The perception of Nuclear power in Sweden
How engineering students view it

Ali Abdallah
Abstract

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Nuclear power has been an important part of the electricity generating in Sweden in almost half a century. However, the use of nuclear power raises many complex issues such as economy, accident risks, and radioactive waste management and storage. Nuclear power has therefore been debated intensively in Sweden as in many other countries since the 1970s. Several countries have changed their nuclear policy and started decommissioning programs following the nuclear accident in Fukushima back in 2011. Citizens’ support for nuclear power has declined worldwide in last few years, including in Sweden. This study aims to investigate the perception of nuclear power among engineering students and shows that the majority of engineering students, who generally are positive towards technology, have been affected by their surrounding and are against nuclear power. Engineering students in general, both supporters and opponents of nuclear power, agree that Sweden should gradually phase out nuclear power and replace it by renewable energy sources.
Preface

This report is the final part of the Master Programme in Industrial Management and Innovation and concludes in that sense my Master’s studies at Uppsala University. The study has been conducted during the first period of the autumn semester of 2017. The thesis work has been really instructive and enjoyable.

I would like to thank all the students at Uppsala University who have been part of the research process. I am extremely grateful for all the help and feedback that I have received from Ulrika Persson-Fischier, lecturer at Department of Engineering Sciences and Enrico Baraldi, professor at Department of Engineering Sciences, both at Uppsala University. Your expertise has been invaluable.

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1. Introduction

1.1 Background
Nuclear power is considered by many as an efficient and reliable technology for power generation. It has low production costs and is virtually free from climate-affecting emissions. Nuclear power is also surrounded by high security requirements.

In Sweden, electricity has been produced by nuclear power since the early 70's when Sweden's first commercial reactor Oskarshamn 1 was put into operation in 1972. Today there are ten reactors in the three nuclear power plants Forsmark, Ringhals and Oskarshamn. Nuclear power accounts for more than a third of electricity production in Sweden. (Lindmark, 2017)

However, far from everyone is satisfied with nuclear power and see it as a sustainable energy source. Ever since the start, nuclear power has encountered a lot of resistance. Nuclear power is heavily influenced by, among other things, the fear of nuclear weapons and its use, as in Hiroshima and Nagasaki, in 1945, and for nuclear accidents, which often have devastating consequences, similar to those in Chernobyl, in 1986, and quite recently in Fukushima, in 2011. Such accidents led to evacuating the cities close to the power plants. The cities are still uninhabited due to the radioactivity caused by the accidents.

At the present moment there is a lively debate about the nuclear power's being or non-being, where proponents of nuclear power often draw it as environmentally friendly (with low carbon dioxide emissions), while opponents consider that the process involves major risks (environmental, economic and security) in order for it to be defensible. Nuclear power, both the electricity generation and related activities such as nuclear fuel management, are complex systems, both in terms of its technology and its role in Sweden and the world. It is also a hot political issue; nuclear power disasters like the one in Fukushima 2011 become world news and help to influence public opinion on nuclear power and its non-being.

Critics argue that the disadvantage of nuclear power, such as the risks of reactor accidents and the problem of fuel management for the radioactive waste, is weighing over its advantages. At the same time, nuclear power plants have a significant role in Swedish energy production. It contributes to about one third of the annual electricity generation, as mentioned earlier, and nuclear advocates often emphasize the difficulty of replacing nuclear power with other energy types. (Lindmark, 2017)
1.2 Purpose
Engineering students have in general a positive attitude towards technology. Thus it is really interesting to study how engineering students in Sweden perceive nuclear power. The intention is to examine the view on nuclear power and understand why it is as it is. The work has primarily a descriptive purpose to give the image of how Swedish engineering students perceive nuclear power and understanding the underlying reasons behind that. It is interesting to examine whether their general positive view on technology is also transmitted to an advanced technology like nuclear power, or if they are negative towards nuclear power despite their general interest in technology. The idea is to let the respondents describe, discuss and reflect their opinions on nuclear power, and later analyse that and give a picture on its reasons.

1.3 Question formulation
The questions that the study should answer are:

Q1. How do Swedish engineering students perceive nuclear power?

Q2. Which factors affect their view on nuclear power?

1.4 Delimitation
Ten million is a huge number of people and can never be fairly represented by a small amount participant. Thus and due to the scope and timeframe of this work, the main demarcation is to focus on university students and more precisely engineering students. A further demarcation is choosing to focus on engineering students at Uppsala University. Further, the study focuses only on examining the perception of nuclear power and the reasons behind that and not going further and studying other areas like for instance studying how a negative opinion can be improved/changed. Important to mention is that this study is an exploratory study and does not aim to produce any statistical facts.
2. Method

The chosen methods used in this study are described in this section with their respective pros and cons.

2.1 Choice of method

The choice of the method must always be subordinate to the study's purpose and the purpose must therefore control the choice of method (Andersson, 1995). Based on the purpose of the study a literature review was conducted as a first step to get further engaged in the topic and collect information useful for structuring the work. The history of nuclear power in Sweden was studied giving a better picture of the recent situation. The literature review helped further in designing the structure and formulating the questions for the interviews conducted in this study. Both focus groups and semi-structured interviews were used in this study. Important to mention here is that I myself have been working as a system designer in the nuclear power plant Forsmark since January 2015. The knowledge and experience I obtain have helped me a lot throughout the study.

Patel and Davidson (2011) argue that whether the study is quantitative or qualitative depends on how one chooses to generate, process and analyse information. A study can use both approaches in varying degrees. Qualitative research includes how to investigate, interpret and understand the events and incidents that people were part of and also their experiences of these events (Patel & Davidson, 2011). When choosing to use qualitative methods, one intends to obtain information from direct observations or interviews and dialogues. This is preferable when you need to understand the meaning of the information you get. “Meaning” here refers to how emotions and values reflect on how to take a stand on specific questions. This method can be considered more involvement than quantitative since the researcher must be present to be able to take part of feelings and expressions. Two prevalent methods that are associated with the qualitative are interviews and observations. (Eriksson & Wiedersheim-Paul, 2011)

David Morgan (1996) defines a focus group as a research technique where data is collected through group interaction around a topic determined by the researcher. It is a way to reduce the impact and control from the researcher, in comparison with individual interviews. Thus it gives another dimension to the study since it may uncover hidden variables that are hard to get to through structured or semi-structured one-to-one interviews. Besides that the topic is determined by the researcher, other key concepts that distinguish a focus group from other
forms of group interviews are that it aims to collect data through group interaction and that it is conducted for research purposes (Wibeck, 2000).

Using focus groups as a method is useful for attracting the social aspects of the interviewees. The views of a participant can be compared to another participant. Thus it is easier for the interviewer to differentiate between different opinions (Kjaer Jensen, 1991).

### 2.2 Focus groups & semi-structured interviews

A major focus in this study was on conducting focus groups and semi-structured interviews with individuals from the project’s target group, i.e. engineering students. The choice fell on engineering students partly because of their positive view on and their knowledge about advanced technologies. Being myself an engineering student from Uppsala with a lot of contacts is another reason of choosing to focus on engineering students in Uppsala.

Seven short semi-structured interviews and five focus groups were conducted in total. The participants in the interviews and the focus groups were students from different engineering educations at Uppsala University, more precisely Ångströmlaboratoriet. Some own friends studying an engineering education at Uppsala University participated in the study and helped by spreading the word and recruiting more participants from their educations or friends at the university. The distribution of the participants based on educations and gender is as follows:

- 3 males and 1 female studying Master Programme in Electrical Engineering
- 4 males and 2 females studying Master Programme in Energy Systems Engineering
- 2 males studying Master Programme in Chemical Engineering
- 4 males and 3 females studying Master Programme in Sociotechnical Systems Engineering
- 3 males and 1 female studying Master Programme in Engineering Physics
- 2 males and 1 females studying Bachelor Programme in Construction Engineering
- 3 males studying Bachelor Programme in Electrical Engineering
- 2 males and 1 female studying Bachelor Programme in Mechanical Engineering

The participants are between 21 and 29 years old. For each focus group I tried to mix the participants to get students from different educations and different genders in each focus group. After performing the literature review in the study and before starting the work with the focus groups, three short semi-structured interviews with engineering students at Uppsala University were conducted. The aim of these interviews was to examine how the students,
who are the target group for the focus groups, would answer some specific questions, how they choose to answer and what they choose to focus on. This helped a lot in the preparation for the focus groups that were conducted later. The understanding obtained from the interviews facilitated the designing of the focus groups and further formulating the questions discussed between the participants.

Totally 32 engineering students participated in the five focus groups, 14 in two occasions (seven participants each) and 18 in the remaining three (six participants each). The conversations in the focus groups were moderated by the author of this thesis and the respondents were allowed to discuss freely the predetermined questions. The questions discussed in the focus groups are the following:

- How familiar are you with nuclear power?
- What are your thoughts on nuclear power and how do you feel towards that?
- Is there any specific incident that affected your opinion?
- Where do you get your information about nuclear power from?
- Do you trust these sources?
- Do you trust the nuclear power companies/the government/different organisations/media?
- Did your current studies affect your opinion in any way?

The questions were explained further when needed to make sure that the level of understanding was on the highest level possible. Furthermore, discussions on some questions led sometimes to answering other question indirectly leading to more continuous conversations. The discussions were recorded and notes were taken by the moderator, i.e. the author of this study.

After conducting the focus groups, four participants from the different groups were each chosen for a further semi-structured interview. These participants were chosen based on their interesting point of views that they did not get the opportunity to totally discuss in the focus groups due to other dominant participants and other factors such as shyness and lack of time.

Both the interviews and the focus groups were conducted in Swedish. Thus it is important to mention that the results obtained were first translated to English by the author of this study before being analysed and discussed.
2.3 Method Critique

Interviews are socially and linguistically complex situations that require a reflexive attitude (Alvesson, 2011). The qualitative data obtained from the interviews are based on understanding and need therefore neither verification nor falsification. Instead, the material has been interpreted and analysed, which is influenced by the context and the person who analyses the material (Thomsson, 2010). For qualitative methods it can be difficult sometimes to determine whether the respondent has given his true answer in the interview. If the respondent does not understand the question or answers as he thinks the interviewer wants him to answer, so-called adaptation responses, the risk for a distortion of the results is bigger (Abdallah & Zand, 2017). Thus the choice of explaining some questions further and making sure to obtain the highest level of understanding.

Focus group as a method is very useful in such studies however it is still far from flawless. One important disadvantage to take in consideration is that not everyone in a focus group will be able to take equally space. So called shadow respondents will not be able to share as much of their opinions as other participants. Moreover, having several participants sharing a single and same interview occasion will often lead to less time spent on each person than in the case of a personal interview. Even gathering a specific group of people at the same time may be impossible sometimes (Kjaer Jensen, 1991). The author tried to minimize the effects of such problems by conducting additional personal interviews with some of the participants in the focus groups.

2.4 Literature review

The literature review aims to investigate what literature and research is conducted in the area studied. This is important, partly to see if similar work has been done but also to find references that substantiate statements made in the report. The execution of the literature review can largely be described as a work process in different steps. In the first step, a selection of a number of keywords expected to provide a good coverage for the area to be investigated is made. The second step involves searching in a literature database.

In order to limit the number of articles and increase the relevance of the results, searches are made for different combinations of the keywords. The search is further limited by including only articles and studies in relevant subjects in the final step of the process, after which the abstract is read. Depending on the abstract of each article it is then considered if the article is interesting for the work, and thus chosen for further reading of the entire content.
Furthermore, the references in some articles led to other useful literature. The two databases used in this study are presented and described below:

- **DiVA (Digital Scientific Archive)** - The database contains research publications and student essays from 44 Scandinavian universities and research institutes. The literature database was developed by Uppsala University Library, but is being managed today in collaboration with other higher education institutions (DiVA, 2017).

- **Libris Uppsök** - LIBRIS is a national search service with information about titles in Swedish libraries. The Royal Library is responsible for the operation and development of the service. The registering libraries contribute in common to the building of the content. LIBRIS contains nearly 7 million titles from approximately 300 library units at Swedish university, college and research libraries and about twenty public libraries. (Libris, 2017).
3. Nuclear power in Sweden - a historical overview

The Swedish nuclear power era begins immediately after World War II. The atomic bombings during World War II were an alarm clock. In autumn 1945, the Defense Research Institute (FOA - Försvarets forskningsanstalt) requests funding from the government to initiate nuclear energy research. The grant gets approved and FOA initiates research work. A couple of years later AB Atomenergi, owned by the state and industry together, is formed to develop the new power source. Until the 1960s, it had both civilian and military purposes. Sweden's first commercial nuclear reactor was put into operation in Ägesta, south of Stockholm. Unlike previous reactors built in the previous years, the reactor was not used for research purposes, but to produce district heating to Farsta, a suburb south of Stockholm. The Ägesta reactor supplied Farsta with district heating until 1973. During operation, the plant also produced ten megawatts (MW) of electricity. (Leijonhufvud, 1994)

The Governmental Radiation Protection Institute (SSI - Statens strålskyddsinstitut) is formed in 1965. It is an authority instructed to regulate all activities with radiation. In 1968 and after several years of debate, the Government and Parliament decide to write off Sweden's plans to produce nuclear weapons. A new investigation on the future of the nuclear industry is completed the same year which means that Sweden would be self-sufficient in nuclear fuel and nuclear technology. (Leijonhufvud, 1994)

The first commercial nuclear reactor for electricity generating, Oskarshamn 1, was commissioned in 1965 and put into operation in 1972. By this time, nuclear criticism had begun to grow both in Sweden and internationally. Several experts in the field began to talk about the risks of nuclear power and the consequences that an accident can cause with radioactive emissions. Nuclear power is now a serious political issue, with the center party (Centerpartiet) as the most driving party against nuclear power. Swedish Nuclear Fuel Supply AB (SKBF - Svensk Kärnbränsleförsörjning AB) is formed with the task of purchasing uranium and enrichment services on the international market. (Leijonhufvud, 1994)

The second reactor in Oskarshamn (Oskarshamn 2) is taken in commercial operation in 1974. During the year, the center party (Centerpartiet) dissociates itself totally from nuclear power as the first political party in Sweden. In 1975 two nuclear reactors are taken commercially. It is Barsebäck 1, south of Landskrona and Ringhals 2, located on Väröhalvön, north of Varberg.
The years 1976-1979 are politically dramatic years for nuclear power. The nuclear issue is an important poll in the parliamentary elections in 1976. Center leader Thorbjörn Fälldin promises in the election movement in 1976 not to allow new reactors and nuclear power to be established. He and the other liberal parties win the election over the Social Democrats but are forced to compromise with the other government parties and start Barsebäck 2 in 1977. Ringhals 3 is completed but not commercialized because a new law, “villkorslagen”, enters into force in spring 1977. The law means that no new fuel is allowed to be supplied to the reactors unless the nuclear power plant operators can guarantee that they can take care of the waste and the used fuel in a safe way. The law is being implemented because of the fragmentation of the liberal government on the nuclear issue. Fälldin's government falls in 1978 after disagreement on a referendum on nuclear power. At the same time, leading nuclear physics and environmentalists question the nuclear image of the nuclear problem and point to the waste problems. (Leijonhufvud, 1994)

On March 27, 1979, Ringhals 3 is granted permission to start the reactor since the owner has prepared the accounts required by “villkorslagen”. The following day, March 28, the nuclear accident occurs in the Three Mile Island reactor in Harrisburg, USA. As a direct consequence to the accident, a reactor safety investigation is being introduced in Sweden. The investigation proposes a series of measures to strengthen the safety of Swedish nuclear power plants. The investigation proposes, inter alia, technical measures that will help reduce radioactive emissions if the reactor core melts, measures to improve the monitoring of reactors, training
and instructions for personnel. The investigation's proposal also includes increased requirements for safety analyzes (PSAs), increased focus on human-machine issues and increased resources for the governmental authority (Statens kärnkraftinspektion). (Leijonhufvud, 1994)

Viewed from an international perspective, Sweden is the country that then, based on the accident in Harrisburg, takes the most far-reaching security enhancing arrangements. In May of the same year, the parliament decides on referendum in the nuclear issue. Then a temporary law, “Rådrumslagen” (Council Chamber), is also set up, which means that no new reactors may be put into operation before the referendum. Ringhals 3, which is completed, is therefore not taken into operation. The law also affects other reactors that are being built, Forsmark 1 and 2, and Ringhals 4. (Leijonhufvud, 1994)

An important referendum was conducted in 1980 resulting in the parliament deciding that there will be twelve reactors in Sweden, provided that nuclear power should be shut down by 2010. However, the decommissioning of nuclear power should only be initiated when there are alternative energy sources. Nuclear power companies are authorized by SKBF to construct Clab, an interim storage of used nuclear fuel, in Oskarshamn. Forsmark 1 is put into commercial operation in the same year and Forsmark 2 and Ringhals 3 the year after that. Ringhals 4 is put into commercial operation in 1984, Forsmark 3 and Oskarshamn 3 the following year making it 12 Swedish reactors in operation, see figure 2. Nuclear power companies reorganize SKBF and form instead Swedish Nuclear Fuel Management AB (SKB - Svensk Kärnbränslehantering AB), which has overall responsibility for the entire nuclear waste area. (Leijonhufvud, 1994)
1986 is one of the most important years for the development of Nuclear power in Sweden and the rest of the world. On April 26, a serious accident occurs in the Chernobyl reactor in the then Soviet Union. The whole world becomes aware that an accident can have major consequences even far from the scene of the accident. The accident does not lead to any technical changes in Swedish reactors because they are of a different design. Nuclear companies and government agencies improve their readiness. The current Radiation Protection Institute (SSI - Statens strålskyddsinstitut) increases monitoring, among other things, through more and improved measurement stations. Countries strike agreements between each other with the purpose that they undertake to warn each other’s accidents. Nuclear power companies and authorities also begin to talk about security culture as an important part of nuclear power plant safety work. The nuclear industry forms an international trade association The World Association of Nuclear Operators (WANO) to enhance cooperation and the exchange of information and experience. (Leijonhufvud, 1994)
On January 1, 1998, the law of the decommissioning of nuclear power comes into force. The law says, among other things, that the nuclear power plant in Barsebäck should be closed and that no date should be determined for the shutdown of the last reactor in Sweden. The government can thus decide at what time the right to operate a nuclear reactor ceases to apply. Barsebäck 1 was shut down the 30th of November 1999. (Pershagen, 2014)

On September 11 2001, four aircraft are hijacked and two of them fly into the World Trade Center in New York. The terror attacks lead to further intensification of the radiation safety work. The events put focus on issues of nuclear safety protection of nuclear facilities and other radioactivity activities. Nationally, the physical protection of nuclear facilities is being developed and internationally, the International Atomic Energy Agency (IAEA) is expanding its work on, inter alia, an extended convention on physical protection as a result. (Pershagen, 2014)

On January 1, 2005, new regulations enter into force concerning the design and execution of nuclear reactors, SSMFS 2008: 17 (SKIFS 2004: 2). The purpose of the regulations is to increase safety and adapt the requirements to a modern level. With the new regulations, the Authority's requirements for safety are tightened, which means that nuclear power plants need to undertake extensive modernization measures to meet the requirements. Nuclear companies design a transitional plan for each reactor, specifying which measures will be implemented and when. Barsebäck 2 is taken out of operation by decision of the parliament and the last research reactors (R2 and R2-0) at Studsvik are closed down. The government brings together the Radiation Protection Institute (Strålskyddsinstitutet) and the National Nuclear Power Inspectorate (Statens Kärnkraftinspektion) to one authority, the Radiation Safety Authority (Strålsäkerhetsmyndigheten), which starts operating on 1 July 2008. Swedish Nuclear Fuel Management AB (SKB) chooses Forsmark in the Östhammar County as the place for final disposal of used nuclear fuel, in 2009. (Pershagen, 2014)

On March 11 2011, a serious accident occurs at the Japanese nuclear power plant Fukushima Dai-ichi as a result of an earthquake (9.0 on Richter scale) and subsequent tsunami. The nuclear power plant was designed to resist an earthquake, but the subsequent tsunami level was 13-14 meters high, which was much higher than the 5.7 meter high barrier that was used as protection. The scale eliminates both the regular cooling system and the reservoir system at several reactors. Four out of six reactors were completely destroyed after hardened meltdowns, hydrogen explosions and emergency cooling with seawater and will never be able
to restart. The accident is classified as a seven on the seven-grade INES scale. Following the nuclear accident, the EU Council of Ministers decides that all EU nuclear countries should review how well nuclear power plants are facing events worse than previously thought, so-called stress tests. The work of stress tests is divided into five areas: earthquake, flooding, extreme weather, total power loss, total drop of cooling and waste handling. (Pershagen, 2014)

Important historical events that affected the view on nuclear power:

- Atomic bombings in World War II in Hiroshima and Nagasaki, Japan in 1945.
- Serious nuclear accident in the Chernobyl reactor in the then Soviet Union in 1986.
- Serious nuclear accident at the Japanese nuclear power plant Fukushima Dai-ichi as a result of an earthquake and subsequent tsunami in 2011.

On December 29, 2011, the Radiation Safety Authority presents its assessment of the Swedish nuclear power plants stress tests. The Authority's report is submitted to the EU. The Swedish security evaluations with subsequent independent European investigation showed that Swedish nuclear power plants are robust but that a number of security improvements should be made to strengthen safety further. During the year, Swedish Nuclear Fuel Management (SKB) submitted its application to the Swedish Radiation Safety Authority and the Environmental Court to build a final repository of spent nuclear fuel in Forsmark, Östhammar County. (Pershagen, 2014)

Today there are three nuclear power plants in operation in Sweden, Forsmark, Oskarshamn and Ringhals. The plants in Forsmark and Oskarshamn have three reactors each while Ringhals has four reactors. In 2015, Oskarshamns and Ringhals owners decided to wind up two reactors each in advance. Oskarshamn 1 and 2 are already out of operation while Ringhals 1 is planned to be shut down in 2020 and Ringhals 2 in 2019. (Strålsäkerhetsmyndigheten, 2017)
4. Previous studies and relevant theories

Some interesting earlier studies and theories relevant for this work are presented in this section.

4.1 Previous studies

In a study where an opinion poll was conducted in 2007 Vetenskap & Allmänhet\(^1\) (Science & Public), VA, presents several interesting facts on how nuclear power is viewed in the Swedish society. The study shows that age differences are primarily in the view of nuclear research. The willingness to invest in nuclear research increases with increasing age. More than half of the participants, 54 percent believe it is important to invest in nuclear research, but young people are more doubtful than older people. Only four out of ten between 16 and 29 years of age consider nuclear research important while one out of three young people believes that nuclear research is not important, compared to the average of 22 percent. (Vetenskap & Allmänhet, 2007)

Young people (16-29 years old) do not consider nuclear research as important to invest in with government funds. The same group shows optimism for research opportunities to introduce environmentally friendly and efficient energy sources. Furthermore, the study shows that those with higher education want to invest more often in nuclear power than those with only primary education. The study points out that men prioritize nuclear research higher than women. Women, however, do not classify nuclear power as unimportant, but more closely in between, i.e. three out of five. (Vetenskap & Allmänhet, 2007)

The SOM-institute\(^2\) at Göteborg University performs annually studies on the Swedish opinion on nuclear power and other energy sources. In their study for the year 2017, Swedish Opinion on Nuclear Power 1986 – 2016, they show the following.

The figures 3-6 bellow show the results of the annual nationwide surveys in Sweden. The size of the sample is 3 000 Swedish people 16–85 years old. The surveys were based on mail questionnaires with an average response rate of 60 percent. The survey question asks about

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\(^1\)Vetenskap & Allmänhet (Science & Public), VA, works to increase people's - especially the youths - interest and commitment to knowledge. The association strives to make conversations based on issues that interest and engage people. To investigate the attitudes of knowledge, science and researchers, VA studies how the public and different groups in society look at these areas as well as the researcher's attitude to dialogue.

\(^2\)The SOM Institute is an impartial research organization at the University of Gothenburg. Since 1986, the SOM institute has worked with researchers in a number of research fields to highlight public opinion and to understand Swedish social development. The institute performs national and local questionnaires annually and organizes seminars on the theme Society, Opinion and Media.
Swedes’ opinion on the use/long term use of nuclear power as an energy source in Sweden. Response alternatives, including a “no opinion” alternative, are phrased as fairly concrete policy proposals and have varied somehow over the years. The number of substantial response alternatives was five up until 1996/97, but there after reduced to four. The words “use nuclear power” and “phase out nuclear power” has all the time been used in the response phrasings, making it possible to distinguish between people in favour of using nuclear power versus people in favour of phasing out nuclear power. (Holmberg, 2017)

It is obvious that the resistance against nuclear power is growing and has grown a lot in the last few years, especially after the Fukushima Daiichi nuclear disaster in 2011. More than half of the participants in the surveys are in the favour of phasing out the nuclear power while less than 30% are in favour of using it. These numbers are the total opposite of the numbers back in the early 2000s. See figure 3.

One interesting conclusion that can be drawn from the SOM institute’s studies is that young people (between 16 and 29 years old) are those in less favour of phasing out nuclear power. Although 46% of the young Swedes are in favour of phasing out nuclear power, it is still considered a slightly better number than the results from the other age groups. Even though there is barely any difference in the percentage. See figure 4.
Further, the SOM institute studies the opinions on nuclear power among Swedes in different educational groups showing that people with higher education tend to be more in favour of phasing nuclear power than those with lower education. See figure 5.
Figure 6 shows the Swedish trust in information about energy and nuclear power provided by different groups. Environmental organisations are considered to be trusted among Swedes in comparison to other sources. The trust for the Swedish government which is much less than for the environmental organisations have had a huge variation over the years, most probably due to the variation of the governments in charge. The nuclear power industry have lost the Swedish trust slowly but surely the last few years while the little trust for the journalists is growing slowly (16% to 36%). See figure 6. (Holmberg, 2017)

4.2 Risk communication
Several studies conducted in the last 50 years have shown that many people in different industrialized countries are constantly worried about various risks that threaten their survival. Pollution, environmental degradation and nuclear accidents are some of these risks. Such risks are caused by different activities, technologies and techniques that mankind is using. Studies show that large groups of people are worried because they feel that such risks are unacceptably high. The concept of risk communication has been frequently studied and used since its first appearance in the literature in the mid-80s. Researchers from various science disciplines have published lots of articles and studies that deal with different aspects of risk communication (Gurabardhi et al., 2004). Such theory is relevant for this study because of the risks of nuclear power and enormous consequences that an accident can lead to.
4.3 Resistance to Attitude Change
Richard Petty and Jon Krosnick (2014) define a theory describing the resilience that may exist towards attitude change. They believe that once becoming well-rooted in an existing attitude structure, attitudes are really strong, meaning that attitudes are psychological phenomenon that shows when a person expresses if he or she is for or against a specific object, so-called attitude object. The strength of attitudes is defined as links between attitudes and other aspects linked to knowledge.

Only after coming in contact with an object a person can either react positively or negatively towards the object. This contact makes it possible to evaluate the object and develop emotionally or cognitively attitudes towards it. The feeling experienced the first time one comes into contact with the attitude object is considered important. Feeling from the first contact may cause a psychological tendency leading to similar reaction the next time one comes into contact with the object. This leads further to strengthening the inner attitude structure previously experienced towards the attitude object. (Petty & Krosnick, 2014)

The inner structure usually includes a cognitive content that consists of the recipient’s both concrete and abstract beliefs in the characteristics of the attitude object. Concrete images are created by occasional experiences or events while abstract images are created due to the combination of several experiences or events. These images are basis for beliefs in the attitude object’s characteristics. The internal structure of the attitude can further include an emotional behavioural pattern that is linked to the attitude object causing often a pattern to be associated with the object. Emotions, moods and sympathetic nervous system activities that the person has experienced in relation and associated to the attitudinal object are basis in the emotional part of the emotional behavioural pattern. Besides the emotional patterns, even behavioural patterns are included in the inner attitude structure and created depending on past events and experiences. The behavioural patterns are created in a similar way as the emotional behaviour and affect how the recipient acts toward the attitude object. (Petty & Krosnick, 2014)

The inner structure of the attitude toward an attitude object consists of the overall extent of the cognitive, emotional and behaviour structures that the person has associated with the attitude object. Petty and Krosnick (2014) consider that it requires a multi-level of attitude change in order to be able to change the internal attitude structure toward the attitude object.
4. Results & Analysis

Section 3.1 Nuclear power in Sweden shows that nuclear power has been and still is a vital part of the electricity production. It contributes to about 40% of annual electricity generation. However, this has not been unproblematic. Nuclear power is a serious political issue. Resistance towards nuclear power in Sweden has always been there through the years. It has sometimes led to delays in building and start-up of nuclear power reactors and recently even shutting down some. Swedish people have different opinions on nuclear power. As shown in the SOM-institute study presented in 3.2 Previous studies, a big part of the Swedish people are against nuclear power and want to phase it out while another part of the people want to continue using it. The aim of this study is to examine how Swedish engineering students perceive nuclear power and the following results were obtained.

All participants in this study consider that they have sufficient knowledge on nuclear power and feel familiar with the nuclear issue; although discussions showed that some participants are less familiar with the subject than others. Engineering students are in general positive to technology and therefore it is easy to assume that most of them would be in favour for nuclear power, but so wasn’t really the case. Only nine of the participants were positive towards nuclear power, 19 participants were against nuclear power while four participants were somehow neutral and neither for or against it. There was no significant difference between students studying a master program and a bachelor program. Neither was there any difference depending on the gender of the participants.

Most of the students argue that they do not want to be exposed to the risk of being forced to choose between increased cancer risk or to abandon their hometown forever and these are the unpleasant choices that remain after a nuclear accident. Here one can directly connect to risk communication that Gurabardhi and others describe, because of the huge environmental and health damage a nuclear accident may cause. Students discussed different nuclear accidents like the ones that occurred in the Three Mile Island reactor in Harrisburg, USA, the Chernobyl reactor in the then Soviet Union and at the Japanese nuclear power plant Fukushima Dai-ichi. The Harrisburg accident was discussed by some and not everyone has heard about it while Chernobyl and Fukushima are well-known and were discussed a lot. Beside the nuclear accidents, terror attacks were discussed heavily and mostly the terror attack on the World Trade Center in New York, USA back in 2001, even though it isn’t a nuclear accident. Most of the participants, for, against and even neutral ones fear terror attacks and feel that it has been increasing a lot lately, even in peaceful countries like Sweden. They feel that if the
World trade Center can be hit of course a nuclear power plant would be a goal for terrorists. What students disagree about here is the level of security we have in our power plants.

Sweden is one of the countries with the highest security standards in nuclear power, having different organisations and institutions monitoring that. A lot of safety investigations and analyses, regulations, laws and security adjustments were executed through the years. Students for nuclear power pointed out the fact that we have a safe nuclear power in Sweden and that we have had that since the beginning. They meant that Sweden has been handling it right and that we are aware of its danger and thus been showing it the “respect” it deserves by enhancing the security and the safety around it. However, as one of the participants in the focus groups said,

“High security does not mean that accidents do not occur” - translation

“Hög säkerhet betyder inte att olyckor inte inträffar” - original

Both neutral and negative participants discussed that although security measures would do and are doing a good job, there is always a risk that something goes wrong. The risk of a serious accident is not negligible, as the consequences would be immense. For instance, millions of people in the Stockholm region would end up with no home in the Stockholm region if the Forsmark nuclear power plant would encounter a serious accident.

The trust for the industry’s and government’s ability to operate a safe nuclear power is low among the participants. Only a small proportion of the participants want to invest more in nuclear power. Students in favour of nuclear power mentioned and discussed some pros like it being an efficient and reliable technology for power generation and a solution for climate problems, as it reduces greenhouse gas emissions. The method is virtually free from acidifying and climate-releasing emissions. Furthermore, the low production costs were mentioned by many as well as the high security level that was criticized by students against nuclear power. Some positive students blame the energy companies for the negative view on nuclear power in Sweden meaning that the companies themselves promote and shed light on other energy sources rather than trying to improve the view on and acceptance of nuclear power by focusing more on it in their marketing.

On the other hand, students against nuclear power, who were the majority, discussed among other things, as mentioned earlier the uncertainty due to its large scale, which makes it sensitive to operational disturbances and natural disasters and even to direct attacks on nuclear
power plants. The dependence on imports of nuclear fuel was mentioned as a disadvantage as well as the link between nuclear power and nuclear weapon that increases the risk of nuclear attacks. Furthermore, some participants do not consider nuclear power as a pure energy source meaning that even if you ignore the risk of emissions from reactors, a constant emission of radioactivity occurs in the handling of uranium. Some consider nuclear power to be as bad as coal and oil, meaning that nuclear power should be shut down immediately. Moreover, there is only a limited amount of uranium, which will lead to an increased cost of the breakdown for the extracting of the uranium that is used in the reactors. In addition, the waste is extremely radioactive and must be stored for hundreds of thousands of years before it can be handled. Many students don’t like the idea of leaving the radioactive waste for future generations, which will take care of costs and risks.

When discussing the possible alternatives for nuclear power one student said the following,

“The nuclear industry wants us to believe we cannot manage without it.” – translation

"Kärnkraftsindustrin vill få oss att tro att vi inte kan klara oss utan den.” - original

Most students, both in favour and against nuclear power, agreed that there are enough renewable alternatives to meet our needs, and they are sustainable methods. The disagreement here was around when to phase out nuclear power with the supporters meaning that we are yet not ready to phase out all nuclear power now and definitely not all in once. That should be a successive change for later in the future. Following are a couple of interesting comments from participants positive towards nuclear power on the topic of phasing out nuclear power.

“We wouldn’t manage to cover for nuclear power if it is removed all at once. We are really dependent at it as a base power in our electricity generating system.” – translation

“Vi skulle inte klara av att täcka upp för kärnkraft om den tas bort helt på en gång. Vi är verklig beroende av det som en baskraft i vårt elproduktionssystem.” – original

The participants described and discussed the importance of nuclear power in Sweden, how reliant we are on it and it simply is not as easy to replace as some people think. They discussed the important part it has had in the electricity generation throughout the years and how much it simplifies by always being available and reliable. It is always available when needed to compare with different renewable sources that are dependent on the weather, sun, wind or rain. It has been very efficient to use nuclear power as a base power and regulate the
electricity generation with waterpower, since we consume different amount of electricity depending on which part of the day or day of the week.

“Nuclear power has been an enormously important and significant part of electricity generation in Sweden for almost 50 years; we cannot be suddenly removed and rely on renewable energy sources to take its place.” - translation

“Kärnkraft har varit en enormt viktig och stor del av elproduktionen i Sverige i nästan 50 år, man kan inte plötsligt ta bort det och förlika sig på att de förnybara energikällorna klarar av att täcka upp för det.” - original

The opponents on the other hand believe that nuclear power is not a sustainable solution as an energy supply, since it is not renewable. Renewable energy is a better option because it provides a faster reduction of carbon dioxide emissions, is cost-effective, reduces vulnerability and is sustainable in the long term. I felt that the supporters gave convincing explanation in this matter and I was expecting some opponents to agree with them, but so wasn’t the case. The discussion heated up instead and both sides refused to agree with each other. Here one can simply connect to Petty and Krosnick’s theory Resistance to Attitude Change. The participants established attitudes affect them a lot in such matter. They choose between what to listen to and accept and what to ignore. They totally ignore information that is against their attitude no matter how true or logic it is. They choose instead to focus on information that strengthens their point of view. Thus this shows that an attitude change is really difficult and almost impossible when an attitude has become well established in an individual.

When indicating what they were influenced to establish their views on nuclear power, the participants gave different answers. Among the positive students, media, social media and politicians have been influential for many. For some, relatives and friends have instead been more important in developing an opinion on the issue. Those who have a close relationship with someone or more who work or have worked in the nuclear industry tend to be more positive towards nuclear power. They also seem to rely more on the relationships they have with those working in the industry than they rely on "external influences" like media and others. However, media, social media and politicians are the factors that, to a large extent, affected the opponents of nuclear power when establishing their view on nuclear power.
When it comes to what sources the participants today get their information from, it looks a bit different between the positively and the negatively biased towards nuclear power. Media, politicians and teachers are the categories that the negative students mentioned the most. Friends, relatives and social media provide the greatest dominance for those with a positive attitude. The supporters indicated that the categories affected them slightly positively while the negatively set indicated that they were adversely affected. Interestingly, however, is that the media seems to affect the negative group to a greater extent. It is clear that in places close to a nuclear power plant, the social networks of nuclear workers and their relationships are often a contributing factor in increasing the acceptance of nuclear power in society. Media and politicians, on the other hand, seem to be the factors that affect students negatively mostly due to the negative news on nuclear power produced from these sources. Following are some interesting statements mentioned during the focus groups.

“One rarely reads a positive article or hears positive news about nuclear power nowadays.” - translation

“Det är sällan man läser en positiv artikel eller hör positiva nyheter om kärnkraft nuftördten.” - original

“It is clear that most politicians and many high-ranked in Sweden are against nuclear power”

- translation

“Det är tydligt att de flesta politiker och många högtuppsatta i Sverige är emot kärnkraften” - original

Such statements may not be fully true but obviously there is a lot of perceived truth in them. It is what we see in media, what we hear and what we read about all the time. These statements show furthermore how much media and politicians affect the population’s and thus many students’ opinions although the students mention that they don’t really trust everything they read or hear about. However hearing and reading similar news from different sources or claims from different politicians will make many people believe that what they are hearing is the truth. Here one can connect to both theories chosen in this study, risk communication and Resistance to Attitude Change. Both media and politicians help to increase the effect of risk communication, directly and indirectly. By always mentioning and highlighting the backsides of nuclear power they give people more reasons and remind them to worry and be more anxious towards risks with nuclear power and nuclear accidents.
Further it is obvious that not everything that is mentioned by media is negative towards nuclear power and not all politicians are against it. The majority of students who had a position against nuclear power were adversely affected by more information while the majority of those who had a position in favour for nuclear power were positively affected by more information. This as well can be linked to section 4.3 Resistance to Attitude Change. Petty and Krosnick (2014) explain the difficulty of an attitude change when an attitude has become well established in an individual. If an individual has an established attitude towards an attitudinal object, such as nuclear power, the individual often ignores new knowledge about the object that does not support the established attitude. This can further strengthen the established attitude. This means that participants, who previously had a positive view on nuclear power, tend to have a similar or more positive image of it when further knowledge is discovered. The opposite applies to someone who previously has had a negative image on the attitude object. Obviously, this does not always apply. It all depends on the individual and the basic principles that build the attitude of this individual.

Finally, the majority of the supporters of nuclear power feel that their education has increased their acceptance to nuclear power. However, some feel that their acceptance had remained unchanged by the education. Three students who expressed their support for the use of nuclear power have had courses in nuclear power. Two of those indicated that the education had increased their acceptance while the last one felt that it had not affected. On the other hand, students against nuclear power felt that their education led to an opposite effect. The majority of those felt that the education had reduced their acceptance of nuclear power, while some felt that they were not affected neither positive nor negative by their education.
5. Conclusion

Nuclear power has been and still is a vital part of the Swedish electricity production. However, the use of nuclear power raises many complex issues such as economy, accident risks, and radioactive waste management and storage. Nuclear power has therefore been debated intensively in Sweden as in many other countries since the 1970s.

The majority of the engineering students in Uppsala that participated in this study are against nuclear power. The participants discussed, among other things, the uncertainty of nuclear power due to its large scale, which makes it sensitive to operational disturbances and natural disasters and even to direct attacks on nuclear power plants. Further the issue that high security does not mean that accidents do not occur and that the risk of a serious accident is not negligible, as the consequences would be immense was discussed.

The trust for the industry's and government's ability to operate a safe nuclear power is low among engineering students where both supporters and opponents have mistrust in both energy companies and politicians.

Media, social media and politicians affect a lot of engineering students in building their opinion on nuclear power. Students with relatives or friends working in the nuclear industry tend however to rely more on the relationships they have with those working in the industry than they rely on "external influences" like media and others. Those students tend as well to have a more positive view on nuclear power than students with no connections to people working in the industry.

The education is important for how attitudes are affected. Students, who are positive toward nuclear power, tend to obtain either an unchanged level or a higher level of acceptance. Students against nuclear power tend to experience the opposite. Both seem to build their opinions based on their education, thus interpreting and using what they learn in completely different ways. Their opinions are formed in combination with, as mentioned earlier, first contacts, emotions and social networks among others.

Engineering students in general, both supporters and opponents of nuclear power, agree that Sweden should gradually phase out nuclear power as it can be replaced by renewable energy sources and energy efficiency.
6. Further studies

Due to the scope and the timeframe of the study the choice fell on engineering students in Uppsala as a target group and conducting interviews and focus groups with them as a method. For further studies it would be interesting to conduct a questionnaire and try to get a sufficient number of respondents. A questionnaire could be designed to cover a bigger group of students and maybe even other universities in Sweden. Besides a questionnaire even a series of more detailed in-depth interviews built on the results in this study could be conducted to get a better understanding on different issues.

Other target groups could be studied to get a better picture on how different groups of Swedish people view nuclear power. For instance, one of the ideas that the author of this work had, before deciding to focus on engineering students, was to study people that work in the nuclear industry, trying to understand what they think about the Swedish view on nuclear power and specially trying to understand how they feel towards all the negativity. Such study would help understand the situation from a different dimension and may further lead to other interesting results hard to get from people outside the nuclear industry.
7. References


### 7.1 Figures

Figure 1 Barometern. Carlsson, R. Available: http://www.barometern.se/oskarshamn/okg-slipper-sarskild-tillsyn-efter-tre-ar/ [2017-10-05].

Figure 2 Slideplayer. Hellström, S. Available: http://slideplayer.se/slide/1973599/ [2017-10-05].


