. Safety Culture rising may be explained with regained focus after the partly Safety Culture related accident in Fukushima. Many interviewees felt that the term Safety Culture was heavily abused. The term was regarded as commonly used when you cannot point directly at a specific problem. The problem that arises when "everything is Safety Culture" is that technical issues become human issues. Many were also concerned that it would get even more focus in the future and that it might take focus from other important aspects. Human performance was generally considered as the area where the regulator exceeded the utilities in competence. It was however felt that the approach had become very academic and not very practical. The increased focus on aging is due to the fact that a large part of the Swedish nuclear fleet is or will soon be entering LTO. One of the utilities described the aging problem as follows:

> *"The biggest problem with aging is that no-one wants to invest in safety for a power plant that will soon be decommissioned. At the same time the oldest plants are probably those that require most resources in order to run safe."*

The increased effect of fees, taxes and grants can be explained with the current strained situation of the Swedish nuclear industry. Low electricity prices combined with large and costly modernization projects have lowered the margins. According to a utility respondent:

> *"Fees and taxes used to be something that was complained about, now the industry is suffering."*

Competence rising in significance was considered to depend on several factors. The Swedish nuclear industry is subjected to a challenge because of the retirements of large amounts of skilled personnel, at the same time as experienced personnel is hard to find. Lack of political

and financial sustainability, recent accidents and international influences are likely to make young people invest in careers in other areas than nuclear. As one of the utility respondents put it:

> *"New-build is a prerequisite to keep the competence. Who wants to work in a business that will be discontinued? This will have an enormous significance."*

Another respondent claimed that the competence today is spread out on a large amount of people, which increases the requirements on leadership in order to properly use the competence:

> *"The lack of both sufficient leadership and the ability to prioritize, results in that the competence is not used properly. The larger the organization, the larger this problem becomes."*

According to some utility respondents, the extensive use of consultants within the nuclear industry has become a significant financial problem. This is how one respondent expressed it:

> *"Consultants are used in a very large extent; they strengthen their positions and then bring in their consultant colleagues. The organization grows as long as there is nutrition and space; we are now out of nutrition."*

Operational experience and feedback was regarded as important; all of the respondents had various programs for controlling this factor. Many of the respondents claimed that they were very good at compiling and analyzing data, the implementation was however worse. This was realized as many of the mistakes that occur have happened before. This factor was considered to get increased significance. With the utilities having smaller margins, they cannot afford to make the same mistakes over and over again. New analysis methods were recognized as having effect, but as the methods evolve over time, the change was regarded as fairly stable.

The Swedish respondents were asked to identify other factors that affect their work. The regulator recognized different types of events, incidents and accidents, both national and international. Also, certain things are contemporary to assess, they get increased significance. Factors identified by the utilities were leadership, this having an increasing significance. Especially how the top management regards safety issues, they set the level of ambition. One identified important factor that was said to have affected the Swedish power industry in a large extent is the deregulation of the electricity market. This was regarded to have resulted in an unstable financial situation with large fluctuations that made it hard to recoup large investments. One large investment that most likely is very difficult to recoup, at least with the electricity prices today, would be building new nuclear power plants.

4.4.2 Finland

The following rankings of the given factors were made by the Finnish respondents; see Figure 11.

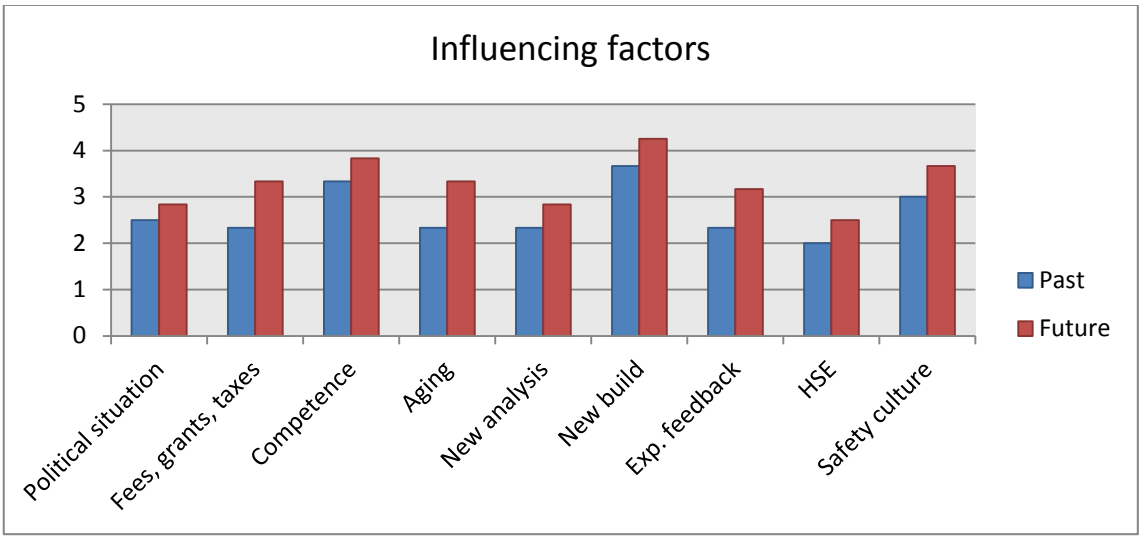

Figure 11. The significances of the affecting actors given by the Finnish respondents.

The answers from the Finnish respondents are very similar to the ones from their Swedish colleagues. Comparing Figure 10 and Figure 11 gives that the factors that differs the most between the countries are new-build and aging. Also, all the factors were ranked somewhat lower, meaning that the Finnish respondents are affected to a lower extent than the Swedish respondents. As Finland has had ongoing new-build since many years and also has met some new-build-related obstacles, this result was expected. Aging was regarded as not especially critical and not increasing much, this can be related to the fact that the Finnish nuclear fleet is younger than the Swedish, making this a somewhat more distant problem. According to the respondents, finding experienced personnel was not very difficult, mainly because of the adversities of the paper industry. The impact of fees and taxes were said to starting to get tough, but not critical yet. One of the utilities explained the high capacity factors of the Finnish plants in this way:

> *"We have a tradition of making one small change at the time and to evaluate it before we proceed with the next investment. This differs from Sweden where rather large investments are made continually."*

The focus on Safety Culture was said to increase, STUK performs Safety Culture reviews on the plants. As in Sweden, many of the respondents thought that the term was misused.

> *"Safety Culture as a term is something difficult, nobody knows what it is. Safety Culture is made of how you work. It is a bad term that should not be used."*

When asked for other influential factors, the regulator mentioned the overall economic situation in the country and in Europe. This has a large tendency to influence companies and that may influence the regulator as well. Cost reductions and savings are affecting the plants; this can be an area that needs to be observed.

The utilities mentioned the media, saying it affected them quite much, as things presented in media put pressure on the regulator. Currently the situation was good, but this has varied. The media was however regarded as nuclear-neutral in Finland.

4.4.3 Canada

The Canadian respondents ranked the affecting factors according to Figure 11 and Figure 12.

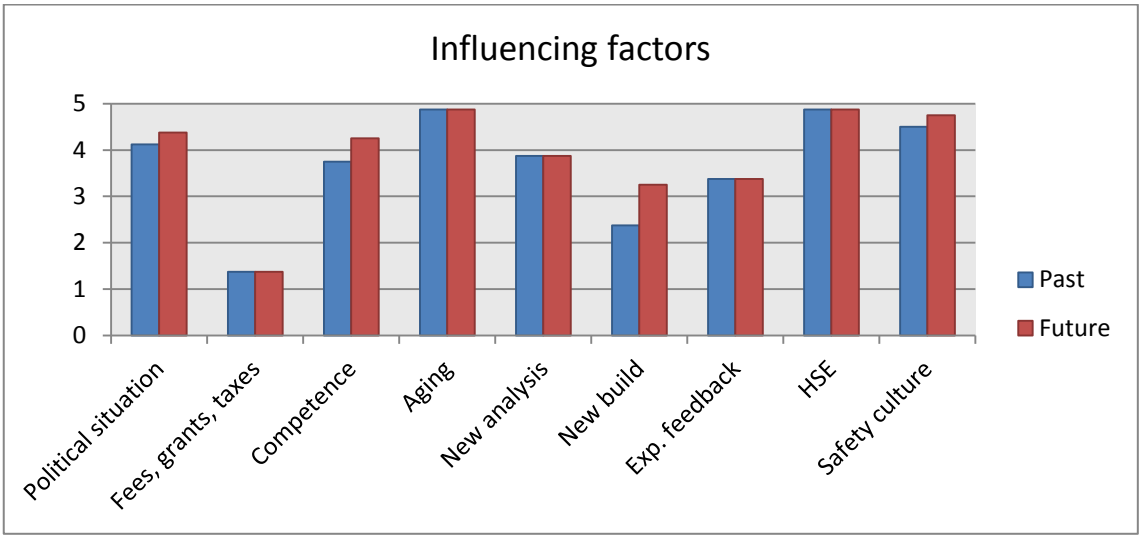

Figure 12. The significances of the affecting actors given by the Canadian respondents.

The factors that the Canadian respondents considered most affecting in the past were aging, HSE, Safety Culture and political situation. All of these factors were predicted to remain as affecting in the future or to increase slightly. The reason for the large importance of aging was explained by the utility:

> *"Aging is a big issue. The CANDU reactor pressure tubes can only be run for so long because of the change in the metallurgy. So eventually we will have to replace them (usually after 25 years). This is extremely expensive."*

HSE and Safety Culture were regarded as important and prioritized areas, both for the regulator and the utility. Political situation was regarded as important, partly because of the public relations:

> *"Sometimes the public have influenced the regulator to enforce new requirements on us. We put a lot of effort on public relations to maintain a positive attitude."*

Competence was ranked high and rising. The utilities considered PSA (PRA) as an area with a future risk of deficiencies in availability of personnel and loss of subject matter competency, mostly due to demographics and the unavailability of specialized training. The answers from the Canadian respondents regarding the affecting factors imply stability as future effects are predicted to more or less equal past effects.

When asked for additional affecting factors, the regulator mentioned non-governmental organizations and aboriginal groups.

4.4.4 USA

The following rankings of the given factors were made by the U.S. respondents; see Figure 13.

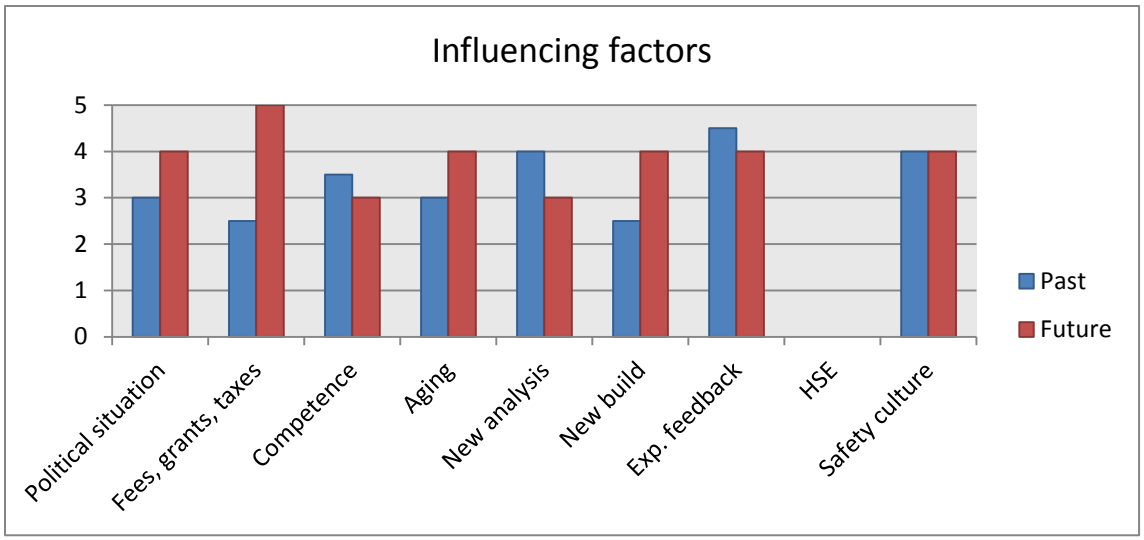

Figure 13. The significances of the affecting factors given by the U.S. respondents.

According to the U.S. interviewees, the most affecting factors in the past were: experience and operational feedback, new analysis methods, Safety Culture and competence. Factors predicted to be important in the future were: fees, grants and taxes, political situation, aging, new-build, experience and operational feedback and Safety Culture. The rankings imply a situation in change, especially when it comes to fees, grants and taxes, political situation and new-build. According to the utilities, increased requirements challenge the licensees:

> *"Plants are currently challenged to meet the increasing requirements and resources associated with increased oversight following Fukushima. Ultimately, this impact could cause some units to shut down, as evidenced with the closure of four U.S. units in less than 16 months, with one additional unit to close at the end of 2014."*

When asked for additional affecting factors, the U.S. utility respondent stated that USNRC has been structured to insulate it from various influences in its decision making in several ways. This does not guarantee absolute independence, but the aim is to minimize factors that can negatively affect the oversight.

4.4.5 Comprehensive analysis

Political climate was regarded as something that has had or had importance in all of the visited countries, although in various extents. Fees, grants and taxes were also regarded to have large effect on the work performed. Here, a distinction can be made between the regulators and utilities as the utilities were far more burdened by financial aspects than the regulators. A concluding remark from one of the interviewed utility respondents:

> *"Politics and money are the two factors that will decide of nuclear power survives or not."*

Low electricity prices, unstable political climate and the increased costs of building new nuclear have resulted in that several utilities sees it as an investment that cannot be recouped, or at least is associated with too high risk. As the existing plants in many countries are old and associated with high costs for maintenance and regulatory compliance, it is likely that they will be replaced with something else than nuclear.

Competence was ranked high and increasing in importance by almost all the respondents. Both regulators and utilities agreed on that the ability to find competent personnel will affect the nuclear oversight and the development of the safety work. The ease of finding sufficiently experienced personnel varied between the countries, this was though mitigated by the fact that many utilities train the personnel themselves. Specific competences such as PSA (PRA) were considered scarce or associated with risk of becoming deficient, partly because of decrease in educations. Analogous with the approach of the utilities, young people investing by choosing their careers are likely to choose areas with either better sustainability or risk-reward ratio.

In Sweden, several utility respondents felt that the regulator had a decline in their technical competence. This was believed to come from several factors. One reason was that more juridical and formalistic approach raises demands for skills other than technical. Also, difficulty finding competent people was regarded as a reason for the decline.

One factor that was associated to competence was the ability to run projects. The Finnish utilities emphasized that they run smaller project that require small investments and lower resources, they also evaluate the results before starting a new project. These projects generally go well. The Swedish licensees generally run very large projects that require large investments and massive resources; these projects generally do not go very well in terms of planned time and cost. Larger projects are more demanding, not only in terms of investment and resources, but in skillful planning and leadership. One of the Swedish utility respondents claimed that they must become better at running large projects. A quite obvious remark would be that they should become better at running the project size they can handle.

Aging was a factor that was considered important and rising. As all of the countries studied mainly had plants that were built between 60s and 80s, long term operation of the parts of the nuclear fleet was imminent. In Canada, this had already been actualized as their reactor design requires periodic exchange of major components.

All of the interviewees recognized new analysis methods as something that both affected and had affected their work. The evolution of the methods was however said to have been continuous and that this have mitigated their impact.

The Swedish and Canadian utility respondents regarded new-build of nuclear as something that was not feasible under current circumstances or in the near future. The main prerequisites, i.e. stable political climate and stable sufficient electricity price, were not considered present.

All of the respondents had and used systems for operations and experience feedback. A common opinion was that the compiling and analyzing of data was more successful than the implementation.

Safety Culture and human performance was regarded as very important by all of the interviewees. Many also agreed that the term was being abused in various ways. The poor definition was claimed to facilitate the misuse, enabling that everything can be regarded as Safety Culture. Safety Culture was also said to sometimes be used to excuse poor technology, putting focus on the people handling it. The importance of the cultural effects on safety should not be underestimated as many of the severe nuclear accidents have had this root cause in common.

Other recognized factors that affected the safety-work were:

- **Events and accidents**, as they were said to have had large significance for the evolution of the regulations.
- **Management**, how the top management look at safety issues has large effect, they set the ambition.
- **Leadership**, as the competence today is distributed over a large amount of people; sufficient leadership will increase in importance.
- **Economy** was considered highly important for the work of the utilities. This was related mostly to corporate and national economy but also the economic situation in larger contexts, for instance in the European Union. The respondents that were affected the most by the financial situation were the Swedish utilities, claiming that they are going under as it is today. And, as recognized by the Finnish regulator; cost reductions and savings do affect the plants.
- **Media** was also considered to be affecting the work of both utilities and regulators. For example, in Canada, the media have on occasion focused so much on minor problems that both licensees and regulator have been forced to perform large investigations just to prove the insignificance. In Sweden, organizations like Greenpeace have occasionally had similar effect.

4.5 Level of detail within the reactor requirements

An important factor to take into account when comparing any regulations between countries is how detailed the requirements are. I.e. to what extent do the requirements specify what is expected of the licensees. The purpose of this heading was to get the respondents view on how detailed the requirements are, if the level of detail is changing in any specific direction and the advantages and disadvantages with the current level of detail.

The level of detail is an in particular interesting subject when it comes to nuclear regulations since it can be regarded as linked with the responsibility distribution. I.e. a higher level of detail is likely to move responsibility towards the regulator and a lower level is likely to move it towards the licensee. Question 16 aims at understanding the respondents view on this issue.

In the first question the respondents are asked to quantify the level of detailed on scale from 0 to 5, where 0 equals no detail at all and 5 very detailed.

Q15. How detailed are the requirements that the authority imposes on the licensees?

Q16. Why do you think that level of detail is preferred?

Q17. Describe how the level of detail has changed. (If it has changed)

Q18. If the level of detail has changed, what does this change depend on?

Q19. What is your impression of this change in the level of detail? Has it had generally positive or negative consequences?

Q20. Is there a risk that the changes in the level of detail affect the responsibility distribution?

Q21. How do you think the licensee/regulator perceives this change? Do they want a higher or a lower level of detail?

4.5.1 Sweden

The average value of how detailed the Swedish respondents perceived the reactor requirements, is seen in Table 11.

Table 11. Perceived level of detail in Sweden.

SSM	Utility
1,8	2,6

Of all the analyzed countries, Sweden was the country with the lowest perceived level of detail. This was an expected result since Sweden in this particular context is quite known for having an exceptionally low level of detail. Why that is depends on a range of factors according to the respondents; however events, history and culture probably have had the highest significance.

Historically, both the vendor and the buyer were very competent in Sweden and therefore no detailed regulation was required. Furthermore since the buyer was fully state-owned, there was no real need to have a strong regulator. Today the situation is different. The level of detail has to increase in Sweden due to several reasons; International pressure (harmonization), events and accidents, politics and the fact that the companies that own and operate the plants are different today. New-build and power up-rates have also had a significant impact in Sweden; this is how one of the SSM respondents put it:

"The level of detail is dependent of the current need. Earlier, there was no need for regulations handling new-build since no new plants were supposed to be built. When we realized that we would have to modernize in order to increase the safety, the design regulation was created. Both we and the licensees underestimated the modernization work severely. Maybe more detail would have increased the clarity."

Almost every respondent also recognized that the level of detail is culturally contingent. Again, the typically trusting relationship between authorities and utility explains to some extent why a low level of detail has been preferred. Some of the respondents' comments on this issue follow:

"The nuclear safety regulation is a projection of the development we have had in our society. The regulation in other countries is a projection of their tradition and culture."

"We have freedom under responsibility with a high focus on self-assessment."

"The level of detail is culturally conditioned; one will assure that the licensee takes the responsibility for safety."

"Swedish regulatory tradition in general: We do not want to be overregulated."

Some respondents also recognized that the level of detail was quite event-driven. I.e. many of the changes can be directly correlated to some of the major nuclear accidents as well as smaller events. Not everyone agreed that this was the case. One respondent said that accidents have not had such a large effect on the level of detail as for example international harmonization pressure. The most influential international organizations in this context are WENRA and IAEA.

"International influences have the largest effect, not accidents. An example: The filter resulting from TMI had a low level of detail, this enabled freedom to choose an optimal solution."

Almost all respondents agreed that the level of detail in Sweden had increased and that it will most likely continue to increase in the future. One respondent expressed the following view regarding the changes:

"The level of detail within the regulations has not yet changed, but the interpretations have. SSM writes informal papers which are used as guides for their own staff to interpret the regulations."

The reason these papers exist is likely because of the low level of detail in the present regulation.

When the respondents were asked about their perception of the change in level of detail, it was generally positive since the Swedish regulatory model needs a "shape-up". The utility is in need for more clarity and SSM seem to be aware of this. However the utility had some concerns about the changes to come. The concerns include:

- Further increase of bureaucracy.
- That the new-build requirements shall apply to old plants.
- If the regulator takes on too much responsibility.

The view on how the level of detail affects the responsibility distribution was unanimous amongst all respondents except for one. The general opinion was that an increased level of detail would shift responsibility towards the regulator. This is how one respondent commented on the issue:

"A disadvantage with increased level of detail is that the regulator assumes some of the responsibility."

When SSM was asked if they thought the licensees wanted a lower/higher level of detail, their answer was:

- Some like them and some do not. Younger generations tend to like more detail.
- Some tend to always want the opposite of what the authority give.
- High level of detail is good for modernization projects since the utility want to know at what level they should relate to.

When the utility respondents were asked the corresponding question, their answer was divided:

- SSM probably do not want higher level of detail, but they have to comply with IRRS.
- They probably feel comfortable with clear requirements.

4.5.2 Finland

The average value of how detailed the Finnish respondents perceived the reactor safety requirements, is seen in Table 12.

Table 12. Perceived level of detail in Finland.

STUK	Utility
4,0	3,3

Finland is generally regarded by other countries to have very detailed regulations. Many respondents have commented that after the USA, Finland has the most detailed requirements in the world. According to the answers in Table 12, not all the Finnish respondents seemed to agree. When the Finnish respondents were asked why that level of detailed was preferred, their answers differed a lot. However there was one fact that most respondents agreed upon: Even though the requirements are detailed, they are written with the leading principle that they do not want to restrict how the utility chooses technology. Some comments about why that level of detail is preferred follows:

"Because of the thoroughness of our inspections of components, materials and construction design. This requires very detailed regulation so that we do not end up with compliancy problems. This may trace back to early years when detailed requirements were necessary in order to have detailed outcomes from the vendor (USSR)."

"We had some problems interpreting the regulation earlier and the regulator had nothing to refer to. One has understood that it is beneficial for both industry and regulator to increase the level of detail."

"The level of detail is a question of responsibility, but it is hard to determine what is sufficient."

When asked if the level of detail recently had changed, the general answer was that it had not, until a recent increase. The reason why it is increasing right now is due to three main factors: International harmonization (especially from WENRA), events (Fukushima) as well as new experiences from the new-build of Olkiluoto 3. However, not all respondents agreed that the level of detail had remained static until now. One recognized that the TMI and Chernobyl-accidents had a significant impact:

"TMI was the start but Chernobyl was the final hit when we started to advance in regulations."

Due to some misinterpretations in the past, STUK has also tried to increase the clarity of the regulations. This have by some respondents interprets into a higher level of detail even though that is necessarily not always the case. In the future, STUK predicts that the level of detail will increase in Finland:

"We are currently updating the guidelines so that optional requirements are decreasing. There will be more 'shall'-sentences in the future."

When the respondents were asked if they were satisfied or not with the increase level of detail, they were generally positive. Mostly because it would increase the clarity, thus the utility would to a higher extent know what to relate to.

"When it comes to analysis we need to have very detailed regulations; how to perform the analysis and what the acceptance criteria is."

Moreover, a higher level of detail would according to some respondents be advantageous for new-build. The only recognized problematic with an increased detail in Finland was that it limits the utility's choices.

By the respondents in Finland, the opinions about the level of detail and the responsibility distribution was divided in half. Two of the utility respondents said that the licensees always have full responsibility for reactor safety; both in practice and by law. The respondent from STUK and a third utility respondent did not agree. This is how they commented on it:

"An increased level of detail does make us (STUK) more responsible; we are putting ourselves into the problem area."

"If the regulator says that we shall run the plant at a certain pH, they take responsibility. It is another thing if they e.g. would say that we shall run at the pH that gives the lowest activity accumulation. So in that sense, they do take responsibility."

When STUK was asked if they thought the licensees wanted a lower/higher level of detail, their answer was:

- The utility want clear and detailed requirements.
- Since they need to enforce requirements on the vendors, they need to be clear.

When the utility respondents were asked the corresponding question, their answer was divided:

- They probably think they have enough details today; they are probably going in the other direction.
- The regulator wants even more details.

4.5.3 Canada

The average value of how detailed the Canadian respondents perceived the reactor safety requirements is seen in Table 13.

Table 13. Perceived level of detail in Canada.

CNSC	Utility
3,0	3,0

The utility and CNSC have the exact same perception of their own level of detail. According to CNSC, the current level of detail is directly related to licensee behavior. Recently the level of detail has increased in Canada, but according to the respondents, it is not likely it will continue to increase in the near future. The changes in regulation are mainly due to three factors: International harmonization, accidents and the licensees desire to have more clarity. CNSC is currently working with adding even more clarity to the requirements but the prescriptiveness will be unchanged.

Both the regulator and the utility were satisfied with the changes. The utility have had their say in the development of the new requirements and they are pleased with the result. CNSC commented that:

> *"A higher level of detail may require less highly specialized personnel to carry out compliance activities. However the persons writing the regulations, the technical requirements and the guidance need to be highly competent."*

CNSC and the utility both agreed that there is a risk that increased prescriptiveness can lead to a shift in responsibility. The utility did however say that that this is not an issue in Canada; it happens occasionally that they take responsibility but then the utility usually tells them. CNSC commented that:

> *"Within the authority there is a risk that too much detail will shift oversight work from important safety measures to less important. We must be aware of this problem and focus on the most important aspects of nuclear safety."*

When CNSC was asked if they thought the licensees wanted a lower or higher level of detail, their answer was:

- They want consistency and a higher level of detail.

When the utility respondent was asked the corresponding question, his/her answer was:

- Some like it and some do not. Some people are almost obsessed with details and they cannot see the big picture. As long as you get to people with a balanced perspective, it is all good.

4.5.4 USA

The average value of how detailed the American respondents perceived the reactor safety requirements is seen in Table 14.

Table 14. Perceived level of detail in USA.

USNRC	Utility
5,0	5,0

One of the representatives from the NRC recognized that the U.S. probably has the most detailed requirements in the world. This prescriptive path jumpstarted with the TMI-accident and has since then increased incrementally. Another large impact had the Probabilistic Risk Assessment Policy Statement that was issued in 1995. This statement instructed the licensees to use PRA as a compliment to the defense-in-depth policy and as a consequence, the level of detail was increased. International harmonization was not considered to have had the slightest impact on the NRC in this matter.

The utility recognized two notable negative impacts with an increased level of detail. Firstly, it would increase the costs associated with the NRC reviews and secondly the fee which the utility has to pay to support the regulator would increase. When the NRC respondent was asked whether he/she was comfortable with an increased level of detail, the response was:

> *"As a regulator I am comfortable with more level of detail. Sometimes the industry did not like it. However the utilities wanted to know what is acceptable. You cannot just say "do good". They want detailed standards to know what to design to."*

The regulator agrees that with a high level of detail, the regulator take responsibility for the power plant. Thus NRC has a significant responsibility for the reactor safety in the U.S. This is how a former director of nuclear reactor regulation commented on it:

> *"Being the director of nuclear reactor regulation at the NRC was extremely stressful. I constantly had the fear that we would have an accident and that I was called before congress to answer why I allowed that to happen".*

But in the U.S., just as any other nuclear country, the law states that the utility is solely responsible for safety. It is important that they are responsible since they will be the ones dealing with an accident if one should occur.

4.5.5 Comprehensive analysis

The perception of the level of detail for the analyzed countries corresponds well with the expectations. U.S. is in this context known for having very detailed regulations and Sweden is known for having very comprehensive regulations. Finland was expected to also have a very high level of detail since their requirements originally came from the NRC. As mentioned earlier in the report, the Canadian nuclear program and its regulations are strongly inherited from the United Kingdom. The U.K. is, just as Sweden, known to have very comprehensive regulations and thus, so should Canada. However Canada has also been very influenced by the U.S. to become more prescriptive, and thus, their level of detail would be slightly higher than the U.K.

In all four countries the level of detail has recently increased or will probably increase in the near future. Not a single respondent talked about a decrease in neither the past nor the future. As stated by several of the respondents, the increase in detail depends on a number of factors. The main factors include: International harmonization, events and accidents, utility/licensee behavior and new experiences.

For international harmonization the main drivers are WENRA and IAEA. Both of these organizations have had a serious upswing recently and they are by many respondents regarded as very influential organizations. The IAEA documents have, according to some respondents, gone from being very comprehensive and not very useful, to being quite detailed and useful. International harmonization does affect the countries differently. The U.S. is hardly affected at all while Canada is slightly affected. The main effect is felt in Europe and especially for those countries that differ most from the others. When it comes to the level of detail, Sweden is a very good example of a country that differs a lot and will have to adapt.

Events and accidents were mentioned as a cause for an increase in detail in all four countries. For the U.S., the TMI-accident was a wake-up call that changed their regulations dramatically and in many ways, the rest of the nuclear power world followed. The recent Fukushima accident has caused dramatic changes in several countries, perhaps more in Finland than in other countries. According to one respondent, this accident caused STUK to change their regulations in such a dramatic way that it can partly explain why the Olkiluoto 3 new-build has been so delayed. Since nuclear accidents and their direct effects on the regulations not have been part of this project's scope, enough information to say with confidence that this is true has not been obtained. However it is very clear that event and accidents do have had a significant impact on the regulations. Many respondents have at several occasions raised concerns that nuclear power in the world today is right on the edge of survival. There is a substantial risk that another major accident in the next decade would mean the end for nuclear power.

Even though some respondents are of different opinions, a high level of detail will in practice be very likely to shift responsibility towards the regulator. The law in every country specifically says that the utility is solely responsible for safety and at the same time, it specifies how the power plant should be run. That can easily be perceived as contradictory.

Lower level of detail within the safety requirements were noticed to be related with higher use of self-assessment. As CNSC explained it:

> *"We do not directly inspect the concrete but we make sure that they (the licensees) have a sufficient inspection program."*

Of the assessed countries, this type of approach is mostly used by Sweden and Canada. Even though the NRC and STUK do have self-assessment requirements, their high level of detail and oversight decreases the room for extensive self-assessment. A high level of detail typically leads to focus on compliance. This tendency was noticeable in both Finland and the U.S where the utilities emphasized compliance rather than self-assessment. Furthermore, a high level of detail may also, according to some respondents, decrease the room for optimized solutions for certain plants. For countries that have many different types of reactors, this fact obviously becomes problematic.

4.6 Harmonization

This chapter aims to explain the respondents' opinions regarding the ongoing harmonization of nuclear safety regulation. The questions covering this area were:

Q22. (Regulator only) Does your agency work for an international harmonization of the reactor safety requirements?

Q22. (Utility only) What advantages come with an increased international harmonization of the reactor safety requirements?

Q23. What disadvantages come with an increased international harmonization of the reactor safety requirements?

Q24. Do you get the impression that the nuclear oversight is developing internationally in any specific direction?

4.6.1 Sweden

The Swedish regulator confirmed that they are working for an international harmonization of the requirements within the nuclear power oversight. The forums used for this were WENRA, CNRA and IAEA.

The largest advantage with harmonization, according to the regulator, was that a set of requirements developed by for instance IAEA has gone through a whole process with technical expert groups and been assessed at different levels, this makes it substantiated. The regulator can then support his requirements upon something that has been critically reviewed by many. Also, harmonized requirements give advantages when reviewing. Advantages for the industry were considered to include the simplicity of harmonized solutions that are commonly accepted.

The utilities also recognized advantages, especially when it comes to new-build. Globally harmonized requirements were also regarded as cost effective. Also, the ability to share experiences was thought to increase, as everybody have the same requirements, utilities can cooperate and discuss how to live up to them. A concluding remark from one utility respondent:

> *"We can for example buy NPPs. We are in a situation where nuclear is regarded as a non-profitable investment as it is, adapting it to unique national requirements becomes another obstacle."*

Some of the disadvantages that the respondents related to harmonization were that the requirements could be based on the lowest common denominator. This was however not considered as a problem in Sweden as SSM already has a high standard and most likely would not lower any requirements. The harmonization was also considered to be tough for those who perform less. Reaching consensus regarding where a safety level should be was also mentioned as a difficulty. A risk of too high level of detail was emphasized, as compliance control is very resource demanding, this could lead to a suffocation of the industry. One of the utilities recognized the risk of costly adaptations of the current nuclear fleet toward new requirements (retrofit). Also concerns about the risk of EU becoming one federal authority

were expressed. One of the interviewees considered that the harmonization would lead to difficulties in making changes in the regulation and that the Swedish regulator can be forced to approve something just because the NRC has approved it.

The last question in this section was asked to obtain the interviewees' beliefs of the international evolution of the nuclear oversight. According to the Swedish regulator, focus would be upon harmonization:

> *"More convergence and more consensus. The whole purpose of WENRA is to find a common level. This shall then be applied to national prerequisites, culture, tradition and the type of plants you have."*

Effort should also be made to improve the way of working as a regulator. Regulators should work in a similar way and have the same way of thinking.

The utilities expected more international collaboration, giving the post Fukushima stress tests as a good example. Increased harmonization and increased level of detail in the nuclear safety regulation was also expected. Predictions were also given regarding more European than national steering, for instance that IRRS would increase. According to another utility respondent, international reviews are increasing:

> *"Everybody wants international oversight after Fukushima. IAEA, WANO and others shall review in some extent. Soon you will need to decide who should handle the reviewing."*

Also that the international organizations will bring clarity was predicted:

> *"IAEA was quite washed out earlier, but has become clearer. WENRA is a newcomer with very clear rules. The clarity increases a lot."*

4.6.2 Finland

The Finnish regulator was asked if the agency worked for an international harmonization of the reactor safety requirements:

> *"Quite a lot, Finland has been one major player for new IAEA and WENRA requirements. We have our own interests in that international requirement level is similar to our own. We feel that same standards should be used in big and small countries alike. We support that IAEA is upgrading their guidance."*

Regarding the advantages of the harmonization, the regulator respondent stated that it would make it easier for international projects to handle any national requirements. Also, having more people behind the requirements would increase their credibility. The utility respondents regarded having the same requirements in the same market as an advantage. Common requirements makes it easier to buy reactors, the vendors will know if they fulfill the requirements, they can have an "off the shelf" solution. The opinion was also that harmonization is more important for new-build than for existing plants.

Among the disadvantages, the respondents mentioned that site specific requirements should not be the same, for instance regarding seismic protection. Also, the risk that the safety development of the best plants stop, that the vendors settle for a safety level that is sufficient for the harmonized requirements was considered. Another concern was that the vendors would rely too much on standardization, not respecting national requirements. Also, the risk that political opinions would play a larger role for the harmonized requirements was expressed.

When asked for the direction of the international evolution of the oversight, the Finnish regulator considered defense-in-depth, hazards, severe accidents and continuous improvement as focus areas. The utilities predicted more harmonization and increased level of detail in the regulation. Also, the comparison of safety aspects of different plants was thought to increase as well as increased focus on management systems. One utility expressed the following concern regarding the evolution:

> *"The world needs nuclear power and safety must be guaranteed. If it gets too complicated, too much bureaucracy and too political, then it gets too expensive."*

4.6.3 Canada

The Canadian regulator respondents confirmed that they are working for international harmonization of requirements; the forums used were MDEP and IAEA. Better public acceptance and increased regulatory effectiveness were considered to be the largest advantages of harmonization by the Canadian respondents.

As for disadvantages, the risk of ending up with the lowest common denominator was mentioned. Also, that common but in some cases unreasonable requirements are adopted, that the national priorities are not respected.

When asked to predict how the oversight will evolve internationally, the regulator respondents stated that more stringency, development towards harmonization and collaboration were likely to come. The utility predicted that the IAEA through IRRS would influence the regulator towards harmonization with international standards.

4.6.4 USA

When one of the U.S. regulatory respondents was asked if the agency worked for an international harmonization of the reactor safety requirements, he/she regarded that this was done to a very low extent and mostly by people who enjoyed travelling. International harmonization was not considered to have affected the U.S. regulation much.

The advantages associated with harmonization of reactor safety requirements were described by the U.S. utility respondent like this:

> *"The achievement of harmonization of nuclear safety standards could overcome national variations in safety regulations facilitating the emergence of a global market that offers a choice of a small number of reactor types that are recognized by regulators as safe and technologically mature. This important step could kick-start serial reactor construction worldwide."*

According to the U.S. regulator, the advantages of harmonization are for European countries, as it can facilitate consensus. The advantages for the U.S. or Asia were regarded as less significant.

The disadvantages associated with the harmonization recognized by the regulator were the risk of overdoing, and ending up with the most stringent safety requirements, which not necessarily mean that it is safer. An example of this is the German containment thickness; stronger, thicker and bigger is not always safer. The utility was more concerned about the risk of relaxation of the standards in order to make them more achievable by less mature nuclear authorities. Also, it was considered that international requirements could lack the flexibility required for them to be effective. Concerns about economic impacts of generic shortcomings in for instance design, resulting in shut-downs due to problems fulfilling international requirements were also expressed.

When asked to predict the international evolution of the nuclear oversight, the regulator stated that the national regulatory agencies were likely to move towards the same philosophy as the NRC:

> *"I think that the national regulatory agencies are getting more like NRC with time. I do not say that NRC is perfect but it has in many ways become the standard that people test themselves against. NRC has a good reputation in the U.S. as technically competent. It was ranked the number one agency in the government."*

The U.S. utility respondent predicted increased regulatory pressure as a consequence of the latest nuclear accident:

> *"Following the event at Fukushima, all nuclear reactor oversight is increasing."*

4.6.5 Comprehensive analysis

Most of the respondents in this study agreed that nuclear oversight was undergoing international harmonization. All of the regulatory agencies in study worked actively with harmonization. The most common forums used for this were IAEA, WENRA, CNRA and MDEP. The IAEA service IRRS was considered as effective tool to put pressure on the regulators to increase their harmonization work.

The largest regulatory advantage with harmonized requirements was the possibility to use well-established requirements that have been critically reviewed by many. Basing decisions on requirements used by many authorities strengthens the credibility of the decision. The commonly mentioned advantage for the industry with the harmonization was that it would facilitate new-build in the global market of today. For a vendor to adapt a reactor type to specific national requirements would lead to increased complexity and increased costs. Also, having "off-the-shelf"-solutions that fulfill harmonized requirements will help saving costs in an industry that is increasingly financially burdened. Better public acceptance and regulatory effectiveness were also mentioned as valuable effects. Harmonization was considered to have advantages mostly for new-build of nuclear, for existing plants the positive effects were regarded as small.

For the negative aspects of harmonization, using both the lowest and highest common denominator was mentioned. Using lower requirements when harmonizing could lead to a stop in the development of the safest plants, that sufficiently safe should be used in order to reduce costs. On the other side, using the highest requirements could lead to overdoing, not necessarily associated with higher safety but with unreasonable costs. The risk of suffocating the industry with so high demands that no company affords building or running nuclear plants was mentioned. Retrofit can also have large consequences, as major redesign of plants not only is costly, but can lead to safety issues.

When asked for the evolution of the nuclear oversight, the respondents were consistent. The common opinion was that harmonization would increase, with IAEA (IRRS), WENRA and CNRA as the primary drivers. International reviews such as WANO peer review and OSART were also predicted to increase. The wish for international reviewing has increased after the Fukushima accident. However, these reviews must be handled with care, as one of the utilities expressed it:

> *"Reviews are a good thing, but we can´t have that the safety work at the plants are based on reviews. It can happen that you cannot cope with your own issues and considerations, as you have to work with the questions raised in the review. Preparatory work, supplementary work and actions related to the review must not be the dominant safety work performed"*

Also, after the Fukushima accident, the demands for an independent regulator have increased. The full implications of this have not yet been seen, it is however likely that the international organizations will put higher pressure on the regulators in this matter, leading to more formalism.

To conclude, the international evolution of nuclear power oversight will move towards harmonization of requirements, international collaboration and reviews. The regulatory pressure on the licensees and utilities will increase together with the level of detail within the requirements. As is common when harmonizing, countries that diverge much will be affected the most.

4.7 Priority areas

This section is intended to give an understanding of how the regulators in the studied countries choose their areas of priority. Also, the extent that the utilities or licensees feel that they are steered by the priorities of the regulator will be looked into. Finally, the existence of forums where priorities can be discussed and consensus regarding these priorities will be handled. The following questions were used:

Q25. (Utility only) Do you know how the authority chooses its priority areas?

Q26. (Regulator only) How does the authority choose its priority areas?

Q26. (Utility only) To what extent is your work steered by the regulator‘s priority areas?

Q27. Is there a neutral forum where safety priority areas can be under discussion with the regulating agency?

Q28. (Utility only) Do you get the impression that the regulating agency often or seldom chooses the same areas of priority as you would have done?

Q28. (Regulator only) Do you get the impression that the licensees often or seldom think you choose the right area of priority?

4.7.1 Sweden

According to the Swedish regulator, priority areas were chosen with regard to their safety significance. This could be due to new knowledge in certain areas or experience and operational feedback. Also, collected evaluations were important. The regulator continuously reviews information from the licensees looking for trends and patterns. Two of the by the regulator issued “Special Supervisions” were based on this. Current activities were also regarded as a way to choose areas of priority, such as control room modernizations and replacement of analogue equipment. International events such as the attack on World Trade Center as well as national events such as Greenpeace intrusions also affect the priorities. Licensee behavior was also reported to affect, as well as reoccurring event reports and the availability of safety related equipment.

Asking the utilities how they perceive that the regulator chooses its areas of priority resulted in the following answers. Operational and experience feedback were considered to be affecting the priority areas, so did reoccurring event reports. Incident and accidents were other motives for prioritizing, also inspections and investigations were assumed to be used. Some respondents claimed that the personal preferences of the administrative officer had significance. Individual administrative officers were considered to have too much authority and that this was enabled because of weak management.

The amount of steering inflicted on the licensees by the regulator was regarded as varying. Some of the respondents reported a quite high amount of steering, leading to that other important areas get lower priority. Other respondents claimed that the steering due to regulator priorities was quite low, but that there were exceptions, such as security. Special Supervision was claimed to be incredibly steering, so were injunctions as they get top priority

and must be handled directly. About 20-30% of the safety work was considered to be steered by the priorities of the regulator.

Regarding neutral forums where the areas of priority could be under discussion, the regulator answered that this could jeopardize the regulatory independence:

"There are not any forums and there should not be any. Then SSM would not live up to the national and international standards of independence."

The utility considered management meetings with regulatory representatives and seminars as forums where priorities could be discussed. The Nordic Owners Group invites regulatory personnel each year in order to let them know what the industry is doing; this was also regarded as an opportunity to discuss the focus areas. Influencing the focus areas was however regarded as quite difficult, as one utility respondent put it:

"The possibility to affect SSM's priorities is more or less impossible."

Regarding consensus when prioritizing, the regulator believed that the licensees thought they prioritized well to a certain degree. According to the utilities, the priorities are correct most of the time, with a few exceptions. Programmable I&C were used as a good example, so was the focus on the emergency diesel generators. Good hope was also expressed regarding reaching consensus when handling the aging of the plants. Human factors, security and Safety Culture were used as examples of areas where consensus had not been reached. Priority areas coming from inspectors were generally considered good.

4.7.2 Finland

According to the Finnish regulator, no certain priority areas exist in the Finnish nuclear oversight. Priorities are based on the most urgent needs, but no specific areas were said to exist. This was confirmed by the utility respondents, saying that STUK does not really have priority areas. Incidents at other plants and experience feedback were however said to lead to directed oversight.

Asking the Finnish utility in what extent the safety work is steered by the regulator resulted in the following answer:

"The regulator has another view than us, but if we combine our views, the result is pretty good."

According to the Finnish utility respondents, priorities can easily be discussed at management meetings:

"The licensees tell STUK what they want to work with and STUK tells them what is important."

The Finnish regulator and utility were asked if they reach consensus when prioritizing. The regulator gave the following answer:

"Sometimes we get criticized that we work on areas that are not very important. The more detailed we are, the more feedback that we are doing the wrong work we get. We

have also gotten international comments that we should prioritize our efforts more. We spend a lot of time approving small things; this affects both U.S. and the licensee."

One of the utilities gave the following answer to the same question:

"*They are often interested in what we find important, for instance if we plan to develop something. If we are looking at developing something and tell them, we may get an injunction saying that we must do it. We are not too happy about getting injunctions regarding our own improvement initiatives. To make some exploratory work is not the same thing as promising that you will do something."*

4.7.3 Canada

According to the Canadian utility respondent, incidents at other plants and accidents were the basis of the regulator´s choice of priorities. The regulator was also considered to listening to the public when prioritizing.

The regulatory respondents agreed upon having priority areas and that they were based on three things; international cooperation, regulation and promotion of compliance and safety. Main priorities were however set by the government; e.g. it was the government that decided that the regulator should be more involved with the public. Priorities were claimed to be set from the top-down with information coming from the bottom, for instance from international events. Feedback from the industry, research, IEEE and operational experiences were also mentioned as sources of information used when prioritizing. In order to focus on important issues when prioritizing, a risk-informed approach was used.

Regarding neutral forums where priorities regarding safety work could be discussed, both the regulator and utility respondent recognized the CANDU-owners group and Standard associations in Canada. The regulator respondent also considered IAEA to be such a forum.

The utility respondent estimated the extent of steering imposed on them from the regulator to roughly 30%. The priorities of the regulator were also considered as accurate, saying:

"A lot of our program comes from their program. Here I would like to give them credit; most of their priority areas are really good."

When asked whether there was consensus between regulator and licensee regarding priorities, the regulatory respondent answered:

"*No licensee thinks the regulator focuses on the right stuff."*

However, asking the utility respondent if the regulator often or seldom chooses the same areas of priority as they would have done, the answer was:

"*For sure. They are often right."*

4.7.4 USA

According to the U.S. regulatory respondent, choices of priority areas are guided by risk assessments. PSA (PRA), operational experience, incidents and accidents were also considered as information sources used when prioritizing. Public opinion and political considerations were also thought to affect. Examples of events that have affected the areas of priority are the attack on World Trade Center and the Fukushima accident.

Asking the utility respondent whether they knew how the regulator choses his priority areas resulted in the following answer:

> *"Currently, there is no publicly available USNRC process for determining the priority of regulatory actions based on predefined measures."*

Both regulatory and utility respondents were asked regarding the existence of neutral forums where priorities regarding safety work could be discussed. The Regulatory Information Centre (RIC) as well as NEI workshops were regarded as such forums.

Asking the regulatory respondent if he/she was under the impression that the licensees thought their priorities were correct, led to the following answer:

> *"There are probably disagreements but since the NRC needs good reason to change regulations, the industry understands where our priority comes from."*

The utility respondent expressed the following regarding the consensus in the prioritizing of the safety work:

> *"The USNRC areas of concern are typically in alignment with licensee areas of concern; however, licensees have expressed the need for an integrated regulatory priorities plan that is based on predefined measures of safety and security significance that have been reviewed by the industry."*

This indicates that some form of increased transparency is wanted from the utility side.

4.7.5 Comprehensive analysis

Considering all the respondents, the priorities of the regulator were in general based on some form of risk-assessment in combination with information from events such as incidents and accidents. Operational experiences, industry feedback and public opinion were also considered as factors affecting the priorities.

All of the utility respondents regarded the priorities from the regulator as being correct most of the time. Most satisfied was the Canadian respondent, followed by the U.S. and the Finnish. In the U.S., the regulator was considered needing good reasons for making priorities, leading to a better understanding of them. The Finnish respondents reported some disagreements, but that they could easily be discussed so that consensus most often could be obtained. The Swedish respondents were least satisfied, having certain areas where consensus was hard to reach. Swedish respondents were also the only ones to report that the personal preferences of the administrative officer were said to influence the priorities of the regulator. This was claimed to be due to weak management enabling too much individual authority

amongst individual administrative officers. The Swedish utility respondents did however consider priorities coming from inspections and investigations as good.

The amount of steering inflicted on the licensees due to regulatory priorities varied between countries. A high level of detail in the requirements can be regarded as highly steering, i.e. if the regulator provides detailed instruction for how the licensees should work, the room for their own programs will decrease. This tendency was noticeable in Finland, some respondents expressed that the programs of the regulator were so thorough and extensive that most of the work was done only to comply. The same tendency was noticed in the U.S., much effort was put into regulatory compliance. Regulatory tools such as injunctions and Special Supervision were also regarded as incredibly steering. Injunctions automatically bypass the prioritizing systems of the licensees and get top priority immediately. Special Supervision was also recognized as imperative as most of the available resources will have to be addressed to correcting the insufficient condition. Both Swedish and Finnish utility respondents reported that they show action plans or even some exploratory work to the regulator, and that they then get injunctions forcing them to perform their own plans. Both of the utilities in the two countries were quite displeased with getting injunctions because of their own improvement initiatives.

The Swedish utility respondents expressed a need for some kind of forum where management and regulator can discuss focus areas early and on a comprehensive level. Also, areas of focus seemed to exist to a higher extent in Sweden than in the other visited countries. The general opinion was that regulator and licensees should agree on focus areas. All of the studied countries had different forms of forums where priorities could be discussed. These were e.g. seminars, Owners Groups meetings and conferences.

4.8 Efficiency

The purpose of this section is to present a view of how the interviewees prioritize, measure, and improve the efficiency of their regulatory or safety related work. The questions used to obtain this information were the following, words in parentheses regard the regulator.

Q29. Is the efficiency of your safety work (supervision) measured?

Q30. If efficiency is measured, how has the method of measuring the efficiency been developed?

Q31. How do you work with increasing the efficiency of your safety work (supervision)? Is increased efficiency a high priority?

4.8.1 Sweden

The Swedish utility respondents measured the efficiency in a number of different ways. PSA (PRA) was used in varying extents and was considered as a good tool that both enabled prioritizing resources and supporting arguments. PSA was also used for finding weak spots in design, and monitoring Risk Increase Factors (RIF, sometimes interpreted also as Risk Achievement Worth, RAW). The use of PSA was said to be increasing, using it for not only design but also for maintenance and operations. Missed opportunities were also measured, ideally the utility wanted to be ahead of the regulator. A system called Early Warning Signs were used, that was based on information from organizations in adversities. Different types of indicators were also used, for instance Key Performance Indicators (KPIs) and WANO Performance Indicators (PIs); the latter were however felt to be very general. The utilities also measured reoccurring event reports (RO) and performed internal audits. Many other variables such as fuel damages, emissions and SCRAMs were also measured, but their effect was considered uncertain.

The regulator was not measuring the efficiency of their supervision as no useful tool for this were said to exist. The methods the utilities used for measuring efficiency were either developed internally or adopted externally for instance from WANO.

Both regulator and utilities claimed that efficiency was something that was significantly focused upon. According to the regulator, work was performed in order to develop a system for efficiency improvement. International work was also performed in this matter. Within the CNRA cooperation, a guide is developed named “The characteristics of an effective regulator”. This guide will use qualitative assessments to improve the efficiency of the regulator. According to the utilities, much focus was put on the WANO indicators. One of the reasons for this was the wish to be able to compare plants within a fleet. An interesting aspect expressed by one utility respondent was that you always make trade-offs. Managers often think faster-better-cheaper, in reality the effect of trade-offs can be significant, especially in a safety demanding industry as nuclear. This area was by some respondents considered analogous with experience feedback, compiling and analysis of data is done well; implementing results are done worse.

4.8.2 Finland

The Finnish regulator explained that they had efficiency measures on higher levels, in agreement with their regulating ministry of social affairs. These efficiency measures of their

efforts included absence of accidents, severe incidents and that the radiation doses should be below certain limits. They had also internal measures, measuring how their regulatory activities were processed. Furthermore, the regulator looked at external measures, such as plant performance. Performance measure could be fuel damages, and how long time it takes to repair safety related equipment for instance.

The utilities used PSA (PRA) in a large extent and regarded it as very important for their improvement work, giving information used for prioritizing. Also, Live-PSA was used in order to understand the risk increase factors. Different types of indicators were also used, such as WANO PIs, KPIs, and internally developed indicators.

According to the regulator, the internal efficiency measures had been developed by CNRA, and the external efficiency measures had been developed by the agency itself.

At the utilities, some of the efficiency measures based on indicators were developed internally, while others were adopted directly, such as the WANO PIs.

Both regulator and utilities regarded efficiency issues as prioritized and growing. The regulator expressed an increasing need to get things done faster; the work performed was managed and tracked in detail, for instance open documents and time spent on document review. The utilities also tracked open jobs, and time spent performing them. One of the utilities considered the WANO indicators to be somewhat problematic since the tendency to report can differ heavily between plants and countries. Some plants were considered to never have work related accidents as they never report any.

4.8.3 Canada

In Canada, the regulator explained that they use internal audits and quality targets to measure the efficiency of their oversight. The performance was also tracked through how well the industry was doing; if the industry should not be doing well, the regulator would have to improve his work. Areas with particularly good performance are assessed in order to improve other.

The utility explained that PSA (PRA) was used in order to prioritize resources and when investing in safety related equipment.

The method used by the regulator to measure efficiency was developed internally. Focus was also put upon documenting their internal processes and procedures. Adding instructions and clarity to requirements were also performed in order to increase the efficiency.

4.8.4 USA

The U.S. regulator used several ways to measure the efficiency of their supervision. The Reactor Oversight Process (ROP) enables collecting information about licensee performance. This information is analyzed with respect to safety significance, and appropriate regulatory actions are made. The Industry Trend Program (ITP) is used by the regulator to monitor trends in the reactor oversight process and indicators of industry performance. Long-term trends are evaluated and there are processes for resolving generic issues.

The utilities and licensees constantly monitored and trended performance and safe operation in an effort to meet the regulatory performance indicators, and also the internal performance indicators and goals.

4.8.5 Comprehensive analysis

All of the utility respondents had various ways of measuring the efficiency of their safety work. Most of them also reported efficiency to be a prioritized area. The most common ways of measuring efficiency were PSA (PRA) and different forms of indicators. Internal audits were also a quite common tool. PSA (PRA) was used in various extents, to prioritize resources, finding best cost-benefit ratios, when performing plant redesign, in maintenance and to find Risk Increase Factors during operation. The indicators used were either adopted from an organization, for instance from WANO or internally developed. The internally developed indicators were often based on different events, such as SCRAMs, fuel damages, emissions, reoccurring event reports, missed opportunities and quality targets. Utilities also considered the overall capacity factor of a plant an efficiency measure, plants succeeding have a high capacity factor.

The variation in how the regulator respondents worked with efficiency improvement was larger than that of the utility respondents. All of the regulators in this study were however involved in CNRA, working for efficiency improvement.

The largest difficulty in this matter is that efficiency is hard to measure. Most respondents agree that existing models are insufficient in different aspects. Yet it is an area that is regarded as important and that is focused upon. All of the utilities use different indicators in order to measure efficiency. Depending of the indicators chosen, this is likely to be a good way of measuring changes over time. But as one of the respondents expressed, it is important to know why you follow indicators and not just follow them blindly. Concerns were also expressed regarding that for instance WANO indicators were used to compare plant performance globally. The largest drawback with this was considered to be due to differences in the tendency to report incidents. One of the utilities also highlighted the trade-offs as side effects of efficiency improvements. As faster-better-cheaper is not always achievable, efforts to improve efficiency can lead to different types of deteriorations. With nuclear being a safety-critical industry, trade-offs are important to consider.

4.9 General questions

This purpose of this section was to get the interviewees' comprehensive perspective of nuclear power oversight and its future development as well as their personal opinions about the current oversight. The following questions were asked:

Q32. (Utility only) Are there any changes that you would like to see within the regulator's supervision?

Q32. (Regulator Only) Are there any changes that you would like to see within your supervision?

Q33. On a comprehensive level, do you get the impression that the regulatory supervision will change in the near future?

Q34. (Utility only) On a comprehensive level, do you think your safety work will be affected by this change in supervision?

Q35. (Utility only) What requirements do you think the licensees should have on the regulator?

4.9.1 Sweden

SSM's current focus is on developing the regulatory model and the approaches used for oversight. Emphasis is put on subject and activity based oversight, clarity, predictability and legal certainty; the requirements shall not be arbitrary. Furthermore, one regulatory respondent said that SSM needs to be tougher and not allow so much time to go by as it sometimes does. The opinions from the utility concerning the changes they would like to see with the regualtor varied a lot between respondents. Below follows a collection of expressed opinions regarding this question.

- *"There should be a more open dialogue regarding safety issues together with the industry; they should not hide behind paragraphs. More like the old times when we could talk with each other and solve problems together."*
- *"The regulators should be better at formulating themselves in writing; they should be able to be more stringent. Today there is no common level, some are very colloquial and some are stricter. Earlier they were more even."*
- *"To keep a low level of detail would be good; you should be able to be clearer anyway."*
- *"You should not have to wait 5 years before you know if an action will be accepted or not. A partial okay is needed; so that you do not work several years in vain."*
- *"The regulator should hire more people with practical nuclear experience. Furthermore, the regulator should diversify its competence. Maybe get some other perspectives from people working in other industries. Perhaps from process or chemical industry."*
- *"SSM should avoid the kind of formalism in the safety work that delays safety enhancements and make them unnecessarily expensive."*
- *"There should be less theory and more focus on concrete things like operations and maintenance. Maintenance has had too low priority. Maintenance is where safety is built; it should be carried out in the right way, in the right time and with the right focus, i.e. much work on high priority objects."*

Both the utility and SSM seem to agree that the newly developed requirements did not have the effect that they should and that further development is needed. SSM is currently working on a new edition that will increase the clarity, the predictability and the legal certainness.

When the SSM respondents were asked if they got the impression that the regulations would change in the near future, some of their answers were:

- *"SSM will work together with other authorities to develop strategies and models for activity-based oversight."*
- *"If someone decides to decommission a plant or to build a new one, a new type of oversight will be developed."*
- *"The oversight will become more formal in order to help the licensees to get more resources from the owners."*

When the utility was asked the same questions, some of their answers were:

- *"The level of detail will increase due to international pressure."*
- *"New-build will probably have a significant impact if Sweden decides to build."*
- *"The oversight will become more formalized."*
- *"It is extremely competence dependent."*
- *"SSM will eventually reach their goal to increase the level of detail."*
- *"It all comes down to who will be the next Director General of SSM."*

The effects on the safety work of these changes will according to the utility be:

- *"The companies will strengthen the corporate-functions with increased oversight, i.e. you build an own oversight within the company. This is due to large financial losses because of the Special Supervision."*
- *"The companies will be more fleet-oriented and the optimal utilization of resources will be prioritized. If they get tougher, we will have to adapt by changing our approach and increasing our competence centrally in decision making positions."*
- *"More people will work with supplying the regulator with answers. There is a risk that it becomes too bureaucratic, i.e. more and more administrators, both at the regulator and at the plants. It would have been better with focus at the plants, being there measuring, searching for errors, assessing, preventing errors, being in the operation. When the regulator visits the plant it is mostly for meetings, they have more and more become administrators. Not much hope of change in that aspect."*
- *"The regulatory oversight has been increasingly formalized the last years; this is not expected to change. An increased level of detail from the regulator is anticipated, driven by increased international standards from e.g. IAEA. If this*

is handled the wrong way it can cause unclearness and take away initiative from the licensee."

- *"It will take massive resources to show the fulfillment of the requirements on the new regulatory codes. Even without changes in design, large resources will be needed to control the compliance."*
- *"The licensee can come to a situation where the detailed regulation goes so far that the primary objective becomes fulfillment of regulatory requirements (compliance) instead of taking the actions that are the most important for safety."*

When the utility respondents were asked what requirements a licensee should have on a regulator, their answers were:

- Predictability
- Transparency – *"One shall understand what a regulator bases their decisions on."*
- Competence – *"In such a technical industry as nuclear, one should require high technical expertise in the top management of the regulator."*
- Objectivity
- Consistency – *"What the regulator says one time shall also apply in the future. There should neither be any differences between the administrative officers."*
- Integrity/Independence – *"A prerequisite to operate reactors is that the public has confidence in the regulator."*
- Keeping schedule – *"A regulator should not undertake tasks that they cannot finish on time."*
- Long-sightedness – *"A regulator should be able to give concrete requirements about the future so that the prerequisites for planning are fulfilled."*

4.9.2 Finland

When the STUK respondent was asked whether he/she would like to see any changes in the oversight, most emphasis was put on prioritization. I.e. increase the efficiency by prioritizing on the most significant phases and issues. Furthermore, since the expectations on STUK had increased, they also had to increase their competence. The answers from the utility respondents were a bit different depending on the respondents. One reoccurring answer was that STUK should not have inspectors with no nuclear experience; assessing plants require experience, you cannot come straight from school. Further changes some utility respondents wanted were less bureaucracy and lower level of detail.

When the STUK respondent was asked if they got the impression that the regulations would change in the near future, some of his/her answers was:

- *"Internationally, EU may come with directives that can affect us. Furthermore, IRRS and OSART will have high significance in the future."*
- *"Nationally, the regulatory oversight will probably not change because of national pressure in near future."*

- *"We will strengthen our ability to make important decisions on the right time."*
- *"The new guides will help U.S. to not miss the main important requirements; there will be more solid reasoning."*

When the utility was asked the same questions, some of their answers were:

- *"The level of detail will most likely remain where it is."*
- *"MDEP will increase in significance."*
- *"People have started to realize that the working-culture has a large significance and that will probably have an effect."*
- *"STUK will be more present at the power plants."*
- *"Internationally, more countries will probably acquire nuclear power and that will result in changes."*

The effects on the safety work of these changes will according to the utility be:

- *"The safety work has and will continue to increase. It will probably also be more result-oriented since the regulator wants quick results."*
- *"The regulator may require new types of reports, the paper work may change."*
- *"The regulatory codes that are written today will be up-to-date with the newest technology. These new requirements will apply to new plants, but also existing plants will have to follow them in some areas. It is important that the impact is reasonable, i.e. that no unrealistic demands are imposed on old plants."*

When the utility respondent was asked what requirements a licensee should have on a regulator, his/her answer was:

- Objectivity
- Technical competence
- Mutual trust
- Predictability – *"A regulator should not change their mind afterwards."*
- Transparency – *"Their decisions must be built on a technical basis."*

4.9.3 Canada

Both CNSC and the utility were overall very pleased with the situation in Canada and no one saw the need for any big changes. The utility respondents said that CNSC could be clearer in some matters. CNSC is aware of this and is currently working with adding clarity to the requirements.

Nationally, neither the utility nor the CNSC thought that there would be any changes in the oversight in the near future besides more clarity. Nationally, they thought it would go towards more harmonization.

When the utility respondent was asked what expectations a licensee should have of a regulator, his/her answer was:

- Predictability
- Transparency
- Risk-informed – *"A regulator should not be arbitrary."*

4.9.4 USA

When one of the NRC interviewees was asked about desired changes in the supervision, his/her answer was:

> *"If I saw a change that was needed I would do it, unless it required a regulation change. That is governed by a legal system; there is a certain way to go about to change regulations."*

When the utility was asked the same question they expressed a concern about the cumulative impacts of regulation that require more and more compliance resources from the industry; some of which do little to enhance safety:

> *"As of today, the USNRC approach to regulation prioritization does not ensure that high priority actions are taken by licensees before those that would have less of an impact on safety and that there are no conflicting requirements or regulatory gaps".*

The big problem in the U.S. seems to be that there is very difficult to change the regulations, especially the removal of requirements. This lead to an accumulation of requirements, just as the utility expressed it. At a certain point the compliance resources will be so high that it is no longer profitable to run nuclear power plants. This issue concerns not only the U.S., but probably all nuclear power countries.

The NRC respondents did not comment on the future. However, the utility thought that USNRC would in the future become more rigid because of Fukushima. This will probably lead to more regulations resulting in licensees performing additional modifications, licensing actions, etc. for compliance. Ultimately, this impact could cause some units to shut down. Additionally, the increase in nuclear oversight needs to be prioritized based on risk informed safety impacts and cost-benefit analyses. A comment closely related to this issue given by the U.S. utility follows:

> *"There are two notable negative impacts for the licensee from an intrusive and engaged regulator: increased costs associated with USNRC reviews and resources to support the regulator (employees, software, modifications, inspection support, etc.) that do not necessarily correspond to an equivalent safety benefit. Combined with the negative impact of government subsidies and mandates for generation from other energy sources, energy deregulation,*

and the low cost of natural gas, the impact from higher regulatory fees due to increased oversight will likely cause more U.S. units to shut down."

When the utility respondent was asked what requirements a licensee should have on a regulator, his/her answer was: The regulator should provide consistent regulation decision making or have stringent criteria for changing standing regulatory positions. I.e. the regulator should be able to technically justify their actions.

4.9.5 Comprehensive analysis

Most respondents thought that internationally, the nuclear power requirement will probably go towards harmonization and thus, the countries that differ most from the others will be affected the most. Nationally, the answers for the respondents differed. However, many thought that the full implications of Fukushima are yet to come.

According to some respondents in Sweden, adding or changing requirements can come with a price, especially if it is done in a slow pace. I.e. if the utility knows there will be extra requirements in a certain area, they typically wait with the safety enhancements until the requirements are out to avoid expensive changes afterwards. Furthermore, many respondents were concerned that additional requirements would not enhance the safety because of the financial margins of nuclear power. I.e. more requirements would not increase the allocated resources to the safety work, only steer the priorities of the current safety work. This can be a dangerous path according to some, because essentially the authority then says that they know better than the licensees where the most safety can be achieved.

4.10 Regulatory Approaches

To assure and verify that sufficient safety is achieved, the regulator can use a number of different strategies. Two different studies sponsored by the Swedish Nuclear Power Inspectorate (SKI, now merged as a part of SSM) 2003/4 [42] and the Swedish Radiation Safety Authority (SSM) 2011/12 [43] have worked out definitions for a number of oversight approaches that can be practiced by a regulator. The definitions from the two studies differed to some extent and an additional approach was added in the latter. According to this study, the following supervision approaches exists, see Table 15. [43]

Table 15. The different regulatory supervision approaches according to. [43]

Approach	Definition
Prescriptive	Establishes specific requirements for conducting activities including technical solutions.
Case/Facility	Determines the safety requirements for each licensee through individual assessment of its design and operation, considering the unique history of each facility.
Outcome	Establishes specific performance goals or outcomes for licensees to attain but does not specify how they shall be attained. Licensees determine how they will conduct their work activities.
Risk/Hazard Informed	Determines the risk/hazard associated with an area to evaluate the appropriate level of regulatory attention. A risk-informed approach uses a specific methodology including probability and potential for harm to identify areas of greatest risk. These areas receive priority for regulatory attention. A hazard approach uses specific criteria for the identification of areas of greatest potential for harm and these areas receive priority for regulatory attention.
Process/system	Identifies specific key processes that lead to safe performance and requires licensees to establish and implement these processes effectively.
Self-Assessment	Identifies of both good practices and problem areas needing improvement, internal reviews & follow up. The regulator evaluates the licensee self-assessment program, reviews the results of the licensee assessments, and selectively inspects the licensees' follow up on self-assessment results.
Influence/Education	Provides information and training opportunities for the industry, including workshops, feedback, research results, and other information, in order to improve industry performance.

The interviewees were asked to assess the evolution of these approaches during the last 10 years, they were also asked to predict how they thought the use would evolve in the future. The approaches above are meant to be used to describe the supervision in different areas of activity; here they were however used to describe the supervision on a comprehensive level. The interviewees were asked to answer if the use of an approach had decreased largely,

decreased somewhat, been unchanged, increased somewhat or increased highly regarding both past and future. The following definitions were given:

Q37. Prescriptive – Establishes specific requirements for conducting activities including technical solutions.

Q38. Case/Facility based – Determines the safety requirements for each licensee through individual assessment of its design and operation, considering the unique history of each facility.

Q39. Outcome based – Establishes specific performance goals or outcomes for licensees to attain but does not specify how they shall be attained. Licensees determine how they will conduct their work activities.

Q40. Risk/Hazard Informed – Determines the risk/hazard associated with an area to evaluate the appropriate level of regulatory attention. A risk-informed approach uses a specific methodology including probability and potential for harm to identify areas of greatest risk. These areas receive priority for regulatory attention. A hazard approach uses specific criteria for the identification of areas of greatest potential for harm and these areas receive priority for regulatory attention.

Q41. Process/System based – Identifies specific key processes that lead to safe performance and requires licensees to establish and implement these processes effectively.

Q42. Self-Assessment based – Identifying of both good practices and problem areas needing improvement, internal reviews and follow up. The regulator evaluates the licensee self-assessment program, reviews the results of the licensee assessments, & selectively inspects the licensees' follow up on self-assessment results.

Q43. Influence/Education based – Provides information and training opportunities for the industry including workshops, feedback, research results, and other information in order to improve industry performance.

4.10.1 Sweden

The answers from the Swedish respondents can be seen in Figure 14 and Figure 15 below.

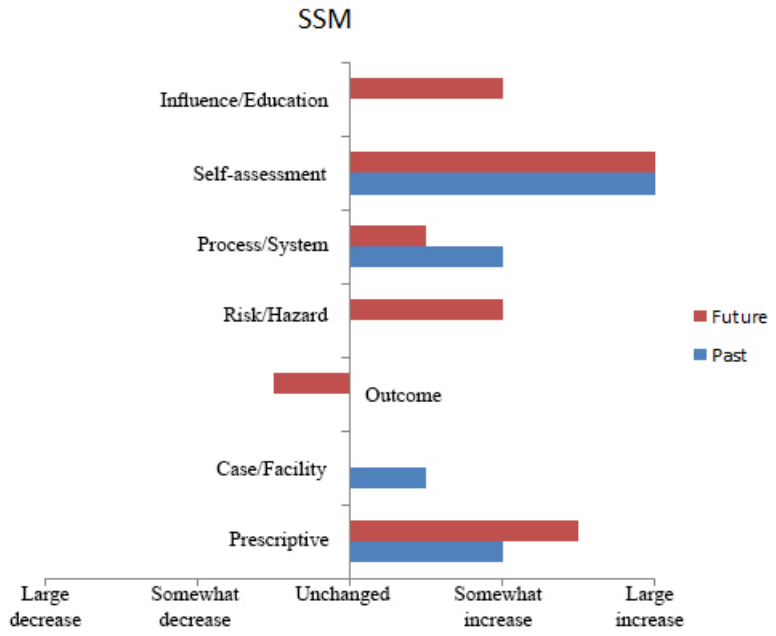

Figure 14.The past and future use of the regulatory approaches according to the Swedish regulatory respondents.

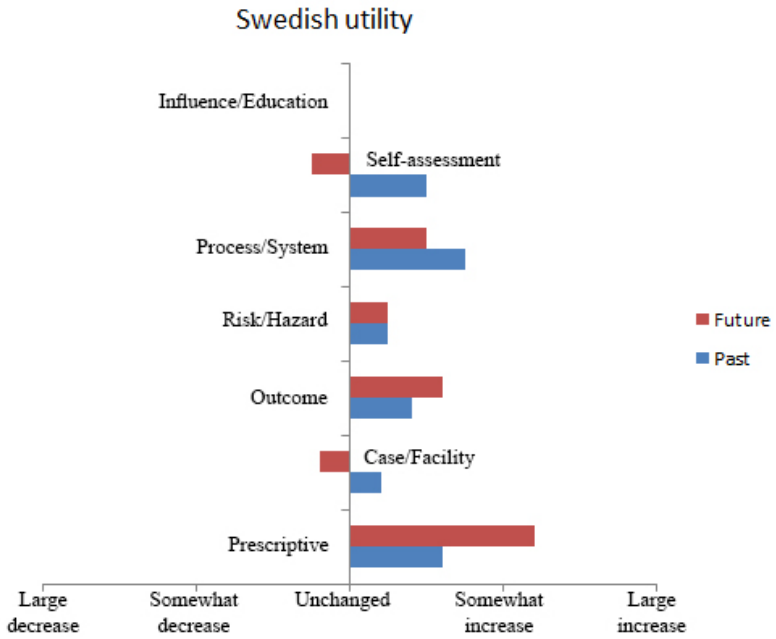

Figure 15. The past and future use of the regulatory approaches according to the Swedish utility respondents.

According to Figure 14 and Figure 15, both the regulator and utility respondents predicted that the prescriptiveness of the oversight would increase in the future. The regulatory respondents also forecasted that both the influence/educational as well as the risk/hazard based approaches would increase. The utility respondents feared that the self-assessment based approach would decline, whereas the regulatory interviewees considered that approach to stay on a very high level of use. The outcome based approach was considered to decrease

by the regulatory respondents, oppositely to the utility respondents who predicted the same approach to increase.

4.10.2 Finland

The Finnish answers regarding the use of the different approaches can be seen in Figure 16 and Figure 17.

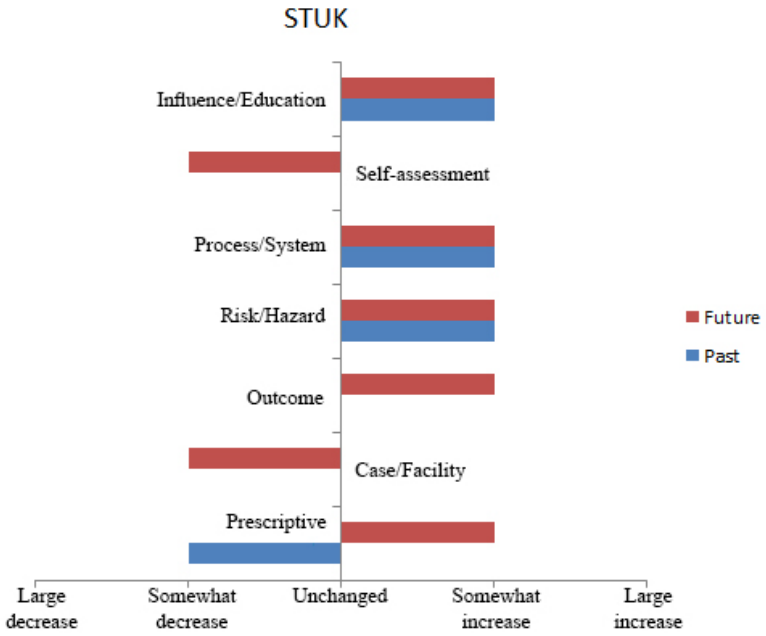

Figure 16. The past and future use of the regulatory approaches according to the Finnish regulatory respondent.

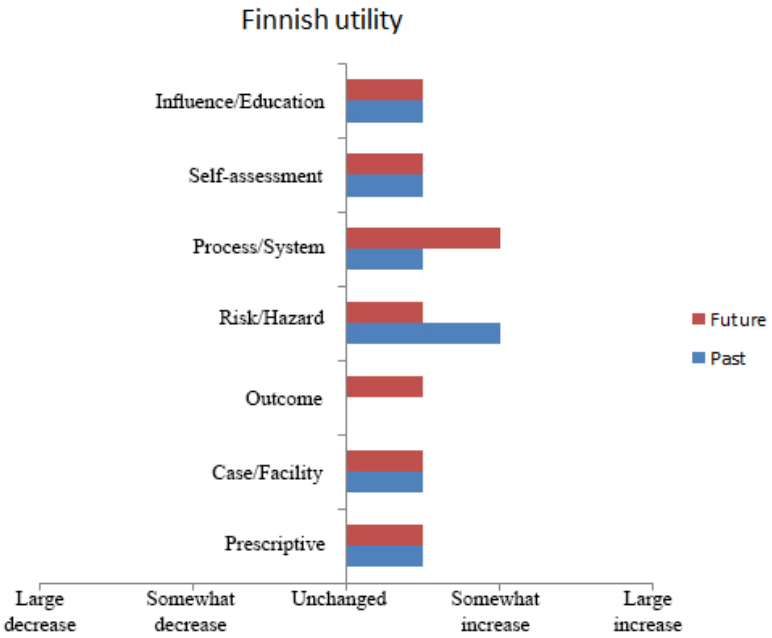

Figure 17. The past and future use of the regulatory approaches according to the Finnish utility respondents.

According to the Finnish regulatory respondent, the prescriptiveness and the outcome based approach would increase in the future. A decline in the use of self-assessment and case/facility based approaches was also foreseen. The Finnish utility regarded the use of the

approaches as quite stable, foreseeing a slight increase in the process/system based approach and a slight decline in the risk/hazard based approach.

4.10.3 Canada

The Canadian respondents´ views of the use of the different approaches are shown in Figure 18 and Figure 19.

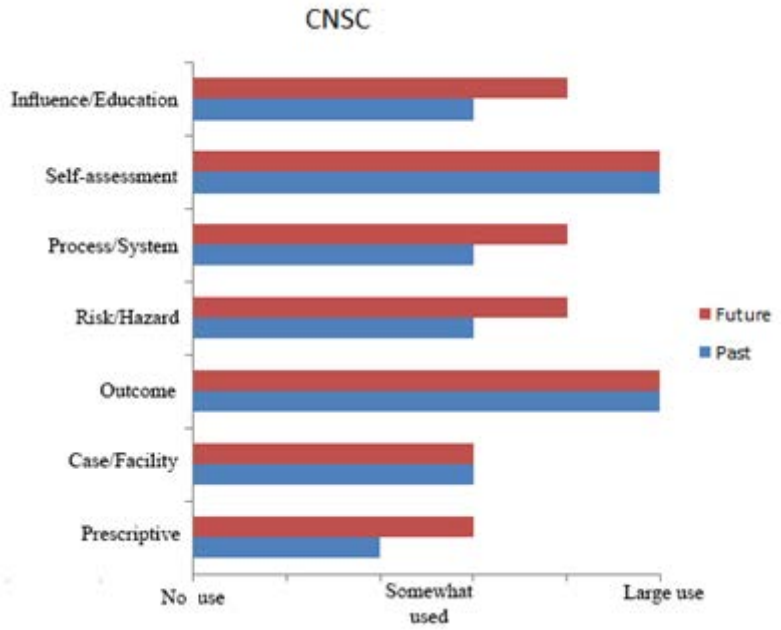

Figure 18. The past and future use of the regulatory approaches according to the Canadian regulatory respondents.

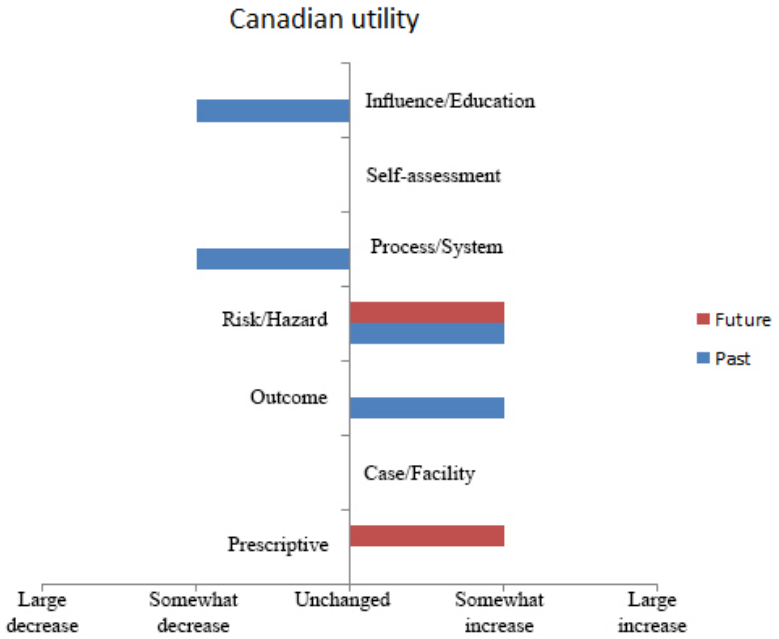

Figure 19. The past and future use of the regulatory approaches according to the Canadian utility respondent.

The utility respondent predicted the risk/hazard informed approach as increasing in the future. Also, the use of the prescriptive approach was predicted to increase somewhat. The regulator respondents chose to respond to the questions regarding the approaches in a somewhat different way. Instead of ranking their change in use, the extent of their use was given. Considering future use of regulatory approaches, the outcome and self-assessment based

approaches were predicted to be used to a high extent. The risk/hazard informed, process/system and influence/education based approaches were predicted to be used in a somewhat high extent in the future.

4.10.4 USA

In the U.S., only utility responses regarding regulatory approaches were obtained as the U.S. regulator respondents chose not to answer those questions. The answers from the U.S. utility are shown in Figure 20.

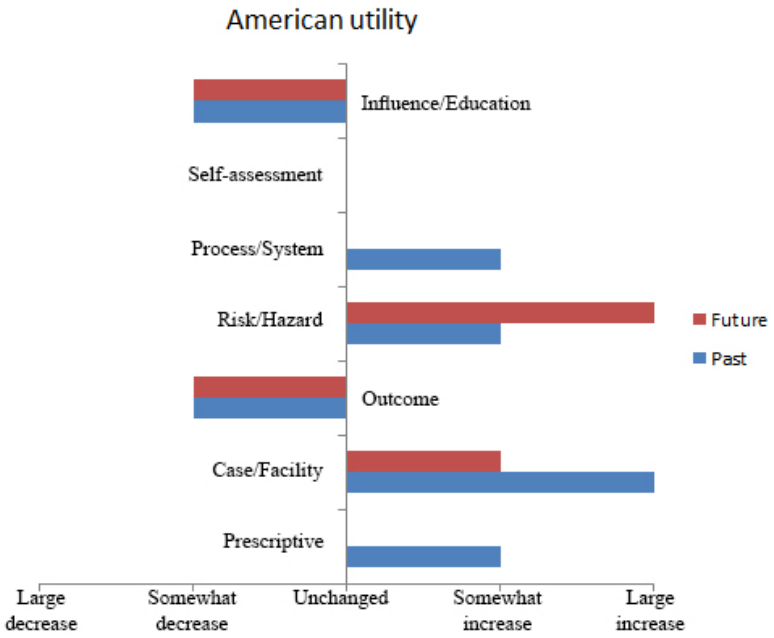

Figure 20. The past and future use of the regulatory approaches according to the U.S. utility respondent.

The U.S. utility predicted an increase in the use of the risk/hazard informed approach. Also the case/facility based approach was believed to increase somewhat. In the use of the outcome as well as the influence/education based approaches, a decline was foreseen.

4.10.5 Comprehensive analysis

All of the respondents predicted that the risk/hazard informed approach would increase. This is likely due to prioritizing, trying to enhance safety where the largest risks are. In Sweden and Finland, both regulator and utility respondents predicted the use of the prescriptive approach to increase. This is in line with other statements from these respondents regarding the direction of the regulatory oversight.

The Swedish and Finnish regulatory respondents also claimed that the use of the influence/education based approach would increase in the future, the Canadian regulator expressed it would be used to a high extent. This can be related to different forms of seminars where the regulators inform about safety, technical or regulatory issues. The Swedish regulator respondents predicted the use of the self-assessment based approach to increase, whereas the Finnish regulatory respondent foresaw a future decline. The Canadian regulator foresaw a large use of the approach. To this can be said that both the Swedish and the Canadian regulators already are relying on self-assessment in a significantly higher extent than their Finnish colleagues.

5. Discussion

5.1 Discussion of Method

In order to gather the information needed for this study, two alternatives existed, i.e. quantitative and qualitative methods. Since the goal of this study was to obtain the thoughts and beliefs of the respondents regarding the evolution of the oversight, the use of quantitative methods was considered insufficient. The use of qualitative interviews enables studying behavior and also increases the openness of the interviewees.

To verify that the questions used for the interviews covered the goal of this study, they were remitted to the stakeholders for review and feedback. This procedure most certainly decreased the risk of using irrelevant or not fully covering questions, although the risk still exists.

5.2 Discussion of Results

The outcome of this study is dependent of several factors; the most significant identified are the coverage of the interview questions as well as the choice and number of interviewees. The interviewees were chosen based on industry or regulatory experience as well as experience from regulatory interaction. As the degree of experience from regulatory interaction varied, this can have affected the results.

One likely source of error is the differences in how the interviewees have interpreted the questions. When asked for clarification of questions, this was given in same way to all interviewees, it is however likely that some questions may have been misinterpreted or that perceptions may vary. Some of the answers obtained covering neutral forums imply presence of differences in perception of the term “neutral”.

In some of the studied countries interviewees were easily found, and in some countries the efforts were futile. Consequently, the coverage and validity of this study is best for the countries where interviewees were available. Most interviews were performed with Swedish respondents, whereas the validity of those results most likely is the highest. Also Finnish respondents were abundant, likely leading to rather high validity. The validity of the results from Canada is likely to be somewhat lower, as they are based on information from only three respondents. Worst validity is likely to have been obtained in the U.S. Due to extremely low availability of interviewees; the information from the U.S. utility was obtained through questionnaire only. As this method substantially decreases the amount of information that can be retrieved, it is likely to have affected the results. Also, as the responses from the U.S. regulatory respondent only regarded past and not future matters, this most likely also has affected the results.

As openness is strongly affected by national culture, this can have affected both the amount and depth of the information obtained through interviews.

6. Conclusions

The differences in nuclear oversight between the analyzed countries of this study are clearly largely dependent on the culture and history of that country. Furthermore, the culture of a country is decisive for how susceptible it is for international influences. Sweden, Finland and Canada were very open to influences while USA is quite restrictive.

In Sweden, Finland and Canada, international organizations working with nuclear matters have a very large and increasing influence on the nuclear oversight. Most important organizations for the regulators are IAEA, WENRA and CNRA. For the Swedish, Finnish and Canadian utilities, the most influencing organization is WANO and its significance is increasing. In the U.S., INPO has the largest influence on the utilities.

In Europe, ongoing harmonization of the nuclear safety requirements is a fact. Eventually, all countries will have to comply with the IAEA Safety Standards. This harmonization work is strongly driven by the IRRS and WENRA. The countries that will be most affected by the harmonization, are the ones that deviate most from the rest. Since Sweden has a tradition of comprehensive authority regulations with a low level of detail, the impact of harmonization will be significant. In theory, harmonization could lead to reduced costs and increased sustainability. However, compliance with the cumulative regulatory load has instead showed to burden the utilities extensively.

All of the respondents in this study confirmed that the work associated with regulatory compliance will increase. Many also feared that the increase in regulatory burden would eventually reach a level where the financial incentives associated with nuclear power generation are gone.

Which factors that affects the evolution of nuclear oversight the most differs between countries. In Sweden, the most influencing factor in the future will be LTO, followed by Safety Culture and competence. The Finnish equivalence was new-build followed by competence and Safety Culture. The factors affecting the Canadians were similar to those affecting Sweden; first LTO followed by HSE and Safety Culture. In USA, the most important factors were: Fees, grants and taxes, experience feedback, political situation, aging, new-build and Safety Culture. A very important affecting factor that is common for all countries is incidents and accidents.

Nuclear power is a highly technical industry and it requires highly technical people. Respondents in all visited countries stress the extreme importance of mutual technical competence. Lack of technical competence within a regulator will, according to several respondents, lead to more bureaucracy, less dialog and lack of respect from the utility. Of all the studied countries, Sweden was the only country where the utility respondents were concerned about a decline in technical competence within the regulatory agency.

A prerequisite to keep the competence in the nuclear industry is new-build since no one will invest a career in an industry that will be decommissioned. According to the respondents, the prerequisites for new-build in Sweden are not currently fulfilled, which threatens the competence.

When considering priority areas of the nuclear regulator, those with a low level of detail in their requirements have a greater opportunity to have priority areas. This could explain the fact that Swedish respondents experienced priority areas within the regulator's oversight to a higher extent than respondents from other countries.

Regarding regulatory approaches, risk/hazard informed is increasing according to both regulatory and utility respondents from all studied countries. This is likely due to prioritizing, trying to put efforts where risks are. In both Sweden and Finland, both regulatory and utility respondents foresee an increase of prescriptiveness.

Sweden is most likely the country in this study that has suffered most from the low sustainability in the political climate. Both the regulator and the utilities have been forced to continually adapt to changes that have been extremely demanding. These changes have varied from a positive climate enabling the building of our current fleet, to a very negative one with forced decommissioning, to a somewhat positive, giving possibility for new-build but without the basic prerequisites. These variations are often given as the reason for the maintenance debt that some of the Swedish plants have and are struggling with. It is however most likely that the same variations have given cause for a regulation debt that in many cases can burden the Swedish utilities even more.

7. Glossary and Abbreviations

AEC	Atomic Energy Commission
AECB	Atomic Energy Control Board
ASEA-Atom	Se. Allmänna Svenska Elektriska Aktiebolaget, a Swedish nuclear vendor that built BWRs in Sweden and Finland. Today merged as a part of Westinghouse Electric Sweden AB.
BWR	Boiling Water Reactor
BWROG	BWR Owners Group, a co-operation between BWR owners.
CANDU	CANada Deuterium Uranium, a Canadian developed reactor type.
CNRA	Committee on Nuclear Regulatory Activities
CNSC	Canadian Nuclear Safety Commission, the Canadian nuclear regulatory agency.
COG	CANDU Owner's Group, a co-operation between CANDU owners.
DOE	Department of Energy
EPR	European Pressurized Reactor
EPRI	Electric Power Research Institute
Enrichment	The increasing of the U-235 isotope in natural Uranium.
ENSREG	European Nuclear Safety Regulators Group
EU	European Union
EURATOM	European Atomic Energy Community
Heavy water	Water with Deuterium as the hydrogen isotope.
HRA	Human Reliability Assessment
HSE	Health-Safety-Environment
I&C	Instrument and Control
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical and Electronics Engineers, standards.
IEC	International Electrotechnical Commission, standards.
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operations
IRRS	Integrated Regulatory Review Service, a service provided by IAEA.
ISO	International Organization for Standardization, standards.
IVO	Fi. Imatran Voima, a Finnish energy company, today merged as a part of the energy company Fortum.
KPI	Key Performance Indicator
KSKG	Se. KärnkraftensSäkerhetsKoordineringsGrupp, the Safety Coordination Group of the nuclear industry.
KTA	De. Kerntechnischer Ausschuss, Nuclear Safety Standards Commission.
Licensee	The holder of the permit to operate a nuclear facility.
LOCA	Loss of Coolant Accident
LTO	Long Term Operation, operation beyond original technical lifetime.
MDEP	Multinational Design Evaluation Program
Moderator	Material used to thermalize fast neutrons, making them suitable for fission, e.g. light water, heavy water or graphite.

MTO	Se. Människa-teknik-organisation, Human-Technology-Organization affecting factors, Human Factors.
NEA	Nuclear Energy Agency
NKS	Se. Nordisk KärnSäkerhetsforskning, a Nordic nuclear safety research forum.
NOG	Nordic Owner's Group, a co-operation between Nordic BWR owners.
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission, the U.S. regulatory agency.
OECD	Organisation for Economic Co-operation and Development
OKG	Se. Oskarshamns kraftGrupp
OSART	Operational Safety Review Team, a service provided by IAEA.
PI	Performance Indicator
PSA (PRA)	Probabilistic Safety analysis (Probabilistic Safety Review)
PSR	Periodic Safety Review
PWR	Pressurized Water Reactor
RHWG	Reactor Harmonization Working Group, a part of WENRA.
RIF	Risk Increase Factor
RL	Safety Reference Levels, developed by WENRA.
RO	Se. Rapportervärd Omständighet, Event Report.
SCRAM	Safety Control Rod Axe Man, the emergency shutdown of a nuclear reactor.
SKI	Se. Statens Kärnkraftsinspektion, the Swedish Nuclear Inspectorate, today merged as a part of SSM.
SKIFS	Se. Statens Kärnkraftsinspektions Författningssamling, Regulatory Codes from SKI.
Special Supervision	A regulatory tool used for increasing the supervision in certain areas due to identified needs.
STUK	Fi. Säteilyturvakeskus, the Finnish nuclear regulatory agency
SSI	Se. Statens Strålskyddsinstitut, the Swedish Radiation Protection Institute, today merged as a part of SSM.
SSM	Se. Strålsäkerhetsmyndigheten, the Swedish nuclear regulatory agency.
SSMFS	Se. Strålsäkerhetsmyndighetens författningssamling, Regulatory Codes from SSM.
TMI	Three Mile Island, a NPP situated in Harrisburg, PA.
TUKES	The Finnish Safety and Chemicals Agency.
TVO	Fi. Teollisuuden Voima Oy, a Finnish energy company.
USNRC	United States Nuclear Regulatory Commission, the U.S. nuclear regulatory agency.
Utility	A corporation that owns and operates a nuclear facility.
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
WGWD	Working Group on Waste and Decommissioning, a part of WENRA.
WOG	Westinghouse Owners Group a co-operation between owners of Westinghouse reactors.
VTT	Fi. Valtion Teknillinen Tutkimuskeskus, Finnish Technical Research Center
VVER	Ru. Voda Voda Energo Reactor, a Russian designed PWR.

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Chalmers University of Technology

Appendix A - Questionnaire for the Licensee

Background

The following questionnaire is part of the master thesis project 'The Evolution of Regulatory Approaches in Nuclear Power Supervision' which is performed on behalf of Chalmers University of technology, with E.ON and Vattenfall as main stakeholders. The project will be completed in June 2014, published by Chalmers and therefore become a public document.

The answers to the following questions will be used to assess the different factors that have affected the design of the regulatory supervision; they will also be the basis for a forecast of how the regulatory supervision will develop.

Your answers should to a large extent represent the common opinion within your company. If you in any question should have an opinion that you know differs from the company's, we would appreciate to hear that too. The report will be designed so that your answers cannot be linked to you or your company. No citation will be made without your written consent.

After the interview is done and the answers are gathered you will be given the opportunity to look through your answers. This is to ensure that everything has been perceived correctly, you will also be given the opportunity to exclude material of a sensitive nature. At least two weeks before the publication of the report you will be able to take part of a draft, to see how your information has been used in the report.

CITY and DATE

Björn Arkborn

Alexander Engström

Questionnaire ID: Licensee:#

Personal information

The following information will be fully confidential and will not be part of the report. This data will only be used by us to separate people that have participated in our interviews.

Name: _____

Current position: _____

Former positions (last 10 years):_____

_____

Years within the nuclear industry (both supervision and NPP company): _____

Years within the company: _____

E-mail:_____

Design

Below, 43 categorized questions follow. The italic text below the main question is intended as a help or clarification; these questions do not need to be answered. If any of the questions need further clarification, this will be done during the interview.

Tradition, culture and organization

1. How has the use of nuclear power developed in your country?
   E.g. domestic development or imported concepts? Have you been influenced by any other countries? Has the political climate affected the development?

2. How is the regulatory supervision of reactor safety organized in your country?
   Is it divided in several authorities? Do you use certified bodies to assess the plants? Is self-assessment used to a large extent?

3. Can you identify any cultural characteristics that are affecting or have affected your regulatory model?

4. At what degree has your culture and tradition affected the regulatory model that is used today?
   Specify on a scale from 0-5, where 0 is insignificant effect and 5 is very high effect.

Organizational influences

5. How large significance have the following organizations and services had for your safety work? How large significance do you think they will have in the future?
   For every organization and service, assess how much safety work influence (significance) you think they have had the last 10 years and how much influence they will have in the future. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

Organization	Service	Significance	
		Past	Future
IAEA			
	IRRS		
	OSART		
	PSR		
WENRA (RHWG)			
CNRA			
INPO			
WANO			
ENSREG			
EURATOM			

6. Are there any organizations with perhaps associated services above missing which are of importance to your safety work?
   In that case, which organizations? How large significance do you think they have?

7. To what extent do international organizations affect how the safety work is conducted?
   Try to weigh in the total influence from all organizations. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

8. Do you have any direct contact with other licensees where an internal exchange of information and experiences takes place?
   In that case, which one/ones? What kind of exchanges? Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

Relationship between authority and licensee

9. Are there any neutral national forums where authority and licensee can communicate?
   Comment how well it works if it exists or else why do you think that such forums do not exist? Do you think they should exist?

10. Describe briefly your relationship with the authority.
    Is it open, close, distant etc.? Is the communication one-way or two-way?

11. What advantages and disadvantages do you, from a safety perspective, see with this type of relationship?

12. From your perspective, what would an ideal authority – licensee relationship be like?

Affecting factors

13. Below, some identified factors which currently have or have had significance for the development of nuclear supervision and safety work follows.
    Assess for each factor how large significance you think it have had the last 10 years and how large significance it will have in the future. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

Affecting factor	Significance	
	Past	Future
1. Political situation *Concerns both people's opinion and governing parties.*		
2. Fees, grants & taxes *Concerns both the fees the licensees pay to the authority as well as governmental grants received by the regulator.*		
3. Competence *Concerns the availability of personnel with the right competence and education.*		
4. Aging *I.e. long term operation*		
5. New analysis methods *This concerns refined measuring equipment (I&C), new test methods, new software etc.*		
6. New build *How large significance will new build or planned new build have for the safety work?*		
7. Operations and experience feedback *How large impact will/have experience feedback have/had on the safety work?*		
8. Health-Safety-Environment (HSE)		
9. Safety culture		

14. Can you think of any other factors that affect the regulatory supervision and safety work?
    In that case, which are they and how large significance will they have or have had?

Level of detail within the nuclear safety requirements

15. How detailed are the requirements that the authority imposes on the licensees?
    Specify on a scale from 0-5, where 0 is not detailed and 5 is very detailed.

    ☐

16. Why do you think that level of detail is preferred?
    Are there any cultural/historical explanations for the level of detail?

17. Describe how the level of detail has changed. (If it has changed)
    Has it increased or decreased?

18. If the level of detail has changed, what does this change depend on?
    E.g. accidents, international harmonization, political pressure etc.

19. What is your impression of this change in the level of detail? Has it had generally positive or negative consequences?

20. Is there a risk that the changes in the level of detail affect the responsibility distribution?
    Can a too detailed steering shift the responsibility towards the authority?

21. How do you think the authority perceives this change? Do they want a higher or lower level of detail?

Harmonization of the reactor safety requirements

22. What advantages come with an increased international harmonization of the reactor safety requirements?

23. What disadvantages come with an increased international harmonization of the reactor safety requirements?

24. Do you get the impression that the nuclear oversight is developing internationally in any specific direction?

Priority areas

25. Do you know how the authority chooses its priority areas?

26. To what extent is your work steered by the regulator‘s priority areas?
I.e. how large part of your safety work is directed by the regulator.

27. Is there a neutral forum where safety priority areas can be under discussion with the regulating agency?
If not, do you think such a forum should exist?

28. Do you get the impression that the regulating agency often or seldom chooses the same areas of priority as you would have done?

Efficiency

29. Is the efficiency of your safety work measured?
    Efficiency is in this context defined as the amount of safety obtained with respect to the work. This could be e.g. comparisons of PSA-results.

30. If efficiency is measured, how has the method of measuring the efficiency been developed?
    Has an existing model been adopted? Has it been developed by your company?

31. How do you work with increasing the efficiency of your safety work? Is increased efficiency a high priority?

General questions

32. Are there any changes that you would like to see within the regulator's supervision?
    This might include: Higher/lower level of detail, other laws, other working methods, other areas of priority etc.

33. On a comprehensive level, do you get the impression that the regulatory supervision will change in the near future?
    Try to give an answer both nationally and internationally.

34. On a comprehensive level, do you think your safety work will be affected by this change of supervision?
    Will the safety work increase, decrease, be unchanged or change direction?

35. What requirements do you think the licensees should have on the regulator?
    Predictability, transparency, objectivity, etc.

36. Can you think of any other relevant questions to add to this questionnaire?

Approaches

Below, 7 different approaches for nuclear supervision follow. These approaches have been defined by amongst others, the Swedish Radiation Safety Authority. They are used to describe the supervision within different areas of action. Please read through the definitions and try to, on a comprehensive level, answer if the use of a specific approach has decreased, remained unchanged or has increased during the last 10 years. Also, please answer how you think it will evolve onwards.

37. **Prescriptive –** Establishes specific requirements for conducting activities including technical solutions.

	Largly decreased	Somewhat decreased	Unchanged	Somewhat increased	Highly increased
Past:	☐	☐	☐	☐	☐
	Large decrease	**Somewhat decrease**	**Unchanged**	**Somewhat increase**	**High increase**
Future:	☐	☐	☐	☐	☐

38. **Case/Facility based** – Determines the safety requirements for each licensee through individual assessment of its design and operation, considering the unique history of each facility.

	Largly decreased	Somewhat decreased	Unchanged	Somewhat increased	Highly increased
Past:	☐	☐	☐	☐	☐
	Large decrease	**Somewhat decrease**	**Unchanged**	**Somewhat increase**	**High increase**
Future:	☐	☐	☐	☐	☐

39. **Outcome based –** Establishes specific performance goals or outcomes for licensees to attain but does not specify how they shall be attained. Licensees determine how they will conduct their work activities.

	Largly decreased	Somewhat decreased	Unchanged	Somewhat increased	Highly increased
Past:	☐	☐	☐	☐	☐
	Large decrease	**Somewhat decrease**	**Unchanged**	**Somewhat increase**	**High increase**
Future:	☐	☐	☐	☐	☐

40. **Risk/Hazard Informed** – Determines the risk/hazard associated with an area to evaluate the appropriate level of regulatory attention. A risk-informed approach uses a specific methodology including probability and potential for harm to identify areas of greatest risk. These areas receive priority for regulatory attention. A hazard approach uses specific criteria for the identification of areas of greatest potential for harm and these areas receive priority for regulatory attention.

	Largly decreased	Somewhat decreased	Unchanged	Somewhat increased	Highly increased
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41. **Process/System based** – Identifies specific key processes that lead to safe performance and requires licensees to establish and implement these processes effectively.

	Largly decreased	Somewhat decreased	Unchanged	Somewhat increased	Highly increased
Past:	☐	☐	☐	☐	☐
	Large decrease	**Somewhat decrease**	**Unchanged**	**Somewhat increase**	**High increase**
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42. **Self-Assessment based** – Identifying of both good practices and problem areas needing improvement, internal reviews and follow up. The regulator evaluates the licensee self-assessment program, reviews the results of the licensee assessments, & selectively inspects the licensees' follow up on self-assessment results.

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43. **Influence/Education based** – Provides information and training opportunities for the industry including workshops, feedback, research results, and other information in order to improve industry performance.

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Appendix B - Questionnaire for the regulator

Background

The following questionnaire is part of the master thesis project 'The Evolution of Regulatory Approaches in Nuclear Power Supervision' which is performed on behalf of Chalmers University of technology, with E.ON and Vattenfall as main stakeholders. The project will be completed in June 2014, published by Chalmers and therefore become a public document.

The answers to the following questions will be used to assess the different factors that have affected the design of the regulatory supervision; they will also be the basis for a forecast of how the regulatory supervision will develop.

Your answers should to a large extent represent the common opinion within your agency. If you in any question should have an opinion that you know differs from the agency's, we would appreciate to hear that too. The report will be designed so that your answers cannot be linked to you or your agency. No citation will be made without your written consent.

After the interview is done and the answers are gathered you will be given the opportunity to look through your answers. This is to ensure that everything has been perceived correctly, you will also be given the opportunity to exclude material of a sensitive nature. At least two weeks before the publication of the report you will be able to take part of a draft, to see how your information has been used in the report.

CITY and DATE

Björn Arkborn

Alexander Engström

Questionnaire ID: Regulator:#

Personal information

The following information will be fully confidential and will not be part of the report. This data will only be used by us to separate people that have participated in our interviews.

Name: _____

Current position: _____

Former positions (last 10 years):_____

_____

Years within the nuclear industry (both supervision and NPP company): _____

Years within the agency:_____

E-mail:_____

Design

Below, 43 categorized questions follow. The italic text below the main question is intended as a help or clarification; these questions do not need to be answered. If any of the questions need further clarification, this will be done during the interview.

Tradition, culture and organization

1. How has the use of nuclear power developed in your country?
   E.g. domestic development or imported concept? Have you been influenced by any other countries? Has the political climate affected the development?

2. How is the regulatory supervision of reactor safety organized in your country?
   Is it divided in several authorities? Do you use certified bodies to assess the plants? Is self-assessment used to a large extent?

3. Can you identify any cultural characteristics that are affecting or have affected your regulatory model?

4. At what degree has your culture and tradition affected the regulatory model that is used today?
   Specify on a scale from 0-5, where 0 is insignificant effect and 5 is very high effect.

Organizational influences

5. How large significance have the following organizations and services had for your supervision? How large significance do you think they will have in the future?
   For every organization and service, assess how much supervision influence (significance) you think they have had the last 10 years and how much influence they will have in the future. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

Organization	Service	Significance	
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	IRRS		
	OSART		
	PSR		
WENRA (RHWG)			
CNRA			
INPO			
WANO			
ENSREG			
EURATOM			

6. Are there any organizations with perhaps associated services above missing which are of importance to your supervision?
   In that case, which organizations? How large significance do you think they have?

7. To what extent do international organizations affect how the supervision is conducted?
   Try to weigh in the total influence from all organizations. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

8. Do you have any direct contact with other regulating agencies where an internal exchange of information and experiences takes place?
   In that case, which one/ones? What kind of exchanges? Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

Relationship between authority and licensee

9. Are there any neutral national forums where regulator and licensee can converse?
   Comment how well it works if it exists or else why do you think that such forums do not exist? Do you think they should exist?

10. Describe briefly your relationship with the licensee.
    Is it open, close, distant etc.? Is the communication one-way or two-way?

11. What advantages and disadvantages do you from a safety perspective see with this type of relationship?

12. From your perspective, what would an ideal authority – licensee relationship be like?

Affecting factors

13. Below, some identified factors which currently have or have had significance for the development of nuclear supervision and safety work follows.
    Assess for each factor how large significance you think it have had the last 10 years and how large significance it will have in the future. Specify on a scale from 0-5, where 0 is insignificant influence and 5 is very large influence.

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14. Can you think of any other factors that affect the regulatory supervision and safety work?
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21. How do you think the licensee perceives this change? Do they want a higher or lower level of detail?

Harmonization of the reactor safety requirements

22. Does your agency work for an international harmonization of the reactor safety requirements?
    In that case, how?

23. What advantages come with an increased international harmonization of the reactor safety requirements?

24. What disadvantages come with an increased international harmonization of the reactor safety requirements?

25. Do you get the impression that the nuclear oversight is developing internationally in any specific direction?

Priority areas

26. How does the authority chooses its priority areas?
    Are there any organizations which actively or passively affect your priority areas?

27. Is there a neutral forum where safety priority areas can be under discussion with the regulating agency?
    If not, do you think such a forum should exist?

28. Do you get the impression that the licensees often or seldom think you choose the right area of priority?

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