TAMPERE UNIVERSITY OF TECHNOLOGY

MINNA KINNUNEN

ELECTRICAL ACCIDENT HAZARDS IN THE NORDIC COUNTRIES

Master of Science Thesis

Prof. Kaija Leena Saarela has been appointed as the examiner at the Council Meeting of the Faculty of Business and Built Environment on 6th March 2013.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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KINNUNEN, MINNA: Electrical Accident Hazards in the Nordic Countries
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The Nordic electrical safety authorities co-operate on issues related to electrical safety e.g. electrical accidents. Certain electrical accidents need to be reported to the electrical safety authorities. Deeper knowledge on Nordic electrical accidents was collected in this study. The aim of the study was to find ways to improve electrical safety in the Nordic Countries. Electrical safety problem areas, emerging risks and best practices were also studied.

The Nordic electrical safety authorities do not have information on the total number of occurred electrical accidents because of under-reporting. Former studies have focused on electrical accidents in one Nordic Country and mainly on electrical accidents of electrical professionals. Electrical accidents from the year 2011 given by the Nordic electrical safety authorities were analyzed in this study. The material was divided into occupational electrical accidents of electrical professionals and those of laymen and leisure time electrical accidents. In addition, the representatives of the Nordic electrical safety authorities were interviewed on electrical accident information collection and electrical safety problem areas in this study.

The Nordic electrical safety authorities have a bit different understanding of electrical accidents on the basis of the electrical accidents reported to them. The electrical accident material from the different Nordic Countries diversifies together the understanding. The material should be utilized in cooperation more effectively than nowadays in electrical accident prevention. The occupational electrical accidents of the electrical professionals resulted mostly from not obeying instructions and occupational electrical accidents of laymen from damaged electrical installations and products. It needs to be questioned how widely the causes were mentioned in the material. It seems that certain causes stand out in the electrical accident reports. Only few leisure time electrical accidents were reported to the electrical safety authorities in 2011 which complicated making conclusion of those accidents. Emerging risks connected mainly to the development of the technology. It needs always to be remembered that electrical accident prevention is continuous work.

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Pohjoismaiset sähköturvallisuusviranomaiset tekevät yhteistyötä sähköturvallisuuteen liittyvien asioiden kuten sähkötapaturmien parissa. Tietynlaiset sähkötapaturmat pitää ilmoittaa sähköturvallisuusviranomaisille. Tähän tutkimukseen koottiin tarkempaa tietoa pohjoismaisista sähkötapaturmista. Tutkimuksen tarkoituksena oli löytää keinoja parantaa sähköturvallisuutta Pohjoismaissa. Lisäksi tutkimuksessa selvitettiin sähköturvallisuuteen liittyviä ongelma-alueita, uusia riskejä sekä parhaita käytäntöjä.

Pohjoismaiset sähköturvallisuusviranomaiset eivät tiedä sattuneiden sähkötapaturmien todellista lukumäärää aliraportoinnin vuoksi. Aikaisemmat tutkimukset ovat keskittyneet yhden Pohjoismaan sähkötapaturmiin ja pääasiassa sähköalan ammattilaisten sähkötapaturmiin. Pohjoismaiset sähköturvallisuusviranomaiset antoivat tutkimuksen aineistoksi vuonna 2011 Pohjoismaissa tapahtuneet sähkötapaturmat, jotka jaettiin sähköalan ammattilaisten ja maallikoiden työssä sattuneisiin sähkötapaturmiin sekä vapaa-ajan sähkötapaturmiin. Lisäksi tutkimuksessa haastateltiin pohjoismaisten sähköturvallisuusviranomaisten edustajia sähkötapaturmatiedon keräämisestä ja sähköturvallisuuteen liittyvistä ongelma-alueista.

Pohjoismaisilla sähköturvallisuusviranomaisilla on hieman erilainen käsitys sähkötapaturmista heille raportoitujen sähkötapaturmien perusteella. Eri maiden sähkötapaturma-aineistot monipuolistavat yhdessä kuvaa sähkötapaturmista. Sähkötapaturma-aineistoa tulisi hyödyntää yhteistyössä nykyistä tehokkaammin sähkötapaturmien ennaltaehkäisytyössä Pohjoismaissa. Ammattilaisten sähkötapaturmat johtuivat suurimmaksi osaksi ohjeiden noudattamatta jättämisestä ja maallikoiden työssä sattuneet sähkötapaturmat puolestaan vaurioituneista sähkölaitteistoista ja –laitteista. Pitää kuitenkin kyseenalaistaa se, kuinka kattavasti syytekijät löytyivät aineistosta. Tietyt syytekijät tuntuvat korostuvan sähkötapaturmaraporteissa. Vapaa-ajan sähkötapaturmia ilmoitetttiin sähköturvallisuusviranomaisille vähäinen määrä vuonna 2011, mikä hankaloitti johtopäätösten tekemistä. Uudet riskit liittyivät pääasiassa teknologian kehitykseen. Sähkötapaturmien ennaltaehkäisy on jatkuvaa työtä, mikä tulee muistaa aina.

PREFACE

As a child I was interested in knowing the colour of electricity. Now as a to-be-graduated masters' student I know more about electricity and especially about electrical accidents than I ever imagined in my childhood. I would like to thank Tukes and NSS to enable this thesis and the Association for Promotion of Electrical Safety (STEK ry) for participating for financing the thesis.

The journey into electrical safety in the Nordic Countries was varied, interesting and multilingual. I received a lot of help and support from my travelling companions. I would like to thank Klas-Göran Sundvall, Jan Sarup, Kim Rehmeier, Oddmund Foss, Örn Sölvi Halldórsson, Finn A. Hansen, Jógvan Sørin Hansen, Stig Nordberg, Harri Westerlund and Tuuli Tulonen for participating in the interviews and answering my questions during the project. Discussing with Tuuli Tulonen, who advised me on my thesis and shared her knowledge on electrical accidents during the thesis project, gave me a lot of new ideas. I would also thank Anne Myrestøl, Roger Kanerva, Hannu Mattila, Jari Tuomi, Minna Päivinen, Mikko Moisio and Milla Suominen. Hennamari Valkeinen, it was an honour that you wrote notes during the interviews, thank you. I was able to participate in two inspections organized by Sakari Hatakka and Ville Huurinainen. I thank you both for the opportunity to explore new issues and the people in the places where we visited for the kindness. Finally, I would like to thank Kaija Leena Saarela for supervising my thesis.

My parents have done a lot from those days when I was little and thirsting for knowledge. I thank my parents and other family members. The dearest thanks belong to my beloved Ville who supported me during the thesis like he always does.

Even thought my journey is over it needs to be remembered that electrical accident prevention is never over.

Helsinki, on 13th May 2013

Minna Kinnunen

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TERMS

AC	Alternating current
Ålands Landskapsregering	The Åland Government, the electrical safety authority in Åland
CENELEC	The European Committee for Electrotechnical Standardization, "responsible for standardization in the electrotechnical engineering field" (Who we are n.d)
DC	Direct current
Dead	"At or about zero voltage that is without voltage and/or charge present" (SFS 6002:2005:en, p. 21)
Direktoratet for samfunnssikkerhet og beredskap	The Directorate for Civil Protection and Emergency Planning, the Norwegian electrical safety authority
DSB	See Direktoratet for samfunnssikkerhet og beredskap
EFTA	The European Free Trade Association
Electrical accident	A direct or indirect accident caused by shock or arc
Electrical accident hazard	A potential source of electrical injury in the presence of electricity
Electrical incident	An event that could have ended up into an electrical accident
Electrical installations	"Includes all the electrical equipment which provides for the generation, transmission, conversion, distribution and use of electrical energy. It includes energy sources such as batteries, capacitors and all other sources of stored electrical energy" (SFS 6002:2005:en, p. 15)
Electrical product	An appliance that uses electricity

Electrical professional	"Skilled person (electrically), person with relevant education, knowledge and experience to enable him or her to analyse risks and to avoid hazards which electricity could create" (SFS 6002:2005:en, p. 17); person who is allowed to do electrical work according to the national legislation in each country
Electrical safety	A situation where electrical accidents are non-existent
Electrical safety authority	The authority that in responsible for issues related to electrical safety: Elsäkerhetsverket, Sikkerhedsstyrelsen, Tukes, DSB, Mannvirkjastofnun, Grønlands Elmyndighed, Elnevndin and Ålands Landskapsregering in the Nordic Countries
Electrical work	"Work on, with or near an electrical installation such as testing and measurement, repairing, replacing, modifying, extending, erecting, maintaining and inspecting" (SFS 6002:2005:en, p. 19)
Elnevndin	The Electrical Safety Board of the Faroe Islands, the Faroese electrical safety authority
Elsäkerhetsverket	The National Electrical Safety Board, the Swedish electrical safety authority
Emerging risk	A new or a familiar risk that appears in new or unfamiliar conditions (The Emergence of Risks 2010, p. 9).
ENTSO-E	The European Network of Transmission System Operators for Electricity
ESAW	European statistics on Accidents at work, a way to classify occupational accidents
EU	The European Union
ILO	International Labour Organization
Instructed person	"Person adequately advised by skilled persons to enable him or her to avoid dangers which electricity may create" (SFS 6002:2005:en, p. 17)
IRGC	The International Risk Governance Council

Laymen	"Person who is neither a skilled person nor an instructed person (SFS 6002:2005:en, p. 17)", in the results of this study a person who is not a skilled person
Leisure time electrical accident	An electrical accident that occur during leisure time
Mannvirkjastofnun	The Iceland Construction Authority, the Icelandic electrical safety authority
NSS	The Nordic committee for the cooperation of electrical safety issues (*Nordiska kommittén för samording av elektriska säkerhetsfrågor* in Swedish)
Occupational electrical accident	An electrical accident that occur at work, not during leisure time, including also electrical accidents that happen to pupils and students at schools and to conscripts at military
OSH Framework Directive	The Occupational Safety and Health Framework Directive, the Council Directive 89/391/EEC
PPE	Personal protective equipment
Sikkerhedsstyrelsen	The Danish Safety Technology Authority, the Danish electrical safety authority
Skilled person	See electrical professional
The Nordic Countries	Sweden, Denmark, Finland, Norway, Iceland, Greenland, the Faroe Islands and Åland
Tukes	See Turvallisuus- ja kemikaalivirasto
Turvallisuus- ja kemikaalivirasto	The Finnish Safety and Chemicals Agency, the Finnish electrical safety authority
Underreporting of electrical accidents	Not reporting all the electrical accidents to the electrical safety authority
VARO database	The accident and damage database of Tukes including for example electrical accidents

1. INTRODUCTION

"We live in an electrical world, with nearly every aspect of modern business and commerce dependent on electrical technologies and interactions with tools, appliances, equipment and systems" (Floyd 2012, p. 1). Electricity is present both at home and at work. Employees can work with electricity directly (electrical professionals) or indirectly (non-electrical professionals). (Reese 2008, p. 163.)

People do not always understand hazards electricity poses (Reese 2008, p. 163). For example, Chi et al. (2012, p. 1205) tell that electrical hazards are among the most dangerous hazards in the construction industry. In addition to that, people underestimate the ability of electricity to cause injuries (Reese 2008, p. 163). It has been said that every electrical accident can cause a death (Cawley & Brenner 2012, p. 2). Cawley and Homce (2003, p. 241) remind that no one wants to get injure or die at work.

The number of fatal electrical accidents has decreased in Sweden between 1975 and 2000 which means that improvements in electrical safety have been effective (Lindström et al. 2006, p. 1383). Knowing the causes of the electrical accidents is essential in accident prevention (Williamson & Feyer 1998, p. 187). People need to be more aware of issues related to electrical safety and they need more education so that electrical accidents can be prevented (Cawley & Brenner 2012, p. 1).

1.1. Background

The Nordic Countries are relatively similar when regarding way of life, history and society (Nordic Statistical Yearbook 2012, p. 3). Nordic electrical safety authorities co-operate on issues related to electrical safety like electrical accidents (Samarbete 2011). The Nordic electrical safety authorities are working for promoting electrical safety and reducing electrical accidents.

The Nordic electrical safety authorities do not know the true number of electrical accidents because of underreporting. Almost every Finnish electrical professional has had an electrical accident which cannot be seen from the electrical accident statistics (Tulonen et al. 2006, p. 46). In a Swedish study consisting of 75 electrical professionals three quarters of the people who had had an electrical accident had not reported the electrical accident to the employer because he/she considered the accident too minor (Kartläggning av elolyckor bland 2005, p. 28). It is estimated that 3000 electrical accidents occur in Norway every year (Goffeng et al. 2003, p. 2003) but 320 electrical accidents were reported to the Norwegian electrical safety authority in 2011(Elsikkerhet nr. 81 2012, p. 9).

Not all of the electrical accidents are reported to the electrical safety authorities even though there is a reporting obligation concerning certain electrical accidents in every Nordic country. The authorities would like to target preventive measures better in order to improve electrical safety. The Nordic electrical safety authorities collect information on electrical accidents. They gave electrical accidents from the year 2011 for the material of this study. By combining Nordic electrical accident data new relevant information can be generated and corrective actions can be identified and designed.

Researches of Nordic electrical accidents have focused on fatal accidents (e.g. Lindström et al. 2006) and accidents of electrical professionals (e.g. Tulonen 2010) in a single Nordic Country. There is no former study that would have combined all the Nordic electrical accidents into one study. Electrical accidents given by Nordic electrical safety authorities were analyzed in this study. This study includes fatal and non-fatal electrical accidents, occupational electrical accidents of electrical professionals and non-electrical professionals (later laymen) and leisure time electrical accidents from the point of view of the Nordic countries.

1.2. Objectives, research problem and outline

The objective of this study is to gain deeper knowledge about electrical safety hazards in the Nordic Countries. It is useful to know what the typical electrical accidents are in each country.

The collected new information will be used for preventing electrical accidents. For example, in Finland the Finnish electrical safety authority will utilize the found information in both electrical safety supervision resource allocation and raising public awareness of identified risks through training and education. Further, this research is meant to help e.g. the Finnish electrical safety authority to improve electrical safety awareness of risks and activate dialogue about electrical hazards especially among laymen.

The main research problem can be presented in the following way:

How can electrical safety be improved in the Nordic Countries?

The main research problem can be divided into subproblems:

- *What are the biggest electrical safety problem areas in the Nordic Countries?*
- *What possible new emerging risks may be identified in the Nordic Countries?*
- *What best practices are there in the Nordic countries that explain the differences in electrical safety between the countries?*
- *Can the recognized best practices be adopted into the other countries?*

In the context of this study electrical safety refers to the ideal situation where electrical accidents are non-existent. This research focuses on electrical accidents caused by electric shocks or arcs. Electrical fires are not examined in this study. The Nordic Countries stand for independent nations (Sweden, Denmark, Finland, Norway and Iceland) and their autonomous regions (Greenland, the Faroe Islands and Åland) in this study.

1.3. Structure of the study

The theory is divided into two parts: starting points and electrical safety (Figure 1). Research methods and material consist of the analysis of the Nordic electrical accidents from the year 2011 and the interviews of the representatives of the Nordic electrical safety authorities. The results present the electrical accident data collection in the Nordic countries, the electrical accidents in the Nordic Countries in 2011 and electrical safety from the perspective of the representatives of Nordic electrical safety authorities. Discussion combines theory and results and examinates the study.

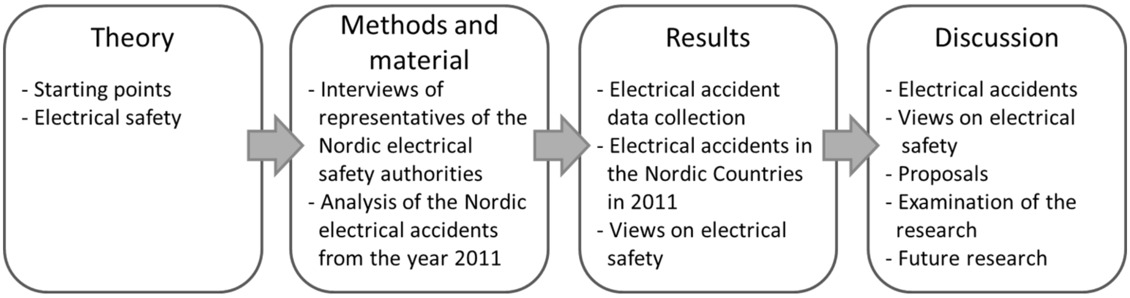

Figure 1. *Stucture of the study*

The theory starts the study and it is presented in Chapters 2 and 3. The methods and the material are described in Chapter 4. Results follows the the methods and material. The results are divided into three chapters; Chapter 5 presents the electrical accident data collection in the Nordic Countries, the results of the electrical accident analysis are presented in Chapter 6 and the viewpoints of the representatitives of the electrical safety authorities on electrical safety are gathered into Chapter 7. Chapter 8 has been owned to discussion. The conclusions in Chapter 9 finish the study.

2. STARTING POINTS

This chapter introduces the Nordic electrical safety authorities. The Occupational Health and Safety Framework Directive that guides actions in every workplace is also presented. This chapter presents the European standard EN 50110-1:2004 "Operation of electrical installations" that guides electrical professionals when performing electrical work. After the directive and the standard the chapter focuses on legislation concerning electrical safety. Some statistics are also presented in the last subchapter.

2.1. Electrical safety authorities in the Nordic Countries

The Nordic committee for the cooperation of electrical safety issues (*Nordiska kommittén för samording av elektriska säkerhetsfrågor* in Swedish, later NSS) is the cooperation body of Nordic electrical safety authorities. NSS's aim is to identify important Nordic electrical safety issues (Samarbete 2011). The purpose is to take e.g. measures that can prevent electrical building fires, electrical accidents and other injuries caused by dangerous electrical installations and products in the Nordic Countries. To reach the goal the Nordic electrical safety authorities (Table 1) co-operate in different ways. For example, they share information on electrical accidents. (Samarbete 2011.)

Table 1. *Nordic electrical safety authorities in order of population of the countries or the regions*

Country/region	Official name	English name
Sweden	Elsäkerhetsverket	The National Electrical Safety Board
Denmark	Sikkerhedsstyrelsen	The Danish Safety Technology Authority
Finland	Turvallisuus- ja kemikaalivirasto, Säkerhets- och kemikalieverket (Tukes)	The Finnish Safety and Chemicals Agency
Norway	Direktoratet for samfunnssikkerhet og beredskap (DSB)	The Directorate for Civil Protection and Emergency Planning
Iceland	Mannvirkjastofnun	The Iceland Construction Authority
Greenland	Grønlands Elmyndighed	The Electricity Authority of Greenland
The Faroe Islands	Elnevndin	The Electrical Safety Board of the Faroe Islands
Åland Islands	Ålands landskapsregering	The Åland Government

2.1.1. Elsäkerhetsverket

Elsäkerhetverket is the Swedish administrative authority of electro technical safety issues. (Om verket 2012). Its vision is "safe and interference-free electricity". The way to fill the vision is to work for a high level of electrical safety and to ensure that electrical products do not interfere each other. (Vår vision och 2010.) Elsäkerhetsverket is responsible for market surveillance of electrical products. The target of market surveillance is not only to protect human lives but also to prevent interference in communications and business operations. One way of market surveillance is to put a ban on sales of electrical products that do not fill requirements concerning for example electric shock, electrical fire and electromagnetic compatibility. (Produktsäkerhet 2012.) Another role of the authority is to inspect electrical installations and to investigate electrical accidents and electrical fires. Elsäkerhetsverket is also responsible for the authorization of electricians. (Om verket 2012.)

Elsäkerhetsverket is working under the Ministry of Enterprise, Energy and Communications (*Näringsdepartementet* in Swedish). The head office is situated in Kristinehamn and regional offices in Stockholm, Hässleholm, and Umeå. (Om verket 2012). The director general and her staff, departments of Electrical Products and Installations, support services, one regional office of inspectors and are situated in Kristinehamn. The other regional offices of inspectors are situated in the other cities. Elsäkerhetsverket employs approximately 45 people. (Organisation 2012.)

2.1.2. Sikkerhedsstyrelsen

Sikkerhedsstyrelsen is responsible for the technical safety of electricity, gas, HPAC (heating, plumbing and air-conditioning), drains, fireworks and product safety in Denmark. In addition, metrology, accreditation and controlling precious metals are among Sikkerhedsstyrelsen's supervising functions. (Organisation n.d b.) Sikkerhedsstyrelsen’s ambition is to enhance the effect of their activities, establish a higher degree of rules-compliance and more correct use of products in order to create sense of safety and to prevent injuries and property damages (Rehmeier 2013). It is a part of the Ministry of Business and Growth Denmark (*Erhvervs- og Vækstministeriet* in Danish). About 125 employees work in Sikkerhedsstyrelsen which is located in Esbjerg. (Organisation n.d b.)

2.1.3. Turvallisuus- ja kemikaalivirasto (Tukes)

Turvallisuus- ja kemikaalivirasto (Tukes) is the Finnish authority dealing with technical safety, technical conformity, consumer and chemical safety. The action of Tukes is diverse and it is aiming at protecting people, property and environment from safety risks. Electricity and lifts, industrial handling of chemicals, mining, fireworks, construction products and articles of precious metals are among Tukes's branches. Because of the several branches Tukes operates under several ministries. The Ministry of Employment and the Economy (*Työ- ja elinkeinoministeriö* in Finnish) is responsible for the administrative steering and supervision. The Ministries of Employment and the Economy, Transport and Communications (*Liikenne- ja viestintäministeriö* in Finnish), Agriculture and Forestry (*Maa- ja metsätalousministeriö* in Finnish), the Interior (*Sisäministeriö* in Finnish), Social Affairs and Health (*Sosiaali- ja terveysministeriö* in Finnish) and the Environment (*Ympäristöministeriö* in Finnish) guide Tukes within their own branches. (Tietoa meistä 2012.)

Tukes employs over 200 people in its main offices that are situated in Helsinki, Tampere and Rovaniemi (Tietoa meistä 2012). The two groups working with electrical safety are situated in Tampere. The electrical product group supervises conformity of electrical products from many points of view and its market surveillance is allocated risk-based (Mattila 2012). The electrical installations group ensures safety of electrical installations and lifts and supervises special requirements of electrical safety and the actions of repair companies, installation companies and auditors. The group investigates major electrical accidents and it is aiming at reducing electrical accidents and incidents. (Savola 2011.)

2.1.4. Direktoratet for samfunnssikkerhet og beredskap (DSB)

Direktoratet for samfunnssikkerhet og beredskap (DSB) answers for many issues regarding safety in Norway. It deals with civil protection, emergency planning and the Norwegian Civil Defense (*Sivilforsvaret* in Norwegian). Other tasks include safety in handling and transport of hazardous substances, fire safety and electrical safety. In addition DSB supervises product and consumer safety in Norway. (Om DSB n.d.) DSB's head office is situated in Tønsberg where 240 employees of the total 600 employees work. The others work at regional electricity supervision offices, schools and in the Norwegian Civil Defense elsewhere in Norway. (DSB som organisasjon 2009.) DSB reports to the Ministry of Justice and Public Security *(Justis- og beredskapsdepartementet* in Norwegian) (Om DSB n.d).

DBS's vision is "A safe and robust society - where everyone takes responsibility". The ways to achieve the vision include for example systematic hazard identification and accident prevention. (Visjon og virksomhetside 2012.) DBS's goal concerning electrical safety is to ensure a reliable power supply and that neither electrical installation nor electrical products cause risk to life, health or property (Elsikkerhet n.d).

2.1.5. Mannvirkjastofnun

Mannvirkjastofnun is responsible for different tasks regarding construction, fire and electrical safety in Iceland (Iceland Construction Authority n.d). The authority is divided into different sectors. The main sectors are construction, fire brigades and fire safety, electrical safety and the Fire Service Technical College. Mannvirkjastofnun is situated in Reykjavik and it has 22 employees (Starfsmenn n.d). The Ministry for the

Environment and Natural Resources (Umhverfis- og auðlindaráðuneytið in Icelandic) directs Mannvirkjastofnun's actions (Organisation n.d a).

The tasks done by the Electrical Safety Department include for example market surveillance and inspection of electrical installations in different places. The department receives electrical accidents and damage reports and it investigates some of those. In addition, it publishes material concerning electrical safety issues. (Main activities n.d.)

2.1.6. Grønlands Elmyndighed

Grønlands Elmyndighed is a part of Nukissiorfiit (Grønlands Elmyndighed n.d). Nukissiorfiit is owned by the Government of Greenland (*Grønlands Selvstyre* in Danish) and it produces and distributes electricity, water and heat in Greenland (Om Nukissiorfiit n.d). Grønlands Elmyndighed supervises and ensures that Nukissiorfiit, consumers and electricians obey operative laws and decrees concerning electricity. The tasks concentrate on electrical safety. The authority is responsible for the electrical safety of production, transmission, distribution and utilization of electricity. In addition, Grønlands Elmyndighed authorizes contractors and administers electrical safety of electrical products. The headquarters are situated in Nuuk and there are local energy services that are responsible for Grønlands Elmyndighed in towns throughout Greenland. (Grønlands Elmyndighed n.d.) Grønlands Elmyndighed employs four people (Medarbejdere 2009).

2.1.7. Elnevndin

Elnevndin is the authority dealing with electrical safety issues in the Faroe Island. It mainly concentrates on administering the electrical legislation. Elnevndin operates under the Faroese department of industry (Generelt n.d). Elnevndin have six employees: a chairman, a secretary and four board members (Hansen, J.S. 2012).

Elnevndin's tasks relate to technical safety. It is responsible for electrical safety of production, transmission, distribution and use of electricity. In addition, it administers electrical product safety and authorizations in the Faroe Islands. Elnevndin does not inspect electrical installations. Instead, an agreement has been made with the national electrical supply company, SEV, for inspecting all the new electrical installations. (Hansen, J.S. 2012.)

2.1.8. Ålands landskapsregering

Ålands landskapsregering’s Electricity and Energy Unit is responsible for electrical safety and electrical inspections in Åland (The Government 2013; Nordberg 2013). Ålands landskapsregering is situated in Mariehamn.

2.2. Directive 89/391/EEC: OSH Framework Directive

The name of the Occupational Safety and Health (OSH) Framework Directive is *Council directive on the introduction of measures to encourage improvements in the safety and health of workers at work*. The directive includes general principles concerning, for example, prevention of work-related risks, protection of safety and health and elimination of risks (89/391/EEC, article 1, 2 §). Prevention is described as measures taken or planned to be taken to prevent or reduce occupational risks (89/391/EEC, article 3, d). The Finnish translation uses the term the occupational hazard (*työssä esiintyvä vaara* in Finnish) instead of the occupational risk whereas the term is used in Danish (*erhvervsbetingede risici* in Danish) and Swedish (*yrkesbetingade risker* in Swedish) (89/391/ETY; 89/391/EØF & 89/391/EEG).

There are still too many occupational accidents and diseases which is the reason to introduce preventive measures to be able to ensure safety and health of workers. The risks the workers face and the taken measures to reduce or to eliminate them need to be informed to the workers. When improving occupational safety and health it is not allowed to consider only economic aspects. (89/391/EEC, recital.)

The employer is responsible for ensuring occupational safety and health of workers (89/391/EEC, article 5, 1 §). The employer shall for example avoid risks, evaluate risks that cannot be avoided, adapt to technical progress, replace the dangerous by the non-dangerous or less dangerous and give instructions to the workers (89/391/EEC, article 6, 2 §). Risk assessment and deciding preventive measures to be taken are one part of the obligations of the employer (89/391/EEC, article 9, 1 §). In addition, the employer shall give adequate safety and health training to the workers. Also the workers from outside undertakings need to receive instructions regarding health and safety risks. (89/391/EEC, article 12, 1-2 §.)

The OSH Framework Directive dictates also the obligations of workers. Every worker shall take care of her/his own safety and health and also health and safety of the others if the worker affects them somehow. The worker has to obey the instructions given by the employer. The worker has for example to use machinery and tools correctly, use PPE (personal protective equipment) and return them to their place after using them. (89/391/EEC, article 13, 1-2 §.)

2.3. European standard EN 50110-1:2004

The European standard EN 50110-1:2004 *Operation of electrical installations* states general requirements for the use of electrical installations and for the work on, with or near them (SFS 6002:2005:en, p. 7). An electrical installation consists of all the electrical installations that are used for production, transmission, conversion, distribution and use of electricity (SFS 6002:2005:en, p. 15). The standard applies to every electrical work on, with and near electrical installations and also to non-electrical work done near the electrical installations like construction work near overhead power lines and ground cables. In addition, the standard is valid in situations when there are risks of electrical hazards. The standard has been designed for electrical professionals. (SFS 6002:2005:en, p. 11.)

National laws, standards and internal rules have influenced the EN 50110-1:2004 standard. The standard agrees different national safety requirements. The standard is meant to help defining the common electrical safety level in the CENELEC (the European Committee for Electrotechnical Standardization) countries in the future. (SFS 6002:2005:en, p. 9.) There is a CENELEC national committee in Sweden, Denmark, Finland, Norway and Iceland (List of CENELEC n.d). CENELEC is renewing the standard EN 50110-1:2004 *Operation of electrical installations* (Project n.d). Iceland uses the current standard only as supportive material for their legislation. Iceland will decide later when the renewed standard will be published if it decides to use the standard or the legislation like is done nowadays. (Sigurdarson 2013.) Table 2 below shows the national standards corresponding with the EN 50110-1:2004 standard used in Sweden, Denmark, Finland and Norway.

Table 2. *National standards corresponding with EN 50110-1:2004 standard*

Country	**Number**	**Name**
Sweden	SS-EN 50110-1, utg 2:2005	Skötsel av elektriska anläggningar
Denmark	DS/EN 50110-1:2005	Drift af elektriske anlæg
Finland	SFS 6002:2005	Sähkötyöturvallisuus
Norway	NEK EN 50110-1:2005	Sikkerhet ved arbeid i og drift av elektriske anlegg

(Ansvarig svensk kommitté n.d; DS/EN 50110-1:2005 n.d; SFS 6002:2005 & NEK EN 50110-1:2005 n.d.)

Using standards is not obligatory but when using them the regulatory requirements are met. In practice standards are used. (Sähköasennuksia koskevat standardit n.d.) However, "even the best rules and procedures are of no value unless all persons working on, with, or near electrical installations are thoroughly conversant with them and with all legal requirements and comply strictly with them" (SFS 6002:2005, p. 9).

This chapter and the sub-chapters are based on the EN 50110-1:2004 standard. The English version (SFS 6002:2005:en) of the Finnish standard SFS 6002:2005 was used as material without the Finnish national supplements. Without the national supplements the standard corresponds to the EN 50110-1:2004 standard.

2.3.1. Qualifications

A skilled person is a person who has relevant education and experience. Education and experience help the skilled person to analyze risks and to avoid hazards caused by electricity. An instructed person is a person who the skilled person has guided in such a way that he/she is able to avoid danger caused by electricity. An ordinary person is defined as a person who is neither a skilled person nor an instructed person. (SFS 6002:2005:en, p. 17.)

2.3.2. Risk

The standard EN 50110-1:2004 sees a risk as a combination of the probability of the damage and the severity of the possible injuries. An electrical injury is a death or a personal injury caused by electric shock, arc and different kinds of electrical fires caused by electrical installations. An electrical hazard is whereas defined as a possible cause of a damage that can injure people and harm their health and that is caused by electricity in an electrical installation. Electrical danger is seen as a risk of an injury caused by an electrical installation. (SFS 6002:2005:en, p. 15.)

2.3.3. Electrical work

Work at, with or near electrical installations is called electrical work. Electrical work can for example consist of testing, measurement, repairing, replacing, modifying, extending, installing and inspecting. (SFS 6002:2005:en, p. 19.) A nominated person in control of a work activity is responsible for the safety of electrical work (SFS 6002:2005:en, p. 25). A nominated person in control of an electrical installation is responsible for the operation of an electrical installation (SFS 6002:2005:en, p. 17). Contrary to electrical work, non-electrical work like building, digging and cleaning is done near electrical installations (SFS 6002:2005:en, p. 19).

Before using an electrical installation or working on, near or with it electrical risks shall be analyzed. A nominated person in control of a work activity has to guide all the workers about those dangers they cannot normally observe. The workers need to wear protective clothing and use PPE suitable for each job. (SFS 6002:2005:en, p. 23.)

Electrical work can be divided into live working, working in the vicinity of live parts and dead working. The working methods are based on protecting from electric shocks, arcs and short circuits. (SFS 6002:2005:en, p. 37.) Live working is work when the worker intentionally touches the live part or reaches into the live working zone by his/her body, tools or etc. Work in vicinity of live parts means situations when the worker comes to the vicinity zone that surrounds the live working zone but when he/she does not come to the live working zone. Dead working is work on electrical installation that is not live and has no charge. In addition to that, adequate measures have been done in order to avoid electrical dangers. When the voltage is zero or close to it, or there is no voltage and/or charge the electrical installation is dead. (SFS 6002:2005:en, pp. 19–21.)

When the work is done dead the following actions need to be done in the specified order unless there is a reason for going in another way:

- disconnect completely,
- secure against re-connection,
- verify that the installation is dead,
- carry out earthing and short-circuiting and
- provide protection against adjacent live parts (SFS 6002:2005:en, p. 37).

The standard reminds that live working shall always be done according to national requirements (SFS 6002:2005:en, p. 47).

2.4. Legislation concerning electrical safety

This chapter presents legislation concerning electrical safety in the Nordic Countries. The chapter presents for example what kinds of electrical accidents need to be reported to the electrical safety authority.

2.4.1. Sweden

Ellag (1997:857)

Ellag (1997:857) obligates issues related to electrical installations (*elektriska anläggningar* in Swedish), trade of electricity and in some cases electrical safety (Ellag 1997:857, 1 cap. 1 §). The electrical installation is defined as an installation used in electricity production, transmission of electric energy or in utilization of electric energy (Ellag 1997:857, 1 cap. 2 §). The electrical installations are divided into strong current (*starkströmsanläggningar* in Swedish) and weak current (*svagströmsanläggningar* in Swedish) electrical installations (Ellag 1997:857, 1 cap. 3 §).

Starkströmsförordning (2009:22)

The decree complements Ellag on electrical safety on issues related to electrical installations (Starkströmsförordning 2009:22, 1 §). A strong current installation (*en starkströmsanläggning* in Swedish) is defined as an electrical installation for such voltage, amperage or frequency that can be dangerous to people or property (Starkströmsförordning 2009:22, 2 §). The owner of the strong current installation is obligated to control that it gives adequate security against personal injuries or material damages (Starkströmsförordning 2009:22, 4 §). The people working with strong current installations have to have skills and competences to ensure adequate security (Starkströmsförordning 2009:22, 5 §). The owner of the grid, who can build and use high current electric installations defined in Ellag (1997:857, 2 cap. 1 §), and the owner of the strong current installations for trains, trams, metros and trolley-busses must inform Elsäkerhetsverket without delay electrical accidents and serious incidents happened at their strong current installations (Starkströmsförordning 2009:22, 8 §). The decree enables Elsäkerhetsverket to give instructions related to strong current installations for accident prevention (Starkströmsförordning 2009:22, 16 §).

Elinstallatörsförordning (1990:806)

The object of this decree is to prevent risks of personal injuries and property damages resulting from a faulty or inadequate strong current installation (Elinstallatörsförordning 1990:806, 1 §). An electrician is a person qualified by Elsäkerhetsverket to do electrical work in the given scale (Elinstallatörsförordning 1990:806, 2 §). Electrical work is allowed only by electricians and skilled workers (*yrkesman,* in Swedish) under the supervision of an electrician who has employed the skilled workers or is working in the same firm as the skilled worker (Elinstallatörsförordning 1990:806, 6 §). The electrician needs to ensure that the skilled worker has the skills and competences to do the work (Elinstallatörsförordning 1990:806, 7 §). Elsäkerhetsverket can give instructions on educational standard and experiences for the qualifications (Elinstallatörsförordning 1990:806, 9 §).

Elsäkerhetsverket's regulations

Elsäkerhetsverket's regulations are called ELSÄK-FS (an abbreviation of *Elsäkerhetsverkets författningssamling* in Swedish) meaning Elsäkerhetsverket's statues. In addition to regulations Elsäkerhetsverket gives suggestive advice that is not binding. (Föreskrifter 2012.)

The regulation *Elsäkerhetsverkets föreskrifter och allmänna råd om elsäkerhet vid arbete i yrkesmässig verksamhet* applies to work in professional activity on and near strong current installations where there is electrical dangers to the workers (ELSÄK-FS 2006:1). An electrical danger means a risk of personal injury due to electric shocks, short-circuits or electric arcs. (ELSÄK-FS 2006:1, 1 §.) The work needs to be done in accordance to good electrical safety practice when there is electrical danger in the workplace and the adequate safety is needed to be ensured for the workers (ELSÄK-FS 2006:1, 1 §). People working in places where there is electrical danger have to know the implications and consequences of the danger and they have to participate safety training directed to the specific tasks (ELSÄK-FS 2006:1, 4 §). Safety measures include measures when the work is done disconnected (the installation needs to be disconnected and dead when working) and when the work is done live (preventing accidents due to electric shocks, short circuits and arcs) (ELSÄK-FS 20006:1, 6-7 §).

The regulation *Elsäkerhetsverkets föreskrifter om behörighet för elinstallatörer* focuses on the minimum educational standard and practice for the qualification to perform electrical work (ELSÄK-FS 2007:2). Electrical work, that can be done by laymen and by electrical professionals or instructed persons under surveillance of an electrical professional, are also itemized in the regulation (ELSÄK-FS 2007:2, 1 cap. 3-4 §).

The regulation *Elsäkerhetsverkets föreskrifter om anmälan av olycksfall, allvarliga tillbud och driftstörningar* from the year 2012 deals with reporting of electrical accidents and incidents to Elsäkerhetsverket (ELSÄK-FS 2012:1). An electrical accident is seen as an unwanted event ended in injury or death caused by electricity

(ELSÄK-FS 2012:1, 3 §). Electrical accidents have to reported electronically to Elsäkerhetsverket (ELSÄK-FS 2012:1, 3 §).

2.4.2. Denmark

Lov om elektriske stærkstrømsanlæg og elektrisk materiel (251:1993)
The law is meant to assure the highest possible safety level in production, transmission, distribution and use of electricity. The law takes into account technical feasibility, social development, international obligations and socio-economic issues. (Lov om elektriske stærkstrømsanlæg 251:1993, 1 §). The law sees a strong current installation (*stærkstrømsanlæg* in Danish) as a power supply with installations whose high voltage or great amperage can cause danger. Power supply installations (*elforsyningsanlæg* in Danish) consist of electrical installations for production, transmission and distribution of electricity. Electrical products (*elmaterial* in Danish) are incorporated into strong current installations. (Lov om elektriske stærkstrømsanlæg 251:1993, 2 §.)

Stærkstrømsloven obligates Sikkerhedsstyrelsen to control and supervise strong current installations and electrical products to be able to secure fulfillment of requirements (Lov om elektriske stærkstrømsanlæg 251:1993, 10 §). In addition, Sikkerhedstyrelsen can provide advice and information on electrical safety issues for electricians and the other electrical professionals (Lov om elektriske stærkstrømsanlæg 251:1993, 21 §).

Lov om autorisation af elinstallatører m.v. (314:2000) also known as elinstallatørloven
The purpose of the law is to ensure that electrical installations are done safely and correctly (Lov om autorisation 314:2000, 1 §). The law defines when a person or a firm is authorized by Sikkerhesstyrelsen to do certain jobs in the strong current installations (Lov om autorisation 341:2000, 2-5 §.) The firm applying for the authorization needs to state that it has an accepted quality management system (Lov om autorisation 314:2000, 5 a §).

Bekendtgørelse om administration m.v. af stærkstrømsloven (177:1995)
This order applies to strong current installations and products included in or connected to these systems. However, the order does not apply to electrical installations and electrical products used on board vehicles, aircrafts and ships. (Bekendtgørelse om administration 177:1995, 1 §.)

According to this order the operator of the power supply installation has to report immediately all the accidents with electrical characteristic occurred in their electrical installations to Sikkerhedstyrelsen. In addition to injuries, explosions and fires in the electrical installations need to be reported. The notification has to include all the information that helps finding the causes of the accident. The notification can be in an electronic form. In addition to that Sikkerhedsstyrelsen can ask network companies to help clarifying the circumstances of the electrical accidents that happened at their area (Bekendtgørelse om administration 177:1995, 3 §.)

2.4.3. Finland

Sähköturvallisuuslaki (L 1996/410)
The law applies to the requirements concerning electrical products and installations, the conformity, electrical works and liability for damages of the owner of electrical installations or electrical products (L 1996/410, 1 §). An electrical product is seen as an apparatus, a machine, an appliance or an implement meant for producing electricity, transmission, distribution and utilization of electricity. In addition, certain electrical features are required from electrical products. An electrical installation consists of electrical products and possible other appliances. (L 1996/410, 4 §.) Electrical products and installations are not allowed to harm life, health or property (L 1996/410, 5 §).

The police, the fire and rescue services, the occupational safety and health authority and the owner of the grid (*jakeluverkonhaltija* in Finnish) need to report electrical damages, which cause serious accidents, to the electrical safety authority (L 1996/410, 52a §). The owner of the grid means a community or a facility that owns distribution network and is allowed to practice actions in the grid (L 1996/410, 4 §). The electrical safety authority needs to investigate occurred electrical accidents if it considers the investigation essential to find out the causes or to prevent electrical accidents (L 1996/410, 52a §).

Sähköturvallisuusasetus (A 1996/498)
The decree clarifies the definition of the serious electrical accident. The accident is regarded serious if

- it causes death or serious damage to health,
- it causes other than minor environmental damage or property damage or
- it causes obvious danger to people, property or environment. (A 1996/498, 20 §.)

Kauppa- ja teollisuusministeriön päätös sähköalan töistä (KTMp 1996/516)
Electrical work means repair work and maintenance work of an electrical product and construction, repair and maintenance work of an electrical installation. Demolition work is not considered electrical work if it is done de-energized. (KTMp 1999/516, 1 §.) The person doing electrical work has to be familiarized and guided to the work and its requirements concerning electrical safety (KTMp 1999/516, 9 §). Laymen can do certain electrical work that cause only minor danger or disturbance (KTMp 1999/516, 10 §). In addition to that, the court order specifies the qualification requirements of electrical professionals (KTMp 1999/516, 11 §).

2.4.4. Norway

Lov om tilsyn med elektriske anlegg og elektriske utstyr (Lov 1929-05-24 nr 4)
The law concentrates mainly on supervision done by the electrical safety authority (Lov 1929-05-24 nr 4). It relates to all the electrical installations (*elektriske anlegg* in Norwegian) and electrical products (*elektrisk utstyr* in Norwegian) (Lov 1929-05-24 nr 4, 1 §). DBS's goal concerning electrical safety is based on this law because according to the law electrical installations and electrical products may not cause risks to life, health or property (Lov 1929-05-24 nr 4, 2 & 10 §). Under this law decrees can be given concerning qualifications of electrical professionals and the works that can be done by laymen (Lov 1929-05-24 nr 4, 12 §).

Forskrift om kvalifikasjoner for elektrofagfolk (FOR 1993-12-14 nr 1133)
The decree presents the minimum qualifications for those who do electrical work or participates in them (FOR 1993-12-14 nr 1133, 1 §). Electrical work involves planning, engineering, design, operation and maintenance of electrical installations and installation and repair of electrical products (FOR 1993-12-14 nr 1133, 2 §). The decree defines an electrical professional (*elektrofagarbeider*, in Norwegian) as a person with formal vocational training in accordance with the law and who is qualified to perform electrical work independently. (FOR 1993-12-14 nr 1133, 3 §.) The decree dictates the language skills of electrical professionals. The contractor and the employer need to ensure that the language skills of employee are such that he/she can work safely and communicate with supervision personal. Both the qualifications and the required language proficiency need to be filled before becoming an electrical professional in Norway. (FOR 1993-12-14 nr 1133, 28 §.)

An electrical accident is also defined in this decree. Electrical accidents are direct injuries or accidents causing property damages caused by electric shock, arc et cetera. Electric shocks and arcs result from technical errors or incorrect use. (FOR 1993-12-14 nr 1133, 3 §.)

Forskrift om sikkerhet ved arbeid i og drift av elektriske anlegg (FOR 2006-04-28 nr 458)
The decree is meant for protecting people working on, near or operation on electrical installations. The activities need to be planned carefully and necessary actions need to be taken for preventing damages to life, health and property. (FOR 2006-04-28 nr 458, 1 §.) The decree applies to planned live working and to situations where the electrical installation can become live (FOR 2006-04-28 nr 458, 2 §). Injuries and property damages caused by electricity or occurred when working on or operating electrical installations have to be reported to DSB as soon as possible (FOR 2006-04-28 nr 458, 8 §).

Forskrift om elektriske lavspenningsanlegg (FOR 1998-11-06 nr 1060)
Low voltage electrical installations are electrical installations with the maximum nominal voltage of 1 000 AC volts or 1 500 DC volts (FOR 1998-11-06 nr 1060, 3 §). Injuries and property damages caused by electricity have to be reported as soon as possible to DBS (FOR 1998-11-06 nr 1060, 15 §).

Forskrift om elektriske forsyningsanlegg (FOR 2005-12-20 nr 1626)
The decree applies to design, construction, operation and maintenance of power supply installations (*forsyningsanlegg* in Norwegian). Power supply installations mean electrical installations and associated buildings for the generation, transmission and distribution of electricity and high voltage electrical installations of industrial companies (FOR 2005-12-20 nr 1626, 1-2 §). An electrical shock is defined here as an effect on the body as a result of electricity travelling through a human body (FOR 2005-12-20 nr 1626, 1-5 §). The owner or the driver of the electrical installation has to report to DBS without delay injuries and major property damages caused by the electrical installations indirectly or directly (FOR 2005-12-20 nr 1626, 3-4 §).

Forskrift om elektrisk utstyr (FOR 2011-01-14 nr 36)
Electrical products are all the articles and objects used for production, transmission, distribution, utilization and measurement of electricity such as artifacts, transformers, converters and wiring (FOR 2011-01-14 nr 36, 4 §). Serious occurrences with electrical products have to be reported to DSB (FOR 2011-01-14 nr 36, 5 §).

Forskrift om maritime elektriske anlegg (FOR 2001-12-04 nr 1450)
The decree applies to marine electrical installations and electrical products that are connected to electrical installations on Norwegian ships, mobile offshore units, floating or mobile installations and yachts (FOR 2001-12-04 nr 1450, 2 §). Injuries and property damages caused by electricity need to be reported to DSB as soon as possible (FOR 2001-12-04 nr 1450, 9 §).

Forskrift om medisinsk utstyr (FOR 2005-12-15 nr 1690)
The person who manufactures or sells medical equipment has to report without delay to DSB malfunctions, any deterioration in the characteristics and/or performance and any lack of labeling or instructions that might lead to or might have led to the death of the patient, the user or the other person or serious deterioration of their health conditions (FOR 2005-12-15 nr 1690, 2-11 §).

2.4.5. Iceland

Lög nr. 146/1996 um öryggi raforkuvirkja, neysluveitna og raffanga
The scope of the law is to reduce the danger and damage caused by electrical installations and products (Lög nr. 146/1996, 1 §). An electrical product is defined as an object that utilizes electricity and an electrical installation is meant for production and utilization of electricity (Lög nr. 146/1996, 3 §). The law applies to electrical

installations and products on land, not to the installations of vehicles like electrical installations on board (Lög nr. 146/1996, 2 §).

The law defines the qualifications of electrical professionals in Iceland (Lög nr. 146/1996, 13 a-e §). Responsible parties at electrical utilities and heavy industrial plants need to make an internal safety control system for electrical installations and electrical contractors need to make an internal safety control system of their operations for being able to ensure safety (Lög nr. 146/1996, 5 §).

Reglugerđ um raforkuvirki nr. 678/2009
A responsible party means a person who owns, controls or has been nominated to be responsible for construction or operation of electrical installations and electrical products (Reglugerđ um raforkuvirki nr. 678/2009, 1 §). The responsible party is obligated to report accidents and damages to Mannvirkjastofnun without delay. Issues that may reveal the cause of the accident need to be explained. (Reglugerđ um raforkuvirki nr. 678/2009, 2.9 §.)

Mannvirkjastofnun is responsible for improving electrical safety in Iceland. It publishes educational material for example about electricity, using electricity and preventive measures. In addition, it can use material of inspections and accidents for education, information and warning. (Reglugerđ um raforkuvirki nr. 678/2009, 2.7 §.)

2.4.6. Greenland

Grønlands Elmyndighed works under the law called Landstings forordning nr. 12 af 3. November 1994 (Grønlands Elmyndighed). Almost every law concerning electricity in Greenland is same as in Denmark (Hansen, F.A. 2012).

2.4.7. The Faroe Islands

The Danish stærkstrømsbekendtgørelse is valid in the Faroe Islands. However, Elnevndin may make changes to the legislation in exceptional cases but it is rarely used. (Generelt n.d.)

2.4.8. Åland Islands

Laws related to electrical safety in Åland are nearly the same as in Finland (Nordberg 2013).

2.5. Statistics

This chapter presents statistics concerning the population of the Nordic Countries, accidents and transmission network installations.

2.5.1. Population

The population of the Nordic Countries was 25 875 183 persons on 1st January 2012 (Nordic Statistical Yearbook 2012, p. 36). Figure 2 presents how the population was divided.

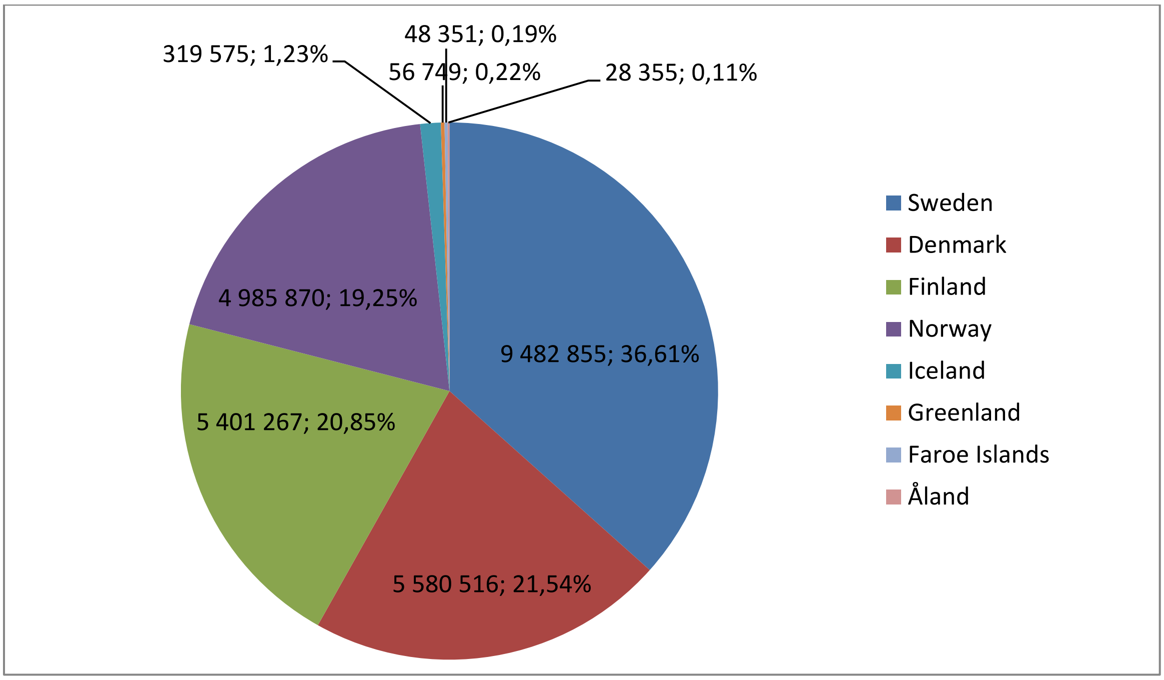

Figure 2. *Distribution of Nordic people on 1st January 2012 (Nordic Statistical Yearbook 2012, p. 36), (n=25 875 183), (%)*

About 37% of the Nordic people live in Sweden. About one fifth of the Nordic people live in Denmark, Finland or Norway each. Icelanders constitutes little over 1% of the Nordic population. The population of Greenland (0.22%), Faroe Islands (0.19%) and Åland (0.11%) is less than 1% of the total population in the Nordic Countries.

Similar demographic development can be perceived in different Nordic countries. People are aging and the immigration increases (Nordic Statistical Yearbook 2012, p. 38 & 46). Most people moving to the Nordic Countries do not come from another Nordic Country expect in Greenland and in the Faroe Islands. Norway had the largest proportion of foreigners, 6.6% of the total population, in 2012. (Nordic Statistical Yearbook 2012, p. 48.)

2.5.2. Accidents

Fatal accidents and the number of days' absence from work

The cause of death statistics are the only reliable statistics on causes of deaths at least in Finland (Kuolemansyytilasto on Suomessa 2011). Table 3 shows the rates of accidents as causes of deaths in the Nordic Countries per 100 000 people. Nordic Statistical Yearbook (2012, p. 54) reminds that small populations of the autonomous areas affects the numbers significantly.

Table 3. *All the accidents as causes of death per 100 000 people (Nordic Statistical Yearbook 2012, p. 54)*

	SWE	DNK	FIN	NOR	ISL	GRL	FRO	ALA
Men								
2005	44	35	81	50	26	82	37	43
2009	37	28	74	45	25	60	63	61
Women								
2005	31	27	36	34	18	53	19	17
2009	25	23	33	35	16	38	13	21

Accidental deaths of men are more common in Finland than in any other Nordic Countries. Accidental deaths of men have decreased in Sweden, Denmark, Finland, Norway and Iceland between 2005 and 2009. There are more accidental deaths of men than accidental deaths of women in the Nordic Countries. The rate of accidental deaths of women is higher in Finland, Norway and Greenland than in the rest of the countries. (Nordic Statistical Yearbook 2012, p. 54.)

Women have more often absences from work for at least a week due to illness than men in Sweden, Denmark, Finland, Norway and Iceland. There is no information concerning the situation in Greenland, the Faroe Islands and Åland. The total absence from work for at least a week due to illness is significantly higher in Norway and in Sweden. It was the smallest in Iceland in 2000 and in Denmark in 2010 (no data available from Iceland in 2010). (Nordic Statistical Yearbook 2012, p. 62.)

Electrical accidents

Table 4 presents the number of electrical fatalities and the total number of electrical accidents that have been reported to electrical safety authorities in Sweden, Denmark, Finland and Norway 2007-2011. Iceland, Greenland, the Faroe Islands and Åland do not publish the number of electrical fatalities and electrical accidents.

Table 4. Number of electrical fatalities *(the total number of reported electrical accidents in parenthesis) in Sweden, Denmark, Finland and Norway 2007-2011*

Year	Sweden [a]	Denmark	Finland [c]	Norway
2011	**3** (*438*)	**1** (*32*) [b]	**1** (*91*)	**2** (320 [d])
2010	**6** (*399*)	**1** (*40*)	**3** (*79*)	**0** (205 [d])
2009	**5** (*310*)	**5** (*42*)	**2** (*67*)	**1** ([e])
2008	**7** (*312*)	**1** (*72*)	**0** (*67*)	**1** (55 [f])
2007	**8** (*321*)	**1** (*75*)	**1** (*63*)	**1** (60 [f])

(Kilsgård 2008, p. 1; Kilsgård 2009, p. 1; Kilsgård 2010, p. 1, Kilsgård 2011, p. 2; Sundvall 2012, p. 5 & 8; Ulykkesstatistikken for 2011 och 2012 2013; Ulykkesstatistikken for 2007 n.d, p. 7 & 10; Ulykkesstatistikken for 2008 n.d, p. 7 & 9; Ulykkesstatistikken for 2009 n.d, p. 7 & 9; Ulykkesstatistikken for 2010 n.d, p. 6 & 8; Toimialan onnettomuudet 2012, p. 13; Elsikkerhet nr. 81 2012, p. 9; Elsikkerhet nr. 79 2011, pp. 12–13; Elsikkerhet nr. 77 2010, p. 15; Elsikkerhet nr 75 2009, p. 8 & 10)

[a] electrical accidents with more than one days' absence from work; [b] not published because of the changes in the database, the numbers from the accident analysis; [c] every reported electrical accidents; [d] ulykker/hendelser; [e] not available because of the new system; [f] electrical accidents with more than 1 days absence from work

The number of reported electrical accidents varies in different countries. The number of reported electrical accidents has increased in Sweden, Finland and Norway. The fatal electrical accidents are presented in more detail in Appendix 1.

2.5.3. Transmission network installations

The European Network of Transmission System Operators for Electricity (ENTSO-E) is an association of transmission system operators in Europe (The European Network 2012). The member companies in the Nordic Countries are Svenska Kraftnät (Sweden), Energinet.dk (Denmark), Fingrid (Finland), Stattnett (Norway) and Landsnet (Iceland) (ENTSO-E Member Companies 2012). ENTSO-E's Statistical Yearbook includes information on transmission network installations in lengths of circuits. The statistics excludes the lengths of under 220 kV transmission network installations. (Statistical Yearbook 2011 2012, p. 106). Table 5 presents how 220-285 kV and 380/400 kV transmission network installations divide into overhead power lines and ground cables in Sweden, Denmark, Finland, Norway and Iceland.

Table 5. *Transmission network installations in 2011(Statistical Yearbook 2011 2012, p. 106)*

	220 - 285 kV			380/400 kV		
Country	Overhead power lines (%)	Ground cables (%)	km in total	Overhead power lines (%)	Ground cables (%)	km in total
Sweden	100,0	0,0	4 400	99,9	0,1	10 716
Denmark	75,2	24,8	933	80,3	19,7	1 879
Finland	100,0	0,0	2 601	100,0	0,0	4 331
Norway	100,0	0,0	445	95,0	5,0	8 797
Iceland	100,0	0,0	851			0

3. ELECTRICAL SAFETY

The definitions of electrical safety may have different emphases. In this study electrical safety means the ideal situation where electrical accidents are non-existent.

This chapter introduces different kinds of issues related to electrical accidents for example how them can be defined, causes of electrical accidents and preventive measures. In addition the chapter presents some key definitions used later.

3.1. Accident models

"An accident can be defined as a short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome". Thus, an accident consists of both the event and the outcome. (Hollnagel 2004, pp. 5–6.) Hovden et al. (2010, p. 950) see an accident as a hazard materializing in a sudden event with harmful consequences that include injuries.

Accident models represent the event, the way how the accident could happen and ways to prevent them in the future (Lundberg et al. 2009, p. 1297). Accident models can be seen as simplified representations of real-life accidents (Hovden et al. 2010, p. 955). Generic accident models help finding the cause-effect relationship behind the accidents (Lundberg et al. 2010, p. 2132). By doing so the models are meant to create information on the causes of the accidents to decision makers (Lundberg et al. 2012, p. 455). The decision makers can utilize the accident models both in reactive and proactive accident prevention. In addition accident models have a large impact on people. The models affect the association of safety, the identification and the analysis of risks factors. (Hovden et al. 2010, p. 955.)

The accident models approach the risk problem differently (Kjellén 2000, see Hovden et al. 2010, p. 955). Many accident models are based on the idea of causality (Hovden et al. 2010, p. 955). There are a lot of different accident models and new models arise all the time (Lundberg et al. 2012, p. 455). The models have evolved over time (Lundberg et al. 2009, p. 1297). According to Hovden et al. (2010, p. 951) Heinrich's domino model (1931), Gibson's basic energy barrier model (1962) and Haddon's matrix (1968) have influenced most accident models. Even though most experts and practitioners still believe in the domino model (Hovden et al. 2010, p. 953) Lundberg et al. (2009, p. 1300) remind that the model was developed in a different era. The domino model focuses on aspects that were important in the 1930's and the model might underestimate aspects that are important in present-day safety research (Lundberg et al. 2009, p. 1300).

Today's accident models are different because they focus on other aspects than human behavior. The models see that a lot of different factors affect accidents in a complex socio-technical system which has deepened the understanding of safety. Modern accident models approach causality in a detailed way and they try to find the factors behind the accidents. (Lundberg et al. 2010, p. 2132.)

Accident models can be divided into different categories. Hollnagel (2006, p. 15) sees three different categories: the simple linear model, the complex linear model and the systemic or non-linear model. The domino model represents the simple linear model and Reason's Swiss cheese model belongs to the complex linear models. The complex linear models can be also called epidemiological models. The epidemiological models see accidents as interactions among agents, defenses and hosts. The third category, the systemic or non-linear model, understands that accidents occur in a complex and variable system. (Hollnagel 2006, pp. 10–12.) Hovden et al. (2010, p. 951) classify accident models into four categories instead of three. The categories are causal sequence models, descriptive models, system models and logical models. The domino model is seen as a causal sequences model and the Swiss cheese model as a system model. The descriptive models focus on sequentially timed events and logical models are inspired by risk analysis. (Hovden et al. 2010, p. 951.)

3.2. Electrical accidents

The first subchapter presents how an electrical accident can be defined. The second subchapter focuses on consequences of electrical accidents.

3.2.1. Definition

NSS defines an electrical accident as "any event electricity has caused to a person, directly or indirectly, who is injured by an electric shock or an arc". Mechanical accidents caused by electrical installations are not electrical accidents because the injury they cause is not caused by an electric shock or an arc. An electrical accident happens, according to the definition, only to one person which means that an electrical accident involving more persons is registered as more than one electrical accident. The definition dates from 1999 and every Nordic Country has accepted it. (Statistik over elulykker 2010, p. 4.) NSS's definition does not include accidents where toxic gases are released when electrical installations burn; thus those kinds of accidents are included in the definition of Queensland's Electrical Safety Office (Electrical Safety Code of Practice 2010, p. 25).

NSS's definition has been used in research. Tulonen et al. (2006, p. 12) used the definition and classified an accident as an electrical accident even when the described injury was minor, for example a small burn or scalloping. The indirect injury included for example falls after having an electric shock. (Tulonen et al. 2006, p. 12.) Pulkkinen et al. (2010, p. 19) investigated how electrical professionals in Finland define an occupational electrical accident. The definitions the professionals used were different and only half of the interviewees defined an accident caused by an arc as an electrical accident. In general, the younger professionals defined all the electric shocks as electrical accidents but the older only the electric shocks with serious consequences. (Pulkkinen et al. 2009, p. 19.)

Elsäkerhetsverket has two separate definitions for electrical accidents that happen at railways. A climbing accident (*klätterolycka* in Swedish) happens when a person (usually a layman) climbs onto the roof of a carriage via its own structure and thus comes too near energized electric lines so that the person is exposed to an electric shock. An occupational accident happens when a person is working at the overhead contact system. (Sundvall 2011, p. 7.) Suicides and electrical accidents caused by lightning were not included in a Swedish longitudinal study on electrical fatalities (Lindström et al. 2006, p. 1383).

This research focuses only on electrical accidents, but nevertheless it is useful to know how an electrical incident can be defined. Capelli-Schellpfeffer et al. (2000, p. 17) suggest that "an electrical incident is an event resulting from either personnel action or equipment failure involving electrical installations that has the potential to result in an injury". Tulonen et al. (2006, p. 12) combine an electrical incident and a near miss as an event where a person could have had an electric shock or could have been injured. As the definition of an electrical accident differed among Finnish electrical professionals also the definition of an electrical incident varied among them. It was more difficult for the electrical professionals to define an electrical incident or a near miss than an electrical accident (Pulkkinen et al. 2009, pp. 19–20).

Capelli-Schellpfeffer et al. (2000, p. 17) state that when people internalize the definition of an electric incident they have better understanding and awareness of electrical safety. This results from that they observed more electrical incidents than they believed beforehand. (Capelli-Schellpfeffer et al. 2000, p. 17.) On the other hand Goffeng et al. (2003, p. 2458) remind that if the authorities want to receive more electrical accident reports it is necessary to define clearer what the accidents are that need to be reported.

3.2.2. Consequences

Every electrical accident can result in death. In the United States electrical accidents cause death more often than many other accident classes (Cawley & Brenner 2012, p. 2). In Sweden, the situation is different because only 0.36% of accidental deaths is due to electricity (Lindström et al. 2006, p. 1383). However, people regard some electrical accidents like they are not serious accidents at all. According to Capelli-Schellpfeffer et al. (2000, p. 17) people who have had an electric shock with no visible injuries do not understand what kinds of consequences the shock could have had. Almost one fifth of the respondents (n=64) in a Swedish research does not seek medical assistance because they have not sensed anything. Over half of the respondents has not had any need to seek medical assistance after the electrical accident or they found the electrical accident not serious enough. (Kartläggning av elolyckor bland 2005, p. 30.) In the research done by Tulonen et al. (2006, p. 18) situations where electrical professionals did not seek medical assistance included even for example blackouts, palpitations and a few days of not feeling well.

According to Reese (2008, p. 164-165) an electric shock can be almost anything from a non-serious electrical accident to a fatal electrocution. Reese (2008, p. 167) continues saying that electric shocks can cause other injuries like falls because of an involuntary muscle reaction. The amount of current flowed, the direction of the current trough the body, the time how long the body was part of the circuit and the frequency of the current influence the severity of the electric shock (Reese 2008, p. 165).

Electric shocks cause most often burn injuries (Reese 2008, p. 166). Arc faults release heat and light which can cause burns (Kowalski-Trakofler & Barrett 2007, p. 597). The injured person does not need to touch electrical parts when the person is injured by arc (Kowalski-Trakofler & Barrett 2007, p. 597). It is essential to notify that in most cases arcs cause burn injuries to many parts of the body (Kowalski-Trakofler & Barrett 2007, p. 603).

3.3. Causes of electrical accidents

Knowing causes of accidents simplifies successful accident prevention. It is essential to understand why accidents happen to be able to prevent them in the future. (Williamson & Feyer 1998, pp. 187–188.) Occupational safety researchers have been and still are interested in finding causes of accidents. Studies have focused on different aspects like for example training and the age of the workers. (López et al. 2011, p. 1104.)

According to Cawley and Homce (2003, p. 244) it is useful to find the primary cause of each occupational electrical accident. Tulonen (2010, p. 1) states that finding the underlying causes is the best way to prevent accidents in the future. A common problem in finding the causes of the accidents is that the investigation stops too early. Only the simple and already-known remedies are found. This can complicate getting a larger picture of the causes of accidents for accident prevention. (Lundberg et al. 2010, p. 2132.) It seems that when the causes have been identified and reported the work is done. If we think that finding the causes is enough for accident prevention we should have better methods for them. (Lundberg et al. 2012, p. 455.)

The first subchapter focuses on human error. In the next two subchapters causes of fatal and non-fatal electrical accidents are presented separately. According to McCann et al. (2003, p. 399) fatal and non-fatal electrical accidents might result from different causes.

3.3.1. Human error

Nowadays most accidents are seen resulting from human error. We are not allowed to judge people not working right and safely. More important is to understand why people did what they did. Saying what would have been done to prevent the accident does not explain what happened and why. (Dekker 2002, p. 371 & 375.) Accidents usually happen in normal situations where people are doing normal things. Errors and mistakes connect to certain circumstances. (Dekker 2002, p. 378.)

There are two viewpoints on human error. The old viewpoint sees human error as a cause of most accident: the systems people work within are basically safe and safety can be ensured by protecting the systems from unreliable people. According the new viewpoint human error is not a cause but a symptom of failure. Human errors result from organizational problems. People make safety; it is not ready-made in the systems. Improving safety demands understanding that "human error is systematically connected to features of people, tools, tasks, and operating environment". (American Medical Association 1998; Reason 2000, see Dekker 2002, p. 372.) Tulonen (2010, p. 21) reminds that the old viewpoint is still used in non-scientific literature. That might result from scarce information on accidents or from time pressures not to investigate accidents further (Tulonen 2010, p. 21).

Human error can be classified differently. Error can be classified into omissions, meaning that things are not done, and commissions meaning that things are done incorrectly (Williamson & Feyer 1998, p. 195).

3.3.2. Fatal electrical accidents

There is little literature on fatal electrical accidents according to Lindström et al. (2006, p. 1383). The literature they mention dates from the 80's and early 90's, so the literature is not so up-to-date. The investigation reports of the fatal electrical accidents (e.g. those of Tukes) were not used as a source here.

Sweden

Lindström et al. (2006) analyzed statistically 285 fatal Swedish electrical accidents from the years 1975-2000. Over half (53%) of the deaths happened at leisure time, 46% was occupational and the situation was unknown in 1% of the deaths. Generally speaking fatal electrical accidents are uncommon in Sweden. The mean age of the victims was 38 years, the medium age was 35 years and the age range from 10 months to 92 years. The median and the mean age of the victims in occupational electrical accidents were 42 years. The median age of victims of leisure time electrical accidents was 28 and the mean age was 35 years. (Lindström et al. 2006, p. 1383 & 1385.)

Overhead power lines caused most of the fatal electrical accidents (40%) and most of those accidents happened at a railway area (54%) and in forest/field (20%). The most common locations of all the fatal electrical accidents were railway (22%), residential properties (19%) and substations (11%). (Lindström et al. 2006, pp. 1383–1384).

None of the electrical accidents happened to women at work and only a few to women during leisure time. Traditionally, men have done more electrical work than women both at work and at home. This gender-related exposure to electricity might explain the distribution of deaths among the genders. (Lindström et al. 2006, p. 1386.)

Most occupational fatalities were electricians (46%) followed by agricultural workers (14%), construction workers (11%) and industrial workers (8%). Almost two thirds (65%) of the occupational electrical deaths resulted from actions of the victim. The victim did not, for example, use protective devices or follow safety procedures. The victim was also the major cause for leisure time electrical accidents. Unauthorized repairs, use of alcohol, overlooking aerial power lines and lack of judgment were listed as factors behind the fatal leisure time electrical accidents. (Lindström et al. 2006, p. 1385-1386.)

Outside the Nordic Countries

Like in Sweden, also in the United States most electrical fatalities result from overhead power lines. During the years 1992-2009 overhead power lines have always been the most common cause of the occupational electrical fatalities in the US (Cawley n.d, p. 2). Direct contact, contact through hand-carried objects and through machines are included in those accidents (Cawley n.d, p. 2).

Taylor et al. (2002, p. 307) note that the highest rates of occupational electrical deaths were in construction (45%), landscape and horticultural services (36%) and agricultural production: crops (33%) in the United States. The situation is not same in Sweden because only 11% of occupational electrical fatalities between 1975 and 2000 happened in construction sites. Between 1990 and 2000 only one death happened in a construction site which can result from recession, improved safety or both. (Lindström et al. 2006, p. 1384 & 1387.) However, electricity is the major cause of the occupational deaths and injuries among construction workers in the US (McCann et al. 2003, p. 398).

The major cause of the electrical deaths and injuries was working live or near electrical wiring and installations in the construction industry in the United States. It was not, however, necessary to work live in many cases. Reasons for working live when fixing a light included timetable-related requirements, the owner of the building did not want power black-outs and the unfavorable attitude of electrical professional towards working dead. (McCann et al. 2003, p. 404.) In a Taiwanese study of electrical fatalities in the construction industry the major cause of the deaths was unsafe acts which included not de-energizing, not maintaining safe distances, improper use of PPE and poor work practices (Chi et al. 2009, p. 641).

In Australia human factors are the most common primary cause of the occupational electrical fatalities. There are more omissions than commissions meaning that it needs to be ensured that all the steps are done. (Williamson & Feyer 1998, p. 195.)

3.3.3. Non-fatal electrical accidents

The Nordic Countries

In Norway organization of work, time pressure and overtime, availability of equipment, degree of specialization and job rotation, distractions at work or working on multiple tasks simultaneously have been seen as possible causes of occupational electrical accidents among electrical professionals. In addition, communication during work has been seen to affect occupational safety. (Goffeng & Veiersted 2001, see Goffeng et al. 2003, p. 2458.) In a Swedish study consisting of 400 respondents the most common causes of the electrical accidents among professionals were negligence (64%) and stress (33%). Time pressure (12%), not being able or allowed to de-energize (11%) and human factor, not thinking before acting and routine (11%) were also common causes of electrical accidents. Not measuring voltage had the distribution of 7%. (Kartläggning av elolyckor bland 2005, p. 14.)

A human failure was the most common reason not to measure voltage. Causes behind the human failure included for example trust that there is no voltage, carelessness and that the tester equipment was not available. (Tulonen 2010, p. 57.) Hurry, customer demand and human failure were the most common reasons not to de-energize among electrical professionals. Human failures appeared as human errors and attitude-related factors. Mentioned human errors included trust that there is no electricity, trust in something or someone and poor communication about whether there is electricity or not. Attitude-related factors included for example laziness, carelessness, negligence, routine tasks and forgetting to de-energize. (Tulonen 2010, pp. 54–55.) The most common reason not to earth was human failure and the reasons were mainly connected to attitudes, know-how and knowledge about how to earth (Tulonen 2010, pp. 58–59).

Pulkkinen et al. (2009, p. 14) estimate that 78% of occupational electrical accidents of electrical professionals result from errors made by the victim, 11% from errors made by the victim and someone else and 11% from mistakes in an earlier stage. The errors made by the victim can be divided into negligence and other actions against the regulations (70%), hurry and setting-out (10%), incompetence (9%), wrong presumptions that the system is not de-energized (9%) and a mistake in job planning (2%) (Pulkkinen et al. 2009, p. 15). To put it short electrical professionals do not always know how to act safely (Pulkkinen et al. 2009, p. 4). Tulonen (2010, p. 86) states that the electrical accidents of the electrical professionals result from omissions of safety procedures in the Finnish standard SFS 6002 which corresponds to the EN 50110-1 standard in Finland. Most electrical accidents result from unexpected energy and accidental contact which confirms the omissions (Tulonen 2010, p. 53 & 86).

The Nordic studies focus mainly on occupational electrical accidents of electrical professionals. The causes of the occupational electrical accidents among laymen and electrical accidents happened during leisure time have not been studied widely. However, the causes of the electrical accidents of the electrical professionals in Sweden and Finland are agreed upon: most accidents result from negligence and other actions against regulations (Kartläggning av elolyckor bland 2005, p. 14; Pulkkinen et al. 2009, p. 15). Tulonen (2010, p. 67) explains that the reasons for working unsafely can include for example need to work quickly, no motivation to work safely, not enough guidance to be able to work safely, not knowing that the work method is wrong and not having adequate equipment.

Internationally

Reese (2008, p. 167) lists three factors that cause most electrical accidents. The factors are unsafe work practices, unsafe environment and unsafe electrical products or installations. In Cawley and Homce's research (2003) 62% of the non-fatal occupational electrical accidents resulted from electric shocks. Reese (2008, p. 164) reminds that "electric shocks occur when a person’s body completes the current path with any one of the following: both wires of an electric circuit; one wire of an energized circuit and the ground; a metal part that accidentally becomes energized because of, for example, a break in its insulation; or another conductor that is carrying current".

Kowalski-Trakofler and Barrett (2007) have studied arc accidents in the United States. They recognized that electrical professionals with more experience have more electrical accidents than the others. That results probably from their decision not to work safely. The causes behind not working according to the safety procedures included time-table related problems, production pressure, insufficient planning and taking shortcuts. The issues resulted in working live, not using PPE and not following the safety procedures. (Kowalski-Trakofler & Barrett 2007, p. 605.)

3.4. Electrical accident prevention

Safety researchers are interested in knowing why accidents still happen even though there are a lot of accident prevention methods and investments on accident prevention (Körvers & Sonnemans 2008, p. 1067). Kowalski-Trakofler and Barrett (2007, p. 603) who studied arc injuries in the United States interviewed 32 injured and almost all of them admitted that the electrical accident could have been prevented. To become successful in accident prevention the causes of the accidents need to be known well. In addition to that it is essential to try to understand why the accident happened in the first place. (Williamson & Feyer 1998, pp. 187–188.)

It is difficult to reduce the severity of the electrical contact (Soelen 2007, see Albert & Hallowell 2013, p. 119). The exposure to electricity and the frequency of the electrical accidents can be reduced when preventing electrical accidents (Albert & Hallowell

2013, p. 119). The electrical accident prevention knowledge can be used widely; it does not matter if the methods are used somewhere else for example in the other industrial field (Cawley & Homce 2003, p. 241). There is no single approach to prevent electrical accident but you have to be innovative and combine different aspects like engineering, management and training (Cawley & Homce 2003, p. 246). Furthermore, Reese (2008, p. 174) reminds that "good judgment and common sense are integral to preventing electrical accidents".

3.4.1. Education and training

Electrical professionals do not always know how to work safely (Tulonen 2010, p. 103). Occupational electrical accidents can be prevented by improving safety awareness, educating employees and collecting their training initiatives (Cawley & Brenner 2012, p. 1). Williamson and Feyer (1998, p. 188) see that improving awareness of electrical hazards related to work can prevent electrical fatalities. Training should be targeted to all the employees and it should focus on the safety procedures (Reese 2008, p. 174). Workers of varying ages might need allocated training (Janicak 2008, p. 617). Casini (1993, p. 34) reminds that both the employees and the supervisors need training on safe work procedures. However, smaller employers do not always offer enough safety training and they might use less safety procedures (Taylor et al. 2002, p. 310).

Education of electrical professionals might include for example orientation, extension courses and other regular training events (Tulonen 2010, p. 103). McCann et al. (2003, p. 404) emphasize the importance of telling about the hazards related to working live because working live is not always necessary. They continue by stating that electrical professionals need training about how to de-energize properly (McCann et al. 2003, p. 404). In addition, it is essential to educate electrical professionals to use lockout-tagouts and PPE properly (Cawley 2011, p. 1367). Kowalski-Trakofler and Barrett (2007, p. 599) point out that using protective clothing does not replace safety training. Training at workplaces targeted at both electrical professionals and laymen should be varied because training might be the only source of safety procedures. Training should be target-oriented and it should be measured by asking employees to show how to work safely. (Casini 1993, p. 37.)

Training is not always the most appropriate way of preventing electrical accidents. For example in mining, correcting breakages and maintaining used equipment prevent electrical accidents more effective than training. (Williamson & Garg 2002, p. 12.) Managers cannot trust too much in training because they have to also understand the importance of engineering control interventions (Manuele 2000, see Cawley 2001, p. 1367). There are also other problems in training and dividing information. The Swedish Transport Administration has noticed that information campaigns concerning safety at the railroads are forgotten over the time. That is a reason for repeating the campaigns regularly. (Sundvall 2011, p. 6.)

3.4.2. Management

According to Cawley and Brenner (2012, p. 1) electrical safety should be among the most important issues for managers in all the industrial sectors and they should promote safety all the time. Organizations which value safety give an example that there are no excuses for unsafe actions (Tulonen et al. 2006, p. 48). However, it is sometimes difficult for organizations to demonstrate how important safety is (Pate-Cornell & Murphy 1996, see Attwood et al. 2006, p. 671). Capelli-Schellpfeffer et al. (2000, p. 17) point out that when people understand the definition of an electrical incident their understanding of electrical safety can increase. Workers are not always interested in sharing their electrical accident experiences. When telling about the possibility to learn about the accidents the interest of reporting may increase. (Capelli-Schellpfeffer et al. 2000, p. 18.) In a Swedish study electrical professionals were asked about how they find information on occurred electrical accidents. Most often the information come from fellow workers (23%) followed by interactive sources, e.g. intranet and e-mail (20%). The proportion of meetings was 19% and the proportion of the employer 9%. (Kartläggning av elolyckor bland 2005, p. 31.)

Both the management and the employees have to commit to electrical accident prevention. The management could, for example, organize safety inspections to demonstrate how interested they are in safety promotion. (Casini 1993, p. 38.) Electrical professionals have sometimes time-pressure. Management can for example reduce work interruptions and change the schedules to reduce hurry. When the foreman does not interfere in unsafe actions because of hurry he/she admits that financial issues are more important than safety at least from the viewpoint of the employees. (Tulonen et al. 2006, p. 48.)

Management does not always evaluate the qualifications and experience of electrical professionals when hiring new workers (Kowalski-Trakofler & Barrett 2007, p. 604). Tulonen et al. (2006, pp. 48–49) point out that the employer should always ensure that the workers know how to work safely and the tools they use are proper. In addition, there should be rules how to work in unexpected situations (Tulonen et al. 2006, pp. 48–49).

3.4.3. Technical ways

Williamson and Feyer (1998, p. 196) consider upkeep of equipment an important medium to prevent occupational electrical accidents of laymen. In mining industry audits, reviews and maintenance of mining equipment could prevent most electric shock accidents. Both safety of existing equipment and safety of future equipment are equal important (Williamson & Garg 2002, p. 2).

In the United States using lockout-tagouts in construction industry prevents fatal electrical accidents (Janicak 2008, p. 620). Lockout-tagouts are not commonly used in construction even though McCann et al. (2003, p. 404) admit how good they are in accident prevention. Inspections, maintenance programs and a residual-current device could prevent electrical accidents involving for example power tools and extension cords. In addition, it is essential to look after that fall protection is in order. In construction, a lot of electrical accidents end up in falls or jumps from ladders. (McCann et al. 2003, pp. 404–405).

3.4.4. Improvement of electrical safety in Sweden 1975-2000

Electrical fatalities have decreased in Sweden between 1975 and 2000. Many issues have improved electrical safety during that quarter of a century. Minimum standards, earth wires, improved wall sockets, ground fault interrupters and arc protection devices are issues that have most likely decreased the number of electrical fatalities in Sweden. (Lindström et al. 2006, p. 1386.) Håkan Lidman from the Swedish Electrical Safety Board listed other issues that have improved electrical safety in Sweden in Lindström et al.'s research (2006, p. 1386). The issues he mentioned were:

- "a forced ban of sales for couplers for industrial purposes with metallic enclosures,
- introduction of an improved rubber compound for flexible cables,
- an improved directional earth-fault relay protection with automatic disconnection of the current when a live conductor of an overhead wire falls to the ground,
- guidelines to electricians of always verifying that the installation is ‘‘dead’’ before work is commenced and
- that it is more common today to make the collector wires of the railway tracks ‘‘dead’’ where railway carriages are parked" (Lindström et al. 2006, p. 1386).

Both occupational and leisure time electrical accidents had a decreasing trend during the study period. The number of occupational electrical accidents decreased proportionally more which might indicate that changes regarding regulations and equipment have influenced more in work places than during leisure time. (Lindström et al. 2006, p. 1387.)

3.5. Safety culture and climate

Accident prevention has evolved from management control to safety culture and safety climate (Lundberg et al. 2009, p. 1299). Safety culture and safety climate can be defined in many ways. Most often the definitions include aspects related to beliefs, attitudes, values and perceptions with relation to safety. (Lundberg et al. 2012, p. 457.) Kowalski-Trakofler and Barrett (2007, p. 599) defines safety culture as shared beliefs on the safety situation among the employees. They (2007, p. 599) continue that organizations with good safety cultures report fewer accidents than organizations with not so good safety cultures. Good safety culture is understood to prevent accidents. However, accidents can occur even in organizations with good safety culture. (Kowalski-Trakofler & Barrett 2007, p. 605.)

People's adventurism may vary in different countries because of values, beliefs and assumptions (Mearns & Yule 2009, p. 780). However, management commitment affects more than national cultures to the behavior at work (Mearns & Yule 2009, p. 784). Spangenberg et al. (2003) who studied work related injury rates between Danish and Swedish construction workers during the Øresund Link project observed that the lost-time injury rate was higher among the Danes. The difference resulted most probably from group and individual level factors. The group and individual level issues can include for example education, attitudes and training. (Spangenberg et al. 2003, p. 529.)

3.6. Under-reporting

In an ideal case all the electrical accidents that need to be reported would be reported to the electrical safety authorities. However, surveys done in the Nordic Countries show strong under-reporting of electrical accidents (Kartläggning av elolyckor bland 2005, p. 7). Under-reporting of accidents consists of two aspects: the number of accidents reported by the employee to the employer and the number of accidents happened to the employee but not reported to the organization. When the difference between the unreported and reported accidents increases under-reporting grows. However, it is essential to have an understanding of the number of unreported and reported accidents. By doing so it is possible to find out how people feel towards accident reporting. Under-reporting can be divided to organizational-level under-reporting and individual-level under-reporting. (Probst & Estrada 2010, p. 1438-1439.)

3.6.1. Results and causes

Occupational safety work is based on the under-reported number of accidents (Hämäläinen et al. 2006, p. 137). According to Goffeng et al. (2003, 2457) under-reporting complicates accident prevention work. Thus there is lack of information on what kinds of electrical accidents occur and what they cause to the injured (Østbye & Gilje 2000, p. 12). Reporting an electrical accident to the electrical safety authority is important so the electrical safety authority would have better understanding of the present state of electrical safety. Moreover, when the present state is more truthful it is simpler to target the needed safety promotion efforts. (Pulkkinen et al. 2009, p. 1.) Because there are no reliable statistics on electrical accidents it is not really known what the overall costs are to the injured, to the organization and the society they are causing (Tulonen et al. 2006, p. 6).

There are many reasons not to report accidents. Probst and Estrada (2010, p. 1442) suppose that a poor safety climate is behind not reporting accidents. When employees think that they can handle the accident there are problems in safety communication and the employees do not benefit anything about reporting the accident. Employees might suspect the commitment of management to safety when they do not report accidents because of the fear that nothing will be done. It is also possible that accidents are not reported because of the aim towards zero accident. Employees may not want to rule out the fulfillment of the aim by reporting accidents. (Probst & Estrada 2010, p. 1442.)

3.6.2. Under-reporting of electrical accidents in the Nordic Countries

The survey Kartläggning av elolyckor bland elyrkesmän (2005) touched on the under-reporting of electrical accidents among electrical professionals in Sweden. The rate of individual-level under-reporting was high because only 16 per cent of the injured reported the electrical accident to the employer. This might result from how the injured defines an electrical accident. Moreover, electrical professionals think that they are responsible for the electrical accidents that happen at work. (Kartläggning av elolyckor bland 2005, p. 3.) The same has been recognized also in Finland (Pulkkinen et al. 2009, p. 21).

In Finland, other occupational accidents are reported more than electrical accidents because the injured feel that the electrical accidents result from their own mistakes, perhaps from working against rules or regulations (Pulkkinen et al. 2009, p. 21). Professional pride, the want not to admit the failures and the breakage of rules are reasons of under-reporting in Norway (Østbye & Gilje 2000, p. 12). According to Pulkkinen et al. (2009, p. 1) people diminish the electrical accidents happened to them in Finland and one reason not to report electrical accidents in Sweden is that the accident is not considered serious enough (Kartläggning av elolyckor bland 2005, p. 28).

All the electrical accidents are not reported either to Elsäkerhetsverket or Tukes. Electrical professionals seldom report electrical accidents directly to Elsäkerhetsverket (Kartläggning av elolyckor bland 2005, p. 4). Instead, electrical accidents are reported to the employer or the industrial safety delegate (Kartläggning av elolyckor bland 2005, p. 4). In Finland, the Federation of Accident Insurance Institutions (*Olycksfallsförsäkringsanstalternas förbund*, in Swedish) guided by the Employment Accidents Insurance Act (L 1948/608, 64 §) keeps a record of compensated occupational accidents and diseases. There are more electrical accidents in the statistics of the Federation of Accident Insurance Institutions than those at Tukes (Pulkkinen et al. 2009, p. 8). This means that all the electrical accidents happened at work are not reported to Tukes (Pulkkinen et al. 2009, p. 27). Hintikka (2007, p. 31) estimates that the Federation of Accident Insurance Institutions knew 4.5 times more occupational electrical accidents than Tukes in 2003 and 2004. Especially minor electrical accidents are under-reported to Tukes (Hintikka 2007, p. 31). There might be reporting routines that do not favor reporting minor electrical accidents (Hultgren & Rosèn 1988, see Goffeng et al. 1997, p. 9).

In Norway, DSB and the Norwegian Labour Inspection Authority (*Arbeidstilsynet* in Norwegian) should in principle receive the same number of electrical accidents. Annually over three times more electrical accidents are reported the Norwegian Labour Inspection Authority than to DSB (Goffeng et al. 2003, p. 2458). However, only 9 percent of serious occupational accidents are reported to the Norwegian Labour Inspection Authority (Gravseth et al. 2003, p. 2057). Goffeng et al. (2003, p. 2457) estimate that there are 7.6 serious electrical accident per 100 persons per year which means that there are over 3 000 electrical accidents in Norway annually. DSB tries to increase the number of reported electrical accidents by offering an anonym way to report accidents. A code word is sent by a text message to DSB but electrical accidents with injuries have to be reported otherwise. (Elsikkerhet nr. 77 2010, p. 14.)

Some electrical accidents need to be reported to Sikkerhedstyrelsen and the statistics of Sikkerhedstyrelsen contains only a part of the occurred electrical accidents. (Statistik over elulykker 2010, p. 3.) In an Icelandic study 33% of the 386 electrical professionals admitted having an electrical accident or a mishap at least once in her/his life (Scope of electrical accidents 2005, p. 9).

The problem of under-reporting is not that people do not know how to report electrical accidents. In Sweden, 72% of electrical professionals know how they should report occupational electrical accidents (Kartläggning av elolyckor bland 2005, p. 4). However, younger electrical professionals are not as familiar with electrical accident reporting than the older workers. 63% of electrical professionals say that there is a routine how to report electrical accidents in the organization but professionals at smaller companies have worse knowledge on how to report. (Kartläggning av elolyckor bland 2005, p. 16.) Elsäkerhetsverket, the trade union and the employer should work together to increase the reporting rate of the electrical accidents. Elsäkerhetsverket should also work for raising awareness of electrical professionals using for example news, regulations and statistics as the media. The employers report electrical accidents to Elsäkerhetsverket but everyone in electrical engineering should have knowledge about Elsäkerhetsverket. The employer and the trade union should try to change attitude of electrical professionals towards occupational electrical accidents. Electrical professionals should not have to decide themselves which electrical accident is serious and thus to be reported and which one is not. By making clear instructions when to report an electrical accident and what kind of health care is needed after different kinds of electrical accidents can raise the number of reported electrical accidents. (Kartläggning av elolyckor bland 2005, pp. 5–6.)

3.7. Hazard identification

A hazard can be defined as a "source of potential harm". A hazard can also be a risk source that might cause risks. Identifying risk sources is a part of risk identification that consists of finding, recognizing and describing risks. (SFS-OPAS 73 2011, pp. 11–12.)

First this chapter introduces electrical accident hazards. Next it focuses on emerging risks that might cause harm in the future. Saari (2001, p. 3) states that people tend to underestimate old known risks and overestimate emerging new risks even though they should be regarded as equal.

3.7.1. Electrical accident hazards

The European standard EN 50110-1 "Operation of electrical installations" defines an electrical hazard as "a source of possible injury or damage to health in presence of electrical energy from an electrical installation" (SFS 6002:2005:en, p. 15). However, in this research electrical energy can come from electrical products. In addition, although the standard concerns only electrical professionals here electrical hazards relate also to laymen.

Most employees are exposed to electricity at work every day and electrical hazards can be seen as common occupational dangers. Only a few employees are aware of electrical hazards and hence many are vulnerable to them. (Casini 1993, p. 35.) According to Reese (2008, p. 163) people underestimate electrical hazards and they do not believe in that those hazards might realize. Even electrical professionals do not consider the presence of electricity a danger (Tulonen et al. 2006, p. 18). However, Janicak (2008, p. 620) states that employees working on, with or near electrical installations should know electrical hazards that are involved. Too little and inaccurate knowledge about electrical hazards can cause electrical accidents (Capelli-Schellpfeffer et al. 2000, p. 16). Knowing the electrical hazards and their places in the workplace is the key to electrical accident prevention (Reese 2008, p. 175). Even some fatal electrical accidents could have been avoided if workers knew better hazards electricity poses (Williamson & Feyer 1998, p. 188).

Electrical hazards can be invisible. Low voltage does not mean a low hazard. (Reese 2008, p. 167 & 176.) According to the US Occupational Safety and Health Administration most electrical accidents result from unsafe electrical products or installations, unsafe environment or unsafe work practices (Chao & Henshaw 2002). Cawley (2001, p. 1361) states that overhead power lines are hazards that need to be considered in mining industry. Fischer (2004, p. 2) tells that there are five to ten arc flash explosions in electrical installations in the US every day. Hazards arcs pose are present almost in every industrial workplace (Kowalski-Trakofler & Barrett 2007, p. 598). However, only in 55% of the 522 electrical accidents the hazards were known in Kowalski-Trakofler and Barrett's study (2007, p. 602).

The exposure to electrical hazards varies among different occupational groups. Electricians and their apprentices have increased exposure to electrical hazards while for example the exposure of construction laborers and groundkeepers was smaller in Cawley and Homce's study (2008, p. 964) on occupational electrical fatalities in the US.

Taylor et al. (2002, p. 306) remind that the exposure to electrical hazards has increased among the people who work more often near electrical sources. However, in Finland fewer occupational electrical accidents of electrical professionals are reported both to Tukes and the Federation of Accident Insurance Institutions than occupational electrical accidents of laymen (Hintikka 2007, p. 31).

As mentioned earlier a hazard can also be a risk source (SFS-OPAS 73 2011, p. 12). Tulonen (2010, p. 63) listed the biggest electrical safety risks among electrical professionals in her study where the respondents had to choose five biggest electrical safety risks. The most often mentioned was hurry followed by working alone and attitudes towards safety. The following ones were working conditions and getting accustomed to the risks. Hurry tends to make people careless and they forget safety procedures in hurry situations. (Tulonen 2010, pp. 62–64.) Also in Iceland, carelessness was the biggest risk among electrical professionals. The second biggest risk was ignorance followed by bad or poor finish, usage, handling and hastiness. (Scope of electrical accidents 2005, p. 6.)

3.7.2. Emerging risks

The International Risk Governance Council (IRGC) defines an emerging risk as a new or a familiar risk that appears in new or unfamiliar conditions (The Emergence of Risks 2010, p. 9). On the other hand the European Food Safety Authority sees an emerging risk as a risk resulting from a newly identified hazard or from an unexpected or an increased exposure to a known hazard (Definition and description 2007, p. 1). Aven (2011, p. 916) completes the definition of an emerging risk based on IRGC's documents. According to Aven (2011, p. 916) the term should be defined as a new risk event/hazard/threat or a familiar risk event/hazard/threat in new or unfamiliar conditions. Emerging risks might be considered threats because the frequency and losses, benefits and costs they cause are unknown (The Emergence of Risks 2010, p. 9). Kleter and Marvin (2009, p. 1024) point out that hazards that have previously existed and that have been discovered again recently can be defined as emerging hazards at least in food safety.

Emerging risks might be seen as significant but they are not totally understood (The Emergence of Risks 2010, p. 9). Europeans are aging all the time but the European Commission does not know what kinds of new risks that can bring on (Improving quality and 2007, p. 10). In addition to ageing of the workforce, globalization, subcontracting and changes in demands of working life might cause emerging risks. (New trends in 2002, pp. 31–32). In addition the European Commission is interested in emerging risks technology poses (Improving quality and 2007, p. 6).

4. RESEARCH METHOD AND MATERIAL

4.1. Timetable

The study was started on 1st September 2012. Figure 3 presents the timetable of the study.

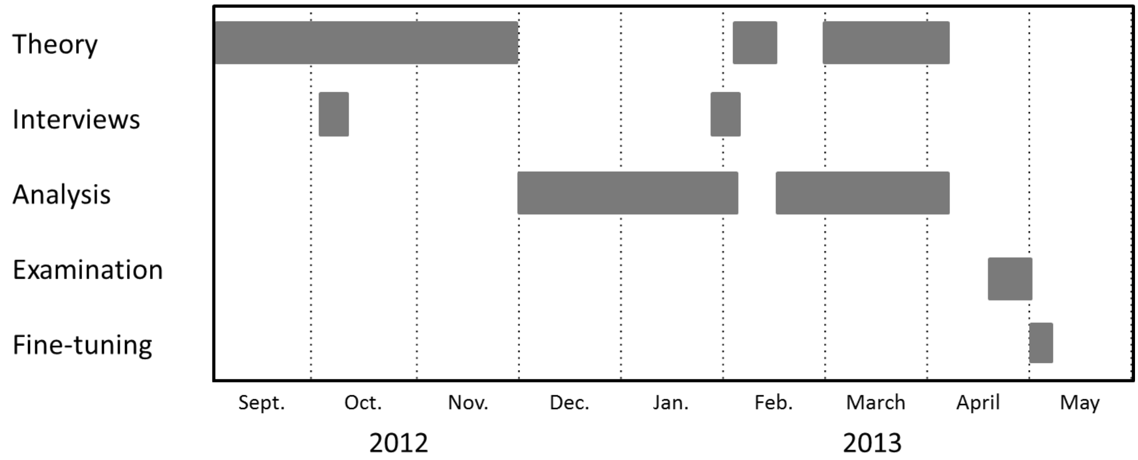

Figure 3. *Timetable of the study.*

The interviews and the electrical accident analysis are presented in more detail in the following subchapters. The representatives of the Nordic electrical safety authorities except the representative from Åland peer-reviewed the thesis before the publication. They made sure that issues related to their countries were correct and that the thesis did not include anything confidential. There were some changes mainly related to the theory that were done during the fine-tuning of the thesis.

4.2. Interviews with Nordic electrical safety authorities

NSS Analysgruppen is one of NSS's subgroups. The group focuses on statistics related to electrical safety issues. They discuss electrical accidents and electrical fires. NSS Analysgruppen consists of representatives of electrical safety authorities from Sweden, Denmark, Finland, Norway, Iceland and Greenland. The members are responsible for different tasks in their native countries for example the compilation of statistics on electrical accidents.

4.2.1. First interviews

To use semi-structured interviews in the first interviews was an easy methodological choice. The freedom the semi-structured interviews offer and on the other hand the themes guiding the conversation were an optimal combination for this study.

Interview themes

The interview crystallized in two themes: electrical accident data collection and electrical safety. The interviews started with background questions and the theme questions followed them. It is essential to know how the electrical accident data utilized in this study is collected in the Nordic Countries and how the data acquisition differs. After the questions related to electrical data collection the interview focused on electrical safety. The representatives were asked about electrical safety risks of today and future and how electrical safety could be improved. Those questions were asked to be able to achieve the objectives of the study.

The idea of the interviews was to capture the images and the expertise of the representatives of the electrical safety authorities, not exact numerical data. For example, the qualitative answers of electrical safety risks are more interesting and more useful than the statistical answers. The interview themes with all the questions are presented in Appendix 2.

Interviews of the representatives from Sweden, Denmark, Norway, Iceland and Greenland

The interviews of the representatives from Sweden, Denmark, Norway, Iceland and Greenland were held in Tampere, Finland, on 9th and 10th October 2012 after NSS Analysgruppen's meeting. The interviewees were members of NSS Analysgruppen. In total six persons were interviewed in five separate interviews. The interviews were organized beforehand. It was easier to gather information by interviewing face-to-face. By having the face-to-face interviews the interviewees and the interviewer could get to know each other better which would help for example in the possible clarification and supplementing later. In addition visual material is easier to be shown during face-to-face interviews. For example the interviewee showing some web pages with the projector or the interviewer drawing something on the board means visual material in this context.

The two themes and one question about underreporting and its reasons were given to the interviewees beforehand. By telling the themes beforehand the interviewees could prepare in advance, for example by searching for documentation (Saunders et al. 2009, p. 328) which was the idea also in these interview. And by telling the themes the interviewees knew how they can prepare better.

A secretary attended in the interviews because they were not audio-recorded. According to Saunders et al. (2009, p. 339 & 341) audio-recording helps the interviewer to listen actively and to concentrate on questioning and on the non-verbal expressions of the interviewee. By audio-recording direct quotes can be used but transcribing requires a lot of time to complete. Audio-recording can also affect the willingness of the interviewees to answer. (Saunders et al. 2009, p. 341.) The interview situation was wanted to keep relaxed and informal which was one reason not to audio-record. The interview situation might be a little unpleasant for the interviewees because of the used language. The interviews were not held in the native languages of the interviewees but mainly in English. The interviewer made notes during the interview. The notes were mainly used for as a basis for the ongoing interview. The notes were written up during the same week. The secretary, who made it possible to the interviewer to fully concentrate on the interviewee, made her notes on paper and wrote them up within a week. The same secretary participated in all the interviews expect the whole interview of the Icelandic representative because of the change of the secretary. The representative was told beforehand about the change of the secretary. The change fell between two themes so if it disturbed the interview it disturbed only a little.

The interviews lasted approximately two hours except one that lasted a little over one hour. The interviews were aimed to keep dialogical situations and there was hoped-for visualization. The interviewees used the projector and the interviewer was given links both on paper and via e-mail. The visual material clarified things and from time to time it guided the conversation.

The interview themes functioned well and the questions outside it were fully allowed. The question on emerging risks was a bit difficult for some of the interviewees even though the new term was explained.

Interview of the Finnish representatives

The interview of the Finnish representatives was held on 19th November 2012. One Finnish member of NSS Analysgruppen and one member of the other group were interviewed. The interviewed Finnish member of NSS Analysgruppen was responsible for the day-to-day guidance of this thesis and the member commented on all the questions before the interview themes were formed.

The background questions were not considered necessary and they were skipped. Same questions as in the interviews of the representatives of the other NSS Analysgruppen member countries were send beforehand. The interview was in Finnish and it took about two hours. The secretary was taking notes almost all the time.

The Faroe Islands

It was not possible to organize a face-to-face interview with a representative from the Faroe Islands. The representative does not participate in the actions of NSS Analysgruppen. The interview was sent by e-mail to the representative on 13th November 2012 and it was answered on 21st November 2012.

Åland

The interviewee from Åland does not participate in NSS at the moment. The interview was organized as an email interview and it was answered on 7th May 2013.

4.2.2. Supplementary interviews

The supplementary interviews were held at DSB headquarters in Tønsberg, Norway, on 30th-31st January 2013 during NSS Analysgruppen meeting. The interviews were unstructured and they focused on issues arisen from the accident analysis. Representatives from Sweden, Denmark, Norway, Iceland and Greenland were interviewed. Clarifications were asked from the Finnish representative as they came up during the winter. The Faroese representative was contacted via email.

4.3. Accident analysis material

Electrical accident material means the data the Nordic electrical safety authorities gave for this study. The material has been collected for the use of the authorities. Saunders et al. (2009, p. 256) regards secondary data as data that has been collected earlier for some other reason. The given material is thus secondary data. Secondary data is permanent and others can check it which makes analyses with secondary data more open to public conversation (Denscombe 2007, see Saunders et al. 2009, p. 269). When using secondary data it needs to be also ensured that the data is comparable: that it has been collected and recorded in the same way (Saunders et al. 2009, p. 269).

The material consists of both fatal and non-fatal electrical accidents. Incidents where people do not get injured (e.g. not having an electric shock) were not included. Cawley and Homce (2003, p. 243) who studied occupational electrical accidents in the US state that using only fatal or nonfatal electrical accidents in the analysis does not reveal all the necessary prevention methods.

The electrical accident material of Sweden was written by the informer. In Denmark, Finland, Norway, Iceland and Greenland the material was written by the authority based on the received information. The Swedish information was written in Swedish, the Danish in Danish, the Finnish in Finnish and the Norwegian in Norwegian. The Icelandic and the Greenlandic accident information had been translated by the corresponding authorities into English for the purpose of this study.

4.3.1. Information request

The electrical safety authorities were asked to give information on electrical accidents that occurred during 2007-2011. They were asked to give, at least if possible, the following information on each electrical accident:

- the case ID number,
- the case title,

- the year,
- was the victim a professional or a layman,
- the outcome (dead, serious (> 30 days away) or less serious),
- the voltage (AC or DC and how much),
- was there a shock or an arc,
- the immediate cause (human error, new or old faulty technology) and
- the accident description.

The electrical safety authorities were not asked to give information concerning electrical installations, electrical products or locations.

4.3.2. Material

Denmark, Finland, Norway and Iceland gave accident information from the years 2007-2011. Sweden could only give the accident information from the year 2011 because of the ongoing changes in the database. Greenland delivered also the information from the same year. Because of these restrictions the analysis could be made only from the electrical accident information from 2011.

An electrical accident was defined in this study like NSS defines it. The total number of electrical accidents to be analyzed was 686 (Table 6).

Table 6. *Number of electrical accidents in the analysis*

Country	Sweden	Denmark	Finland	Norway	Iceland	Greenland	All
Cases	363	28	87	205	2	1	686

The sample itself is described more detailed in Chapter 4.4.2. Next we focus on how the sample was collected.

Sweden

The given material from Elsäkerhersverket consisted of 550 electrical accidents (*elolyckor* in Swedish) and 247 incidents (*tillbud* in Swedish) reported to Elsäkerhetsverket in 2011. Accidents with at least zero days' absence from work were included. The electrical incidents are out of the scope of this research so they were left out. The material included also duplicate cases and empty cases. There were six electrical accidents from the year 2010. There were some electrical accidents without descriptions that resulted most likely making the Excel file and they were also left out. Nine cases had duplicates with different ID numbers because they were reported by different authorities/persons/media or by the same authority/person at different times. The descriptions of the duplicate cases were joined and if the classifications were different, the more accurate classification from the more reliable source was chosen (e.g. an authority versus media when the authority was chosen). 11 cases were not seen as electrical accidents because

- a short circuit in a transformer caused smoke which in turn caused stinging in eyes and shortness of breath in three cases (actually three victims in one situation),
- loud noise from a crack of an extension cable in one case,
- an explosion of a diesel aggregate causing spatters of acid,
- electrical fires in two cases,
- the return of fuse in one case and
- electric shocks caused by static electricity in three cases.

The final number of electrical accidents to be analyzed was thus 363.

Denmark

32 electrical accidents were reported to Sikkerhedsstyrelsen in 2011. Those 32 cases included cases with 0 days' absence from work and cases whose outcome was unknown. Denmark defines electrical accidents as NSS. Because the definition says nothing about outcome all of the 32 cases are seen as electrical accidents (Sarup 2013). The descriptions of four electrical accidents were not finished and their qualitative information was thus too short to utilize. Those four electrical accidents were excluded from the qualitative analysis. 28 electrical accidents were used in the analysis.

Finland

According to Tukes 91 electrical accidents occurred in Finland 2011. Three of the accidents were not according to NSS's definition and they were removed. The accidents were caused by lightning. The description of one electrical accident was missing and also that accident was excluded. Totally 87 Finnish electrical accidents were analyzed.

Norway

324 electrical accidents and incidents were reported to DSB in 2011 according to the received material. DSB had written descriptions for 133 cases of which 128 were electrical accidents with injuries and five incidents. The electrical incidents were excluded from the analysis. The number of Norwegian electrical accidents with written description was thus 128. Three of the electrical accidents with descriptions were not caused by electric shock or arc. One was caused by static electricity, the second by a helicopter accident near a high voltage pole and the third by a fall from a low voltage pole. The accidents were not seen as electrical accidents in this study because of NSS's definition and they were excluded. Six cases were added to 125 electrical accidents because

- there was one accident with two registered injured (from one accident to two),
- there was one accident with three registered injured (from one accident to three),
- the description tells about two injured and the classification about one (from one accident to two) and
- the description told about three injured and the classification about one (from one accident to three).

The additions were made in order to unify the numbers with NSS’s definition. During the supplementary interview the Norwegian representatives promised to write more descriptions. 74 electrical accidents got their descriptions after the supplementary interview. Even though they were shorter than the ordinary ones they were included. Thus 205 Norwegian electrical accidents were ultimately used in the analysis.

Iceland, Greenland, the Faroe Islands and Åland

Mannvirkjastofnun knows that two electrical accidents occurred in Iceland in 2011. According to Grønlands Elmyndighed there was one electrical accident in Greenland in 2011. Mannvirkjastofnun and Grønlands Elmyndighed gave the occurred electrical accidents for the material of the study. Elnevndin did not know about any electrical accident in the Faroe Islands in 2011. Åland participated in the interviews, not on the electrical accident analysis.

4.4. Electrical accident analysis

The electrical accident analysis started by reading through the descriptions written in different languages. When reading through the descriptions notes were taken. The notes included possible keywords for the analysis. The keywords were issues that needed to be examined in more detail or they were issues that repeated in the descriptions. The chosen keywords can be grouped into five parts: general information, where and when, causes, preventing measures and natural phenomenon.

General information was divided into types of accidents, consequences and professionalism. In addition the occupations of those accidents where a layman got injured at work were looked for. When the occupations are known it can be said more precisely who reports electrical accidents or to whom accidents happen.

Where and when included different issues related to locations and accident situations. Accidents needed to be classified into occupational and leisure time electrical accidents for example because occupational legislation concerns only occupational accidents. The locations of the accidents were examined in two ways: whether the accident occurred indoors or outdoors and what the exact location of the accident was. The exact location of the accident could tell where accidents happen or at least what kinds of locations report them. The accident situation means what the injured was doing when the electrical accident occurred.

Electrical installations and electrical products involving in electrical accidents were separated from each other. The separation was made because the authorities use the same division.

Some cause categories were made before the analysis was started. Not measuring voltage was seen as a possible cause from the beginning. Measuring voltage was divided into not measuring voltage and into trust that there is no voltage. In Tulonen's

(2010, p. 57) research human failures are the most common reasons not to test voltage. Trusting as an element of human failure can be seen as:

- trusting that there is no voltage in the system,
- trusting in isolation,
- trusting in the person who de-energized,
- trusting in one's own skills,
- trusting in markings and documentations,
- trusting in visual observation and
- trusting that this system is dead because the adjacent was (Tulonen 2010, p. 57).

The cause categories were developed during the analysis. The final cause categories were:

- action of the worker,
  - hurry, stress, carelessness, oversight or being in a rut
  - not obeying instructions
- problems in electrical work,
  - defective protection or isolation
  - inadequate equipment
  - inadequate grounding
  - live
  - live working instead of dead working
  - not de-energized
  - not measuring voltage
  - not using PPE
  - problems in voltage measurement
  - trust that there is no voltage
  - unconnected, cut or unprotected cables
  - unexpected live parts
  - the electrical installation or a product was live instead of the expectations
- problems connected to installations, products and design,
  - damaged electrical installation or product (during time)
  - defect in an electrical product (could not be said if damaged or faulty)
  - defect in the electrical installation (could not be said if damaged or faulty)
  - design error
  - earth fault
  - faulty electrical installation or product (from new e.g. a factory defect)
  - loosening from the wall or the ceiling
  - mounting fault or a fault in installation
  - short circuit
- documentation, management and communication and

  - danger of the interfering
  - defective planning or risk management
  - inadequate notes or documentations
  - not told to anyone
  - poor communication
  - problems in orientation
  - the assignments had not been gone through before the starting
  - unclear responsibility issues
- work environment
  - cramped space
  - other people or animals involved
  - water etc.

Preventive measures included the preventive measures and corrective actions mentioned in the descriptions. The last issue, the natural phenomenon, was chosen to be studied because storm was mentioned in some cases. In addition, the Finnish Safety Investigation Authority made a report of the serious storms in Finland in July and August 2010 (Heinä-elokuun 2010 rajuilmat 2010). The unusual situation and the clearance of trees from the electric lines have influenced the number of electrical accidents and other accidents happened to people repairing and building the electrical network (Heinä-elokuun 2010 rajuilmat 2010, p. 31).

4.4.1. Classification

The original plan was to use the descriptions of the electrical accidents as the source of information in the analysis. It did not succeed all the time as Kowalski-Trakofler and Barrett state (2007, p. 600) "the quality of the information varies widely, from highly detailed to sketchy". When the description did not include the information it was looked for in the classifications of the accidents. If there were discrepancies between the description and the classification the information from the description was used.

Electric shock and arc
The information if an electric shock or an arc caused the injury was gathered mainly from the descriptions. If there was no mention it was searched for in the classification. Electric shocks and arcs with after-events, meaning for example falling after the electrical accident, were marked as electric shocks or as arcs in the description but the information on after-events could be found in the classification.

Professionalism
The qualification to perform electrical work was defined according to the legislation of each country. When it was possible the qualification was taken from the descriptions. Almost all the Norwegian qualifications were taken from the descriptions, as part of the Finnish qualifications and the Greenlandic qualification. Almost all the Danish and

Swedish qualifications were taken from the classifications or at least they were checked from there. The Icelandic qualifications came from the classifications.

The Swedish cases did not include the class "instructed person". The occupations of the instructed persons in Denmark, Finland and Norway were *elektrikerlærling, elektro-hjelpearbeider / lærling, elektroinstruert person, energimontørlærling, instruert person, kuldemontørlærling, lærling, opiskelija, sähköasentajaopiskelija* and *tehtävään opastettu henkilö*. The total number of instructed persons was 58 of which 53 were from Norway, three from Finland and two from Denmark. The number was joined to laymen and thus in this study the class *laymen* consists of both laymen and instructed persons.

Occupational or leisure time electrical accident

The information was mainly from the descriptions. The classifications were used in the shortest Swedish cases and in a few of the Finnish and Norwegian cases. Occupational electrical accidents include electrical accidents that have not occurred during leisure time. Those accidents include, of course, electrical accidents happened at work but also accidents that have occurred to pupils and students at schools and conscripts at the military. Pupils and students have been included into occupational electrical accidents because they have not been at home or on their own time.

Consequences

The consequences were taken from the classifications of the accidents from Sweden, Denmark, Finland and Iceland. The consequence of the Greenlandic electrical accident was mentioned in the description. Both the classifications and the descriptions were used in the Norwegian accidents. The descriptions were used if there was conflict between the classification and the description.

The combining of the information from six countries demanded some choices. Firstly, Finland reported the consequences the most imprecisely using the following classes: a medical examination or no medical examination without days' absence from work; a medical examination with 1-30 days' absence from work; over 30 days' absence from work and death. The same classes were therefore used for the rest of the countries. For Sweden, Iceland and Greenland, using the same classification was simple because the consequences were reported without using any classes. The Danish electrical accidents included the classification that consisted of 0 days' absence from work, 1-3 days' absence from work, 4-14 days' absence from work and 2-5 weeks' absence from work. The 2-5 weeks' absence from work was combined with the Finnish classification over 30 days' absence from work. The Norwegian material presented the consequences in two ways: with numbers and in writing like minor injury (*lett skade* in Norwegian). If the description mentioned that the only consequence was a medical examination the consequence was seen like the Finnish a medical examination or no medical examination without days' absence from work. 73 Norwegian minor accidents were classified as a medical examination with 1-30 days' absence from work according to the classification because the description did not include that information. However, when observing the descriptions with exact days' absence from work the minor accidents could be either *a medical examination or no medical examination without any days absence from work* or *a medical examination with 1-30 days' absence from work*.

Location

At first it was classified if the electrical accident happened indoors or outdoors. Information on the Swedish cases was from the classification because there was such a category. Indoors/outdoors was concluded in the descriptions for the cases from the other countries.

The information on the exact location was mainly from the descriptions in the cases of Finland and Norway and totally of Iceland and Greenland. The Danish descriptions were improved during the supplementary interview because the accident location was not included in the original information request. The exact location was mainly taken from the classifications in the cases of Sweden. There were two categories describing the location but none of them was categorical. They included qualitative information. If those categories were not used there would have been more unknown locations and locations like cubicles that do not describe the surrounding area. The locations were grouped.

Electrical installations and products

The source of electrical energy was divided into electrical installations and products. The Swedish division was based on the classification and the other countries' on the descriptions. Information on electrical products came from the descriptions. In the Swedish cases some missing information concerning products were looked for in the classifications.

Some of the Swedish descriptions included the exact electrical installation but most did not. The exact electrical installations of the other countries were based on the descriptions. Because there was least information in the Swedish cases all the other cases were added to the Swedish classification scheme. The classes are:

- fixed installations on final circuits including cables
    - *fast installation på gruppledning inkl. kabel* in Swedish
- switchgears and control gears (switching device, switchboards, dummy sections, cubicles) including apparatuses
    - *kopplingsutr. (ställverk, central, kabel-, apparatskåp) inkl apparater* in Swedish
- machines, lifts and other equipment for industrial use
    - *Maskiner, lyftinrättningar etc o annan utrustning (industriellt bruk)* in Swedish
- overhead power lines,
    - *luftledning* in Swedish

- ground cable,
  - *kabel i mark* in Swedish
- trains (including overhead lines or conductor rails at runway operations) and
  - *kontaktledning eller kontaktskena vid bandrift* in Swedish
- other for the cases including insufficient information (not from the Swedish classification).

Occupations of laymen

The occupations of laymen were taken from the descriptions in the cases from Norway and Denmark. The descriptions were also used for most Finnish accidents but some information needed to be improved from the classification. The Finnish classification was open and also the Swedish one. Most occupations of Swedish electrical accidents were looked for in the open classifications and some from the descriptions. The occupation of the Greenlandic injured was told in the supplementary interview.

Accident situations

In this context the accident situation means the actions the injured was doing just before the electrical accident happened. If the description did not include the information it was not searched for in the classification. Only qualitative information was used in order to create totally new information. When analyzing the accident situation information the accident situations were grouped. They were named according to a common denominator.

Causes and prevention

All the causes and all the prevention related information were taken from the descriptions. The causes were classified according to the categories described earlier. The causes of leisure time electrical accidents are presented quantitatively. Prevention measures were aggregated and grouped. They are presented qualitatively in the results.

4.4.2. Portrayal of the used material

The total number of cases, 686, was divided into professionals, laymen and instructed persons (Table 7).

Table 7. *Qualifications of the injured in the sample for the electrical accident analysis*

Country	Professional		Laymen		Instructed persons		Unknown	
	%	n	%	n	%	n	%	n
Sweden n=363	40	147	59	214	0	0	1	2
Denmark n=28	57	16	36	10	7	2	0	0
Finland n=87	41	36	55	48	3	3	0	0
Norway n=205	55	112	13	27	26	53	6	13
Iceland n=2	100	2	0	0	0	0	0	0
Greenland n=1	0	0	100	1	0	0	0	0
In total n=686	46	313	44	300	8	58	2	15

As Table 7 shows there were 15 cases without the information on the qualification of the injured. Those cases were omitted from the analysis because the analysis focused on professionals, laymen and instructed persons. Table 7 indicates that no electrical accident happened to an instructed person in Sweden. The reason to this statistical exception is the Swedish reporting system. In Norway 26% of the electrical accidents happened to instructed persons. Even though the proportion was that high in Norway laymen and instructed persons were analyzed as one because of the Swedish reporting system. Later in this study the term laymen therefore includes both laymen and instructed persons.

Table 8 presents the final sample for the electrical accident analysis. The results of this study present the analysis of 671 electrical accidents.

Table 8. *Material for the electrical accident analysis when laymen and instructed persons are combined and unknown qualifications are excluded*

Country	Professionals		Laymen	
	%	n	%	n
Sweden n=361	41	147	59	214
Denmark n=28	57	16	43	12
Finland n=87	41	36	59	51
Norway n=192	58	112	42	80
Iceland n=2	100	2	0	0
Greenland n=1	0	0	100	1
In total n=671	47	313	53	358

Professionals

All the electrical accidents that happened to professionals *(n=313)* were occupational accidents. None of the accidents happened during leisure time. Figure 4 shows the division of the electrical accidents of the electrical professionals according to country. There was none electrical accidents of electrical professionals in Greenland in 2011.

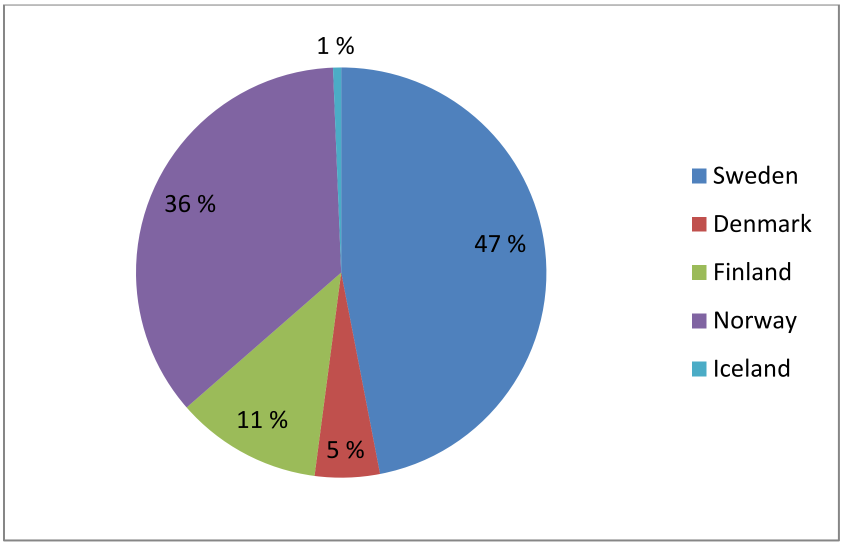

Figure 4. *Division of electrical professionals' accidents according to country, (n=313), (%)*

Laymen

The division of the electrical accidents among laymen according to country is shown in Figure 5. Iceland did not have any cases in this category in 2011.

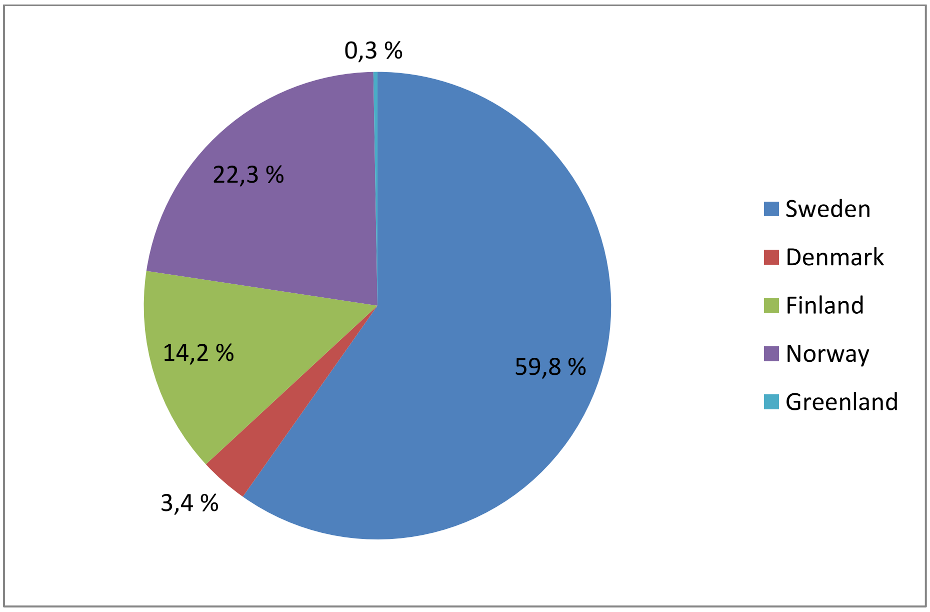

Figure 5. *Division of electrical accidents among laymen according to country, (n=358), (%)*

There were both occupational and leisure time electrical accidents of laymen. Because the material could be divided into occupational and leisure time electrical accidents the electrical accidents are presented with in two separate groups: occupational electrical accidents and leisure time electrical accidents (Table 9).

Table 9. *Distribution of laymen's occupational and leisure time electrical accidents*

Country	Occupational		Leisure time	
	%	**n**	**%**	**n**
Sweden n=214	90	193	10	21
Denmark n=12	100	12	0	0
Finland n=51	73	37	27	14
Norway n=80	93	74	8	6
Greenland n=1	100	1	0	0
In total n=358	89	317	11	41

Figure 6 presents how the occupational electrical accidents were divided between Sweden, Denmark, Finland, Norway and Greenland.

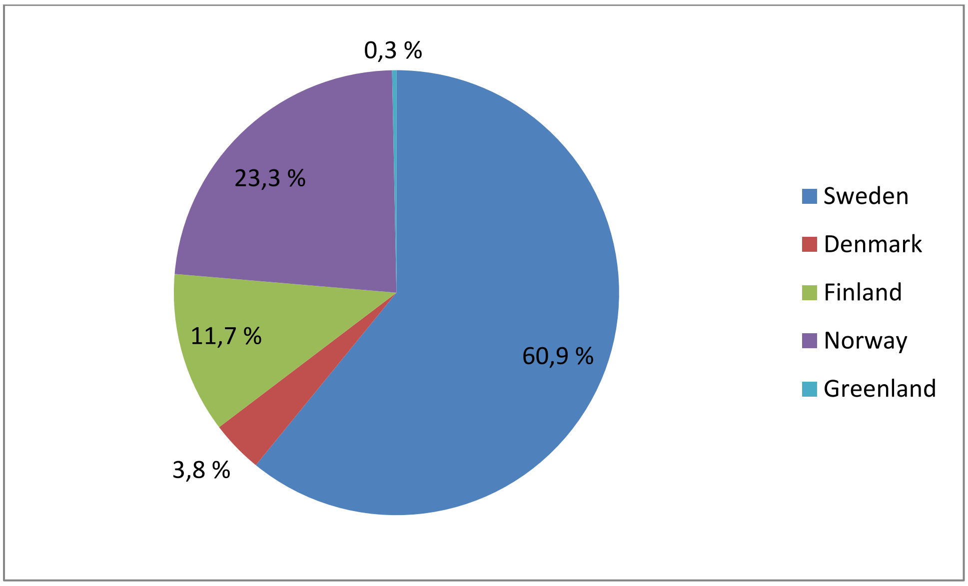

Figure 6. *Distribution of occupational electrical accidents of laymen,(n=317), (%)*

Leisure time electrical accidents were reported in Sweden, Finland and Norway. The total number of reported leisure time electrical accidents was 41 in the Nordic Countries. 51% of the leisure time electrical accidents came from Sweden, 34% from Finland and 15% from Norway.

5. ELECTRICAL ACCIDENT DATA COLLECTION

This chapter describes how electrical accident data is collected in the Nordic Countries. The results are based mainly on the interviews of the representatives of the electrical safety authorities. Electrical safety authorities do not include suicides into the electrical accident statistics. Thus the reported electrical accidents do not include suicides.

International Labour Organization (ILO) has made a short summary of the notification of occupational accidents. In Denmark and Sweden occupational accidents need to be reported both to the insurance institution and the labour inspectorate. In Sweden the insurance institution has to report accidents to the labour inspectorate. In Norway occupational accidents are reported to the labour inspectorate and in Finland to the accident compensation insurance body (meaning the Federation of Accident Insurance Institutions). (Recording and notification 2002.) Employers in Finland have to take out occupational accident insurances for their employees (L 1948/608, 8 §). Employees have to report occupational accidents to employers who report accidents to the insurance company (L 1948/608, 38 §). Insurance companies offering occupational accident insurances have to belong to the Federation of Accident Insurance Institutions (L 1948/608, 30b §). Insurance companies and State Treasury (*Valtiokonttori* in Finnish), that is responsible for compensating occupational accidents and disease that occur to employees of the state, shall report occupational accidents to the Federation of Accident Insurance Institutions (L 1948/608, 30 & 64 §).

EU members and EFTA countries co-operate in statistics (Introduction 2011). EU members and Norway started a project called the ESAW (European statistics on Accidents at work) in 1990 (European statistics on accidents at work 1999, p. 1). Occupational accidents are coded in different ways in the ESAW system. For example there is a class called *Contact — Mode of Injury* which means "the precise way in which the departure from normal practice resulted in an accident." (European Statistics on Accidents at Work 2013, p. 12). There are two options, "indirect contact with a welding arc, spark, lightning (passive)" and "direct contact with electricity, receipt of electrical charge in the body", describing electrical accidents in the classification (European Statistics on Accidents at Work 2013, p. 29). It is possible to use those two categories for collecting electrical accident information if certain corrective actions are made (Hintikka 2007, p. 32).

5.1. Sweden

The owner of the grid and the owner of the strong current installations for trains, trams, metros and trolley-busses are obligated to inform without delay electrical accidents happened at strong current installations to Elsäkerhetsverket (Starkströmsförordning 2009:22, 8 §). Certain occupational accidents need to be reported to the Swedish Work Environment Authority (*Arbetsmiljöverket* in Swedish) by the employer (Arbetsmiljöförordning 1977:1166, 2 §). Only the most serious accidents are reported to the Swedish Work Environment Authority. This results from the occupational accident insurance system. Elsäkerhetsverket receives a lot of information on the occupational electrical accidents from the Swedish Work Environment Authority.

The police know about all the fatal electrical accidents. The fire and rescue services have at least statistics on electrical fires. Elsäkerhetsverket does not have to report electrical accidents to Statistics Sweden. But there are some statistics on occupational accidents. Hospitals or labour unions do not have electrical accident information. Insurance companies may have databases for their internal use.

An electrical accident is seen as an unwanted event caused by electricity that ends in injury or death (ELSÄK-FS 2012:1, 3 §). An electrical accident can result from either an electric shock or an arc. Always when electricity passes through the body or causes a burn injury it is an electrical accident. In most of tables of Elsäkerhetsverket's electrical accident statistics only events with more than one days' absence from work are included.

Electrical accidents have to reported electronically (ELSÄK-FS 2012:1, 3 §) but there is also a paper form available on Elsäkerhetsverket webpages for the use of employers (Anmälan av elolycka 2012). The report needs to include the contact information on the owner of the grid, the accident place, a short description of the event and the eventual injuries (ELSÄK-FS 2012:1, 5 §). The electrical accident needs to be reported on the following working day after the accident (ELSÄK-FS 2012:1, 4 §). Usually the reports are filled too soon after the accident why it is impossible to know the actual number of days' absence from work. Elsäkerhetsverket needs only the information if there is none or more than one days' absence from work.

The electronic form is the most often used way to report electrical accidents. Sometimes the information comes from media, mainly in the cases of deaths. Elsäkerhetsverket has media surveillance (Sundvall 2012, p. 8). Electrical accidents can also be reported via telephone (Sundvall 2012, p. 8). Laymen can also report electrical accidents.

5.2. Denmark

The Danish law obligates the operator of power supply installations for production, transmission and distribution of electricity to report immediately all the accidents with electrical characteristics occurred in electrical installations to Sikkerhedstyrelsen. Like injuries also explosions and fires in electrical installations need to be reported. (Bekendtgørelse om administration 177:1995, 3 §.) In addition to that employers in Denmark are obligated to report within nine days occupational accidents that cause one or more days' absence from work in addition to the day when the accident occurred to the Danish Working Environment Authority (*Arbejdstilsynet* in Danish) (Bekendtgørelse om anmeldelse 2010, 1 §). The notice must be done electronically to the Danish Working Environment Authority via the Danish Working Environment Authority's and the National Board of Industrial Injuries (*Arbedjsskadestyrelsen* in Danish) reporting system called EASY (Bekendtgørelse om anmeldelse 2010, 2 §). The Danish Working environment authority reports electrical accidents via telephone continuously to Sikkerhedstyrelsen.

Sikkerhedstyrelsen has media follow-up concerning for example serious leisure time electrical accidents. Insurance companies might know more about electrical accidents. It is difficult for the insurance companies to co-operate because of The Act on Processing of Personal Data. Earlier hospitals gave information on electrical accidents to Sikkerhedsstyrelsen but not anymore. Statistics Denmark does not collect electrical accident data. The police investigate some electrical accidents but it does not share information on them. The fire and rescue services do not know anything about electrical accidents. Insurance companies may also collect information on electrical accidents. Labour unions tell sometimes about occurred electrical accidents to Sikkerhedsstyrelsen.

Denmark defines an electrical accident in the same way as NSS. Although only occupational accidents with more than one days' absence are reported to the Danish Working Environment Authority Sikkerhedsstyrelsen consider all the electrical accidents electrical accidents not depending on the number of days' absence from work.

The electrical accident notification has to include all the information that helps finding causes of the accident. The notification can be in electronic form. In addition to that Sikkerhedsstyrelsen can ask network companies to help clarify the circumstances of electrical accidents happened in their area. (Bekendtgørelse om administration 177:1995, 3 §.)

5.3. Finland

In Finland the owner of the grid, the police, fire and rescue services and the occupational safety and health authority have to report an electrical damage, that has caused a serious accident, to Tukes (L 1996/410, 52a §). The electrical accident is regarded serious if

- it causes death or serious injuries,
- it causes other than minor environmental damages or property damagse or

– it causes obvious danger to people, property or environment. (A 1996/498, 20 §.)

The employer has to report deaths and occupational accidents with severe injuries to the occupational safety and health authority and to the police (L 2006/44, 39 & 46 §).

The Federation of Accident Insurance Institutions is obligated to publish occupational accident and disease statistics (L1948/608, 64 §). Thus the Federation of Accident Insurance Institutions is one of the authorities or organizations collecting electrical accident data in Finland. The descriptions of the electrical accidents that are informed to Tukes are longer and more informative than those of the Federation of Accident Insurance Institutions (Hintikka 2007, p. 31). When drawing conclusions of qualitative information it is worth using Tukes' information (Hintikka 2007, p. 31). Single insurance companies do not share electrical accident information. In addition to that the occupational safety and health authority publishes inspections reports of occupational accidents including also occupational electrical accidents on the web. These include only a few electrical accidents Tukes does not know about.

The police do not share electrical accident information. Tukes has an access to the Statistics system of Finnish fire and rescue services. It is not possible to use that system searching for electrical accident information because information concerning the health situation is not registered. The fire and rescue services do not publish electrical accident information. Statistics Finland has statistical information also on electrical accidents. Hospitals do not give information concerning electrical accidents. Labour unions do not have their registers for electrical accidents.

The representatives estimated that the occupational safety and health authority and owner of the grid report 10-20 accidents annually. The police report a few and the fire and rescue services reports very rarely. Besides these others report electrical accidents e.g. because of their quality system, occupational or public health and safety reasons. Some companies report electrical accidents to Tukes because reporting electrical accidents is a part of their organizational culture. All the electrical accident reports are looked over at Tukes.

The definition of the electrical accidents of the Finnish representatives follows NSS’s definition. The representatives see both electric shocks and arcs as electrical accidents. The number of days' absence from work does not matter because even minor electrical accidents can cause long-term consequences. The representatives talked in the interview whether a situation where a pylon is struck by lightning and the current travels along electric lines to a person working near the lines is an electric accident or not. Those kinds of situations are not defined as electrical accidents according to the Finnish representatives.

Electrical accidents are usually reported by using a form called Electrical Accident Notification (*Sähkötapaturmailmoitus* in Finnish). Using the form confirms that Tukes gets the basic information concerning electrical accidents or incidents. There is no legislation concerning what the report should be like. In addition to the form the accident can be reported by telephone. Tukes has also media surveillance.

5.4. Norway

The Norwegian legislation sees electrical accidents as direct injuries or damages caused by electricity (FOR 1993-12-14 nr 1133, 3 §). The duty to report electrical accidents to DSB is mentioned in six Norwegian laws. Four laws concern electrical installations:

- *Forskrift om sikkerhet ved arbeid i og drift av elektriske anlegg* (FOR 2006-04-28 nr 458, 8 §)
  - saying that injuries and property damages caused by electricity or occurred when working on or operating electrical installations have to be reported to DSB as soon as possible,
- *Forskrift om elektriske lavspenningsanlegg* (FOR 1998-11-06 nr 1060, 15 §)
  - saying that injuries and property damages caused by electricity in low voltage electrical installations have to be reported as soon as possible to DSB,
- *Forskrift om elektriske forsyningsanlegg* (FOR 2005-12-20 nr 1626, 3-4 §)
  - saying that the owner or the operator of the electrical installation has to report to DSB without delay injuries and major property damages caused indirectly or directly by the power supply installations and
- *Forskrift om maritime elektriske anlegg* (FOR 2001-12-04 nr 1450, 9 §)
  - saying that injuries and property damages caused by electricity on board need to be reported to DSB as soon as possible.

The laws concerning electrical products say the following about accident reporting:

- *Forskrift om elektrisk utstyr* (FOR 2011-01-14 nr 36, 5 §)
  - saying that serious occurrences with electrical products have to be reported to DSB and
- *Forskrift om medisinsk utstyr* (FOR 2005-12-15 nr 1690, 2-11 §)
  - saying that the manufacturer or the vendor of medical equipment has to report without delay to DSB malfunctions, any deterioration in the characteristics and/or performance and any lack of labeling or instructions that may lead to or may have led to the death of the patient, the user or other person or serious deterioration of their health conditions.

DSB knows more electrical accidents than any other authority or organization in Norway. The Norwegian Labour Inspection Authority (*Arbeidstilsynet* in Norway) knows only about occupational electrical accidents not about leisure time electrical accidents. Insurance companies concentrate more on electrical fires than on electrical accidents which is the reason why they do not collect electrical accident data. Statistics

Norway collects information on different kinds of accidents. Hospitals may collect information on electrical accidents for their own purposes. The fire and rescue services do not collect electrical accident information in Norway nor the police. The police investigate fatal and serious electrical accidents. Labour unions do not compile statistics on electrical accidents.

Norway defines electrical accidents like NSS. It does not matter how minor the accident is. The only way to report electrical accidents to DSB is via filling in an electrical form on the DSB web pages. Anyone can report electrical accidents. Most of the data comes from electricity distributors. If something happens to a layman the layman usually informs the distributor first and the distributor reports the electrical accident to DSB.

5.5. Iceland

In Iceland, responsible parties who own, control or have been nominated to be responsible for construction or operation of electrical installations are obligated to report accidents and damages caused by their electrical installations and products to Mannvirkjastofnun without delay (Reglugerđ um raforkuvirki nr. 678/2009, 1 & 2.9 §).

Mannvirkjastofnun has access to the public version of accident database of the Administration of Occupational Safety and Health (*Vinnueftirlitið* in Icelandic) and in addition it reports some electrical accidents to Mannvirkastofnun. Statistics Iceland does not collect or publish electrical accident information. Mannvirkjastofnun does not receive information from insurance companies. The insurance companies and Mannvirkjastofnun probably have the same information on serious accidents. Electrical accident information has not been asked for from hospitals. The police give accident information to Mannvirkjastofnun. Mannvirkjastofnun does not receive electrical accident information from the fire and rescue services. Labour unions do not collect electrical accident information.

Iceland defines an electrical accident almost like NSS. The Icelandic definition sees events as electrical accidents only when there is one or more days' absence from work. The majority of reported electrical accidents occur in distribution companies and industry companies. Therefore most of electrical accident data comes from these companies. Electrical accidents are reported by filling out a form.

5.6. Greenland

In Greenland all the electrical laws are the same as in Denmark. Thus the operator of power supply installations has to report immediately all the electrical accidents to Grønlands Elmyndighed. When Grønlands Elmyndighed gets the information that an accident has happened it sends a form to the firm. In addition to that the Greenlandic occupational health and safety authority (*Center for Arbejdsskader* in Danish) gives information on electrical accidents to Grønlands Elmyndighed once a year. Occupational accidents need to be reported to the Greenlandic occupational health and safety authority. Fatal accidents would be heard of from the newspaper or the police.

The Greenlandic representative defines an electrical accident like NSS. The definition includes both professionals and laymen. The other authorities or organizations do not collect electrical accident data in Greenland. The police are an exception as it knows about fatal electrical accidents that have occurred at home.

5.7. The Faroe Islands

The legislation in the Faroe Islands is almost the same as in Denmark. Elnevndin defines an electrical accident like it is defined in Denmark.

Elnevndin does not collect electrical accident information. They are planning to collect electrical accident information in the future. The electrical accident information Elnevndin gets is provided by the police. When the police give electrical accident information to Elnevndin it needs Elnevndin's help. In addition to police the occupational health and safety authority knows about occupational electrical accidents. It is unsure if the other authorities or organizations are collecting electrical accident information in the Faroe Islands.

5.8. Åland

The legislation related to electrical safety in Åland follows the Finnish legislation. An event is defined as an electrical accident when a check-up at a hospital is needed in Åland.

The electrical accident information comes mainly from local distribution companies and sometimes from other Nordic electrical safety authorities and from media. The occupational safety and health authority, Åland Statistics and the fire and rescue services collect information on electrical accidents. The police and insurance companies collect information depending on accidents. Hospitals and labour unions do not collect electrical accident information in Åland.

6. ELECTRICAL ACCIDENTS IN THE NORDIC COUNTRIES

This chapter presents the results of the electrical accident analysis. Electrical accidents from Sweden, Denmark, Finland, Norway, Iceland and Greenland from the year 2011 were analyzed. There was no electrical accident in the Faroe Islands in 2011. The results are divided into occupational electrical accidents of professionals, occupational electrical accidents of laymen and leisure time electrical accidents.

Most electrical accidents were reported to Elsäkerhetsverket in 2011. Second most electrical accidents were reported to DSB. Tukes got the third biggest number of reported electrical accidents. When proportioning the reported number of electrical accidents to the population of each country 6.42 electrical accidents per 100 000 people were reported to DSB which is more than in Sweden, Denmark, Finland, Iceland or Greenland (Table 10).

Table 10. *Reported number of electrical accidents to electrical safety authorities in 2011 per 100 000 persons*

Sweden [a]	**Denmark** [b]	**Finland** [a]	**Norway** [a]	**Iceland** [b]	**Greenland** [b]
4.62	0.57	1.68	6.42	0.63	1.76

[a] information from Table 4; [b] information from the accident analysis material

Seven people died of electricity in the Nordic Countries in 2011. There were 20 electrical accidents with more than 30 days' absence from work in 2011.

6.1. Professionals

Occupational electrical accidents of electrical professionals were reported to the electrical safety authorities in Sweden, Denmark, Finland, Norway and Iceland in 2011. None occupational electrical accident of electrical professionals was reported in Greenland. The total number of accidents for the analysis was 313.

6.1.1. Consequences

Four electrical professionals died from electrocution at work in the Nordic Countries in 2011 (Table 11). 11 electrical accidents were very serious causing more than 30 days' absence from work. The majority of electrical accidents (86%) caused either 1-30 days' absence from work or a medical examination and no days' absence from work.

Table 11. *Consequences of electrical accidents of electrical professionals in days' absence from work*

Country	0 days or a medical examination		1-30 days		Over 30 days		Death		Unknown	
	%	n	%	n	%	n	%	n	%	n
Sweden n=147	63	93	33	49	2	3	1	2	0	0
Denmark n=16	13	2	50	8	6	1	6	1	25	4
Finland n=36	31	11	56	20	11	4	0	0	3	1
Norway n=112	19	21	57	64	3	3	1	1	21	23
Iceland n=2	50	1	50	1	0	0	0	0	0	0
In total n=313	41	128	45	142	4	11	1	4	9	28

Two of the four electrical professionals died in Sweden, one in Norway and one in Denmark. In Sweden, one was working at a 24 kV transformer outdoors and the other at a 33 kV installation in industry. The professional in Norway was also working in industry but at a 22 kV high voltage installation. The electrical professional who died in Denmark was doing electrical work with streetlamps outdoors when the fatal electrical accident occurred.

As presented in Table 11 four of the most serious non-fatal accidents occurred in Finland. It is one more than in Sweden and Norway and quadruple compared to Denmark. On average the non-fatal electrical accidents were more serious in Finland in 2011; 11% of electrical accidents caused more than 30 days’ absence from work in Finland compared to the Nordic average (4%).

6.1.2. Types of accidents

Most of the Nordic electrical accidents of professionals were due to electric shocks (Table 12). The proportion was the highest in Norway (84%). Iceland has the lowest rate of the electric shocks (50%) meaning one electrical accident. Three quarters of electrical accidents were electric shocks both in Sweden and in Finland. The proportion was a little smaller in Denmark.

On average every fifth electrical accident was due to arcs. There are less arc accidents in Norway (12%) than in the other Nordic Countries expect in Iceland where one of the two electrical accidents occurred due to arcing.

***Table 12**. Types of accidents of electrical professionals, (%)*

Country	Electric shock	Arc
Sweden (n=147)	74	26
Denmark (n=16)	69	31
Finland (n=36)	75	25
Norway (n=112)	88	12
Iceland (n=2)	50	50
In total (n=313)	79	21

The total number of electric shock accidents among professionals was in the Nordic Countries 247 of which 13 were classified as an electric shock with after-events. The after-event was a fall in seven cases and unknown in six cases. Six cases of the 66 arc accidents were classified as an arc with after-events but the after-events were not described in more detail.

All the electrical fatalities of the electrical professionals resulted from an electric shocks (Table 13). Seven of the 11 electrical accidents causing more than 30 days of absence resulted from arcing and four from an electric shocks.

***Table 13.** Consequences divided into electric shock and arc accidents of electrical professionals, (n=313)*

	Electric shock						Arc					
Country	**0 days or check-up**	**1-30 days**	**Over 30 days**	**Dead**	**Unknown**	**In total**	**0 days or check-up**	**1-30 days**	**Over 30 days**	**Dead**	**Unknown**	**In total**
Sweden	75	32	0	2	0	109	18	17	3	0	0	38
Denmark	2	5	0	1	3	11	0	3	1	0	1	5
Finland	11	14	1	0	1	27	0	6	3	0	0	9
Norway	20	55	3	1	20	99	1	9	0	0	3	13
Iceland	0	1	0	0	0	1	1	0	0	0	0	1
In total	108	107	4	4	24	247	20	35	7	0	4	66

When comparing electric shock and arc accidents causing 1-30 and more than 30 days' absence from work it can be noticed that arc accidents are more serious than electric shock accidents. 11% of arc accidents caused more than 30 days' absence from work when the number is 2% with the electric shock accidents. In addition to that 53% of arc accidents caused 1-30 days' absence from work and shock accidents 10 percentage points fewer.

6.1.3. Electrical installations and electrical products

Electrical installations were involved in most of the electrical accidents of electrical professionals (Table 14). Electrical installations caused 92% of electrical accidents of electrical professionals in the Nordic Countries. The proportion of electrical products varied from Sweden's 10% to 0% in Denmark and Iceland.

Table 14. *Electrical accidents of electrical professionals involving electrical installations and products in the Nordic Countries, (%)*

Country	Electrical installations	Electrical product
Sweden (n=147)	90	10
Denmark (n=16)	100	0
Finland (n=36)	92	8
Norway (n=112)	94	6
Iceland (n=2)	100	0
In total (n=313)	92	8

Electrical installations

More than one third of electrical accidents involving electrical installations resulted from fixed installations and almost one third from switchgears and control gears in the Nordic Countries (Table 15). 14% of electrical accidents were due to machines, lifts and other installations for industrial use. Ground cables were involved in 5% of the accidents and overhead power lines in 5%. The proportion of trains was 1%. In 9% of the cases the electrical installation that was involved was not mentioned precisely.

Table 15. *Electrical installations involving in electrical accidents of electrical professionals, (%)*

Installations	All n=289	Sweden n=133	Denmark n=16	Finland n=33	Norway n=105	Iceland n=2
Fixed installations	35	30	31	30	45	0
Switchgears and control gears	31	39	31	33	19	100
Machines, lifts and other installations for industrial uses	14	16	6	15	13	0
Ground cables	5	4	31	9	2	0
Overhead power lines	5	2	0	12	6	0
Trains	1	2	0	0	0	0
Unclassified *	9	7	0	0	15	0

* electrical installations that could not be classified based on the electrical accident material

In Norway, the proportion of accidents involving fixed installations was higher than in the other countries and the proportion of switchgears and control gears was the lowest. It needs to be noticed that the distribution of unclassified electrical installations was the highest in Norway. There was no electrical accident involving overhead power lines in Denmark and the proportion was the highest (12%) in Finland. About one third of the Danish accidents happened due to ground cables when the distribution was 4, 9, 2 and 0% in the other countries.

All the four electrical professionals died because of electrical installations. Two professionals in Sweden and one in Norway died because of switchgears and control gears. In Denmark the reason was ground cables. Switchgears and control gears caused eight of 11 electrical accidents with more than 30 days' absence from work. The electrical installation could not be classified in two serious non-fatal electrical accidents. Trains caused one serious non-fatal electrical accident.

Electrical products
Electrical products were involved in 24 electrical accidents. Lamps were involved in six accidents. Four accidents involved a measuring device or a product used in measuring and three accidents included domestic appliances (a stove, a microwave and a hood). Two IT products were not mentioned more precisely and two power tools included a welding machine and an angle grinder. Miscellaneous electrical products, including five unknown electrical products, a kind of sauna stove and electrical louvers, were involved in seven electrical accidents.

6.1.4. Location

The majority (78%) of the electrical accidents of electrical professionals occurred indoors in the Nordic Countries (Table 16). The proportion of electrical accidents that occurred outdoors was almost the same in Sweden (22%) and Finland (25%). Over half of the Danish accidents occurred outdoors which was more than in any other country. The smallest proportion (13%) of electrical accidents that happened outdoors was in Norway.

Table 16. *Grouping of electrical accidents of electrical professionals into indoors and outdoors electrical accidents, (%)*

Country	**Indoors**	**Outdoors**	**Unknown**
Sweden (n=147)	78	22	0
Denmark (n=16)	44	56	0
Finland (n=36)	75	25	0
Norway (n=112)	86	13	2
Iceland (n=2)	50	50	0
In total (n=313)	78	21	1

Two Norwegian accidents could not be classified according to the accident location. It could not be said if they happened indoors or outdoors. One injured was connecting a communication cable and the other injured was working at a telecommunications installation.

Indoors accidents

The exact accident location was known in 221 of the total number of 245 indoors electrical accidents. Over one third of the 221 indoors electrical accidents of electrical professionals occurred in industry (Table 17). Two electrical professionals died indoors and both of them worked in industry in Sweden and in Norway. 14% of the accidents happened at residential buildings and 11% in electricity distribution and production and production of heat.

Table 17. *Distribution of locations of indoors electrical accidents of electrical professionals excluding the unknown locations, (n=221), (%)*

Place	**%**
Industry	36
Residential buildings	14
Electricity distribution and production and production of heat	11
Public places	8
Office buildings	7
Shops	6
Places that could not been classified *	5
Schools and kindergartens	4
Ships	1
Construction sites	1
Hospitals, retirement homes and fire stations	1
Hotels	1
Restaurants	< 1
Water treatment plant	< 1
Places connected to transport, not rail traffic	< 1
Railway yards and other places connected to trains and metros	< 1
Other	< 1

* not enough information on where the place was e.g. it was mentioned that one accident occurred at kitchen but there was not the information where the kitchen was located

Table 18 presents the three most common locations of electrical accidents in Sweden, Denmark, Finland and Norway. Industry was the most common location in each country and the Icelandic indoor electrical accident occurred also in industry. Electricity distribution and production and production of heat were not among the three most common indoors locations in Finland and Norway. The Finnish public places included seven accidents in a not-defined public place that might include for example schools and shops. In addition one accident occurred at a switchboard and another at an electric power distribution station of a public place.

Table 18. *Three most common indoors locations of electrical accidents of electrical professionals in Sweden, Denmark, Finland and Norway excluding the accidents with unknown locations, (%)*

Sweden (n=108)		**Denmark (n=7)**		**Finland (n=26)**		**Norway (n=79)**	
Order	%	**Order**	**%**	**Order**	**%**	**Order**	**%**
1. Industry	47	**1**. Industry	57	**1.** Industry	35	**1.** Industry	19
2. Residential buildings	16	**2.** Electricity distribution..	29	**1.** Public places	35	**2.** Residential buildings	15
3. Electricity distribution..	13	**3.** Office buildings	14	**3**. Places that could not…	12	**3.** Office	11

All the Danish electrical accidents occurred either in industry, electricity distribution and production and production of heat or in office buildings. There were seven different location classes in Finland. Most electrical accidents of electrical professionals occurred in Sweden and in Norway. The Swedish electrical accidents were divided to 15 classes and the Norwegian ones to 16.

Outdoors

Two electrical professionals died outdoors in 2011. The outdoors accident location was known in 43 electrical accidents. More than two fifths of the outdoor electrical accidents occurred in electricity distribution and production and production of heat. 14% of the accidents occurred at railway yards and other places connected to trains and metros followed by residential buildings (12%).

6.1.5. Accident situation

The accident situation, what the injured was doing when the accident occurred, was known in 290 of the 313 electrical accidents of electrical professionals. The electrical professional was installing, repairing, replacing, modifying or extending the electrical installation (meaning switchgears and control gears and fixed installations excluding installations related to lamps and safety lightning) in almost half of the electrical accidents (Table 19). In 17% of the accidents the electrical professional was testing, measuring or troubleshooting the electrical installation. The proportion of work on or with machines was 7%. 5% of the accidents included work related to lamps and lighting and 5% of the accidents occurred during work on overhead power lines or work done near poles.

Table 19. *Accident situations of electrical accidents of electrical professionals excluding unknown accident situations, (n=290), (%)*

Accident situation	**%**
Installing, repairing, replacing, modifying or extending of electrical installations	49
Testing, measurement and troubleshooting of electrical installations	17
Work on or with machines	7
Lamps and lighting	5
Work with overhead power lines or near poles	5
Safety lighting and fire detectors	2
Ground cables	2
Lifts	2
Street lighting	2
Building and repairing	2
Work with electrical products	2
Industrial works	1
Connecting/switching on or disconnecting/switching off	< 1
Trains	< 1
Touching something or moving something	< 1
Other	< 1
Entering or opening a door	< 1
Cleaning	< 1
Welding	< 1

Installing, repairing, replacing, modifying and extending of electrical installations included those actions on switchgears and control gears and fixed installations excluding fixed installations related to lamps, safety lightning and fire detectors. Installing or its opposite, demolition, was mentioned in over one fourth of the 143 electrical accidents categorized into *Installing, repairing, replacing, modifying or extending of electrical installations*. A cable was as a single word or as a part of the compound in 16% of the accidents. The action had something to do with coupling in 13% and pulling a cable in 4% of the accidents.

Testing, measurement and troubleshooting of electrical installations included switchgears and control gears and fixed installations excluding fixed installations related to lamps, safety lightning and fire detectors. Most (40%) of those 50 accidents occurred when measuring for example voltage in the electrical installation. Little over one third of the electrical accidents occurred when the injured was troubleshooting. Testing and checking were involved in 28% of the accidents.

Only one of the accidents classified into *Work on or with machines* occurred when the injured was operating a machine (it was a trial run). The other electrical accidents occurred when the injured was maintaining a machine.

Most of the electrical accidents related to *lamps and lighting* occurred when installing or removing a lamp and when changing a lamp, a bulb or a starter. Troubleshooting was involved in some accidents related to lamps and lighting.

Natural phenomena and weather

Natural phenomena were mentioned in three electrical accidents. In one description the accident occurred when correcting a fault in a pole transformer after a storm. In another description the transformer had to be changed because the thunder had damaged it. Heavy snow broke an overhead power line in another accident. In addition in one accident it rained when a ground cable was being installed to an overhead power line as live work. The leather gloves got wet and most probably the rain caused leakage current from a connector to the overhead power line.

6.1.6. Causes

The causes of the electrical accidents of electrical professionals were mentioned in 218 electrical accidents which represents 70% of the total sample. There could be one or more causes in each electrical accident. Problems in electrical work were mentioned most often (Table 20). Two fifths of the accidents included problems connected to electrical installations, electrical products and design. Almost one third of the accidents involved human errors. Documentation, management and communication were mentioned as a cause in 14% of the accidents. The proportion of work environment was 10% and the causes were others in 5% of the accidents.

Table 20. *Causes of occupational electrical accidents of electrical professionals excluding the accidents with no causes mentioned, (n=218), (%)*

Problems in electrical work		**77**
Live parts or live electrical installations	12	
Not de-energized	10	
Trust there is no voltage	9	
Not measuring voltage	8	
Not using PPE or improper use of them	8	
Unconnected, cut or unprotected cables	7	
Unexpected live part	6	
Inadequate equipment	6	
The installation was live instead of the expectations	4	
Live working instead of working dead	3	
Inadequacy grounding	3	
Problems in voltage measurement	2	
Problems connected to installations, products and design		**39**
Mounting fault or fault in installation	10	
Defect in the electrical installation	7	
Short circuit	6	
Damaged electrical installation or product	6	
Earth fault	3	
Defective protection	3	
Defects in an electrical product	2	
Faulty electrical installation or product	1	
Design error	1	
Loosening from the wall or the ceiling	< 1	
Problems in isolation	< 1	
Human errors		**31**
Not obeying the instructions	21	
Hurry, stress, carelessness, oversight or being in a rut	11	
Documentation, management and communication		**14**
Inadequate notes or documentations	8	
Defective planning or risk management	2	
Problems in orientation	1	
The assignments had not been gone through before the beginning	1	
Communication	< 1	
Unclear responsibility issues	< 1	
Danger of the interfering	< 1	
Work environment		**10**
Other people or animals involved	7	
Water, humidity	2	
Cramped space	1	
Other *		**5**

* including unclear (2%), other causes that were not mentioned above (2%) and causes that could not been classified (1%)

Problems in electrical work

Most issues gathered under *Problems in electrical work* related to not ensuring voltage and unexpected live parts or electrical installations. People trusted in 9% of the accidents that there was no voltage and that was the reason not to measure the voltage. Trust that there is no voltage was divided further. The more detailed causes were not revealed in almost half of those accidents. Trust in the person who de-energized had the highest proportion followed by trust that there is no voltage in the system, trust in the markings and documentation, visual observation and the system is dead because the adjacent was dead had the same proportion. It was admitted that voltage was not measured in all of the accidents. When voltage was measured the measurement was not successful all the time.

Live parts or live electrical installations included the accidents where it was not mentioned if the electrical work was planned to be done live or dead and it was done live. An unexpected live part meant the situations when some part of the electrical installation (not cables) were energized. Cables were unconnected, cut or unprotected more often.

It was told in 3% of the accidents that the work was done live instead of planned dead working. When the work was done live it was not always done properly. There were problems connected to PPE and equipment. The inadequate equipment included for example a metallic tape measure and screwdrivers.

Problems connected to electrical installations, electrical products and design

Different kinds of faults (damaged and faulty electrical products and installations and other defects in them) were involved in 16% of the accident. Faults in electrical installations were mentioned in 10% of the accidents.

Human errors

Not following the instructions was mentioned in more than every fifth electrical accident. The injured was in hurry or he/she was stressed, careless or in a rut in 11% of electrical the accidents.

Documentation, management and communication

Problems in documentation, poor communication and the danger of interfering were involved in 10% of the accidents. Issues related directly to management, of which most common was defective planning or risk management, were mentioned in 5% of the accidents.

Work environment

Other people and animals were involved in 7% of the accidents. Those accidents included situations where the injured was injured because of someone else and those where rodents had eaten the insulation around the cables. Water and humidity were mentioned in 2% of the accidents. Humid weather was involved in two accidents and the indirect contact through water once (a wet terminal in a junction box). There was too little space to work safely in 1% of the accidents.

6.1.7. Prevention

It was stated in one description that the injured should always consult a physician after the electrical accident. Several organizational ways to prevent electrical accidents were mentioned in the descriptions. To make renewed instructions whose purpose is to improve the inspection methods and that how improve occupational safety was mentioned in one description. Renewing the instructions is not the only way to improve safety because also highlighting the existing instructions was mentioned. Communications is also important. By telling about the occurred accident to employees similar accidents can be prevented. Communications after the accident is not sufficient but there must be communications during work. "Communications is important in every work where multiple parties are involved. There should, for example, be no doubt about which parts of the electrical installation are live and situations like this should therefore be avoided by having clear and unambiguous procedures and agreements between all the parties that are involved." In addition to communications management should inspect the documentation and place the needed warning signs. One accident where the warning signs were mentioned the warning signs should be placed to warn about the hazards of many power supplies. In another description the organization planned to make a new review of the internal controls and the safety regulations.

Better introductory briefing and guiding was also mentioned in the descriptions. Verifying that the electrical installation is dead can be highlighted by organizing training sessions. The employer has to educate and guide all the employees that perform electrical work according to the standard. In another description the employer stated that working against the instructions is not permitted in the company. It was also mentioned that the electrical hazards need to be evaluated before starting electrical work. After the risk assessment how the electrical work can be done safely and who does the work are defined.

The descriptions highlighted the importance to measure voltage. Voltage has to be measured before starting to work. In addition it needs to be ensured that all the parts of the electrical installation are dead before starting to work. In a situation where a teacher was measuring voltage with a voltage tester pen voltage will be measured with a voltmeter in future. The voltage tester pen is no longer in educational use. In addition to measuring voltage the descriptions included other preventive measures related to checking the electrical installation. The condition of all the wires has to be checked on that assumption that they are live. In addition electrical products need to be checked every day and especially when they are rented. One description reminded how important it is to check every work afterward even though the work would be small.

The descriptions included also other preventive measures. One description highlighted that the work should always be done according to the instructions. In that case the electrical installation should have been made dead before installing. If possible the electrical installation should be made dead and the employee should be more careful according to another description. Fixed groundings should be on before the measuring cables are loosened. That advice related to a situation where people were measuring groundings on a substation. One organization where the electrical accident occurred during changing a switch updated instructions related to connection in the following way:

– the supervisor names a worker who ensures that the electrical installation is safe to work with,
– the supervisor signs for when the ensuring is done and
– the supervisor gives a permit to perform the actual work only after all the safety measures have been carried out.

In another description the supervisor of electrical works makes a plan for turning the electrical installation on after certain backups are gone through. The accident resulted from unconnected wires and that is why workers were guided to protect the ends of all the unconnected cables.

The descriptions guided how live working should be done safely. The observation of the working environment belongs to the skills of the electrical professionals. If the electrical installation cannot be made dead equipment should be made of insulating material. The worker should always use proper PPE starting from the beginning of the work. One description highlighted that every metallic object should be removed from the hands, the wrists and the neck before starting to work. In that case it was also mentioned that the work site should be isolated in such a way that arcing cannot occur. The workers need to be guided to use PPE. The employer chooses the needed PPE by assessing the risks of the work.

Electrical accidents can be prevented by improving the technology. The descriptions included many technical and electro technical changes for the electrical installations. For example the voltage area was planned to be changed in one description. In addition to that in another description a signal light, that indicates there is no voltage, was planned to be installed. The cause of that accident was that the worker had not turned the supply cable off when leaving the work temporarily. The cable was live when the worker returned.

6.2. Laymen at work

Occupational electrical accidents of laymen were reported in Sweden, Denmark, Finland, Norway and Greenland in 2011. No occupational electrical accident that had occurred to a layman was reported in Iceland. The total number of accidents for the analysis was 317.

6.2.1. Consequences

No layman died at work of electricity in the Nordic Countries in 2011 (Table 21). Almost half the electrical accidents did not cause any days' absence from work. However, there were eight occupational electrical accidents causing more than 30 days' absence from work.

Table 21. *Consequences of occupational electrical accidents of laymen in days' absence from work*

Country	0 day or a medical examination		1-30 days		Over 30 days		Death	Unknown	
	%	n	%	n	%	n	n	%	n
Sweden n=193	67	130	31	60	2	3	0	0	0
Denmark n=12	17	2	42	5	0	0	0	42	5
Finland n=37	38	14	51	19	8	3	0	3	1
Norway n=74	14	10	59	44	3	2	0	24	18
Greenland n=1	0	0	100	1	0	0	0	0	0
In total n=317	49	156	41	129	3	8	0	8	24

3% of the electrical accidents caused more than 30 days' absence from work. In Denmark and in Greenland there were no such accidents. In Finland the proportion was the highest.

6.2.2. Types of accidents

Most occupational electrical accidents of laymen (93%) occurred due to electric shocks (Table 22). The variation between Sweden, Denmark, Finland and Norway was 0-5 percentage points. In the Nordic Countries 21 electrical accidents occurred due to arcing which was 7% of the total number of electrical accidents.

Table 22. *Types of accidents of occupational electrical accidents of laymen*

Country	Electric shock		Arc		Unknown	
	%	n	%	n	%	n
Sweden n=193	92	177	8	15	1	1
Denmark n=12	92	11	8	1	0	0
Finland n=37	92	34	8	3	0	0
Norway n=74	97	72	3	2	0	0
Greenland n=1	100	1	0	0	0	0
In total n=317	93	295	7	21	0	1

The unknown type of accident happened when a fitter was disconnecting a machine. The supply was done incorrectly and voltage was not measured.

Almost half of (9 of 21) arc accidents presented in Table 21 happened while the layman was performing electricity-related work. In six cases the person was plugging in an electrical product or disconnecting it. Two arc accidents occurred during construction work. The other three arc accidents happened during the replacement of an oil filter, when using a toaster and when using a circular saw. One arc accident that occurred during electrical work was entered as an arc with after-events but they were not revealed more precisely.

14 of the 295 electric shock accidents were entered as an electric shock with after-events. Half of the cases were falls while the after-events of the other half remained unknown. Shocks were involved in five electrical accidents with more than 30 days' of absence from work. Arc caused three same kinds of accidents. The proportion of shock accidents causing more than 30 days' absence from work was 62% that was less than the average (93%).

6.2.3. Electrical installations and electrical products

Two thirds of the occupational electrical accidents of laymen involved electrical installations and one third electrical products (Table 23). In Sweden 56% of the electrical accidents happened due to electrical installations and 44% due to electrical products which is more than elsewhere. Most electrical accidents (86%) in Norway included electrical installations.

Table 23. *Occupational electrical accidents of laymen involving electrical installations and electrical products*

Country	Electrical installations		Electrical products		Unknown
	%	n	%	n	n
Sweden n=193	56	109	44	84	0
Denmark n=12	67	8	33	4	0
Finland n=37	65	24	35	13	0
Norway n=74	86	64	12	9	1
Greenland n=1	100	1	0	0	0
In total n=317	65	206	35	110	1

Electrical installations

Half of the occupational electrical accidents of laymen involving electrical installations in the Nordic Countries included fixed installations. Less than a quarter (23 %) of the accidents involved machines. 6% of the accidents involved ground cables. Overhead power lines and switchgears and control gears caused 5% of the accidents each. Trains were involved in 1% of the accidents. The proportion of unclassified electrical installations was 10%.

Table 24 presents how the different electrical installations involved in electrical accidents were divided in each country. In Denmark one fourth of the accident involved ground cables which was more than in the other countries. However, one fourth means only two accidents. In Denmark and Finland there were proportionally less electrical accidents with fixed installations than in the other countries. There were electrical accidents caused by overhead power lines both in Finland and in Norway but not elsewhere. In Finland the proportion was the highest. The electrical installation could not be classified in 27% of the Norwegian accidents.

Table 24. *Distribution of electrical installations in occupational electrical accidents of laymen, (%)*

Type of electrical installation	**Sweden** n=109	**Denmark** n=8	**Finland** n=24	**Norway** n=64	**Greenland** n=1
Fixed installations	53	38	42	48	0
Machines, lifts and other equipment for industrial use	30	38	29	6	100
Ground cables	6	25	8	2	0
Switchgears and control gears	6	0	4	6	0
Overhead power lines	0	0	17	9	0
Trains	2	0	0	0	0
Unclassified *	3	0	0	28	0

* Electrical installations that could not be classified based on the electrical accident material

There were six electrical accidents with more than 30 days' absence from work caused by electrical installations. Fixed installations were involved in four of those electrical accidents. One accident happened due to ground cables. The electrical installation involved in the sixth accident could not be classified.

Electrical products

Table 25 presents the electrical products that were involved in the occupational electrical accidents of laymen. Domestic appliances caused 23 occupational electrical accidents and lamps 18. The number of extension cables and IT products were 13. Electrical products were involved in two electrical accidents with more than 30 days' absence from work.

Table 25. *Number of electrical products involved in occupational electrical accidents of laymen, (n=110)*

Domestic appliances [a]	23
Lamps	19
Extension cables	13
IT [b]	13
Power tools [c]	6
Appliances at institutional kitchens [d]	6
Devices connected to studying electricity [e]	4
Appliances at laboratories and hospitals [f]	4
Electrical products related to converting voltage or frequency [g]	3
Heating and cooling [h]	2
Aggregates	2
Miscellaneous [i]	15

[a] 4 ovens/stoves, 3 toasters, 3 irons, 3 vacuum cleaners, 2 fridges/freezers, 2 sewing machines, a table fan, a food mixer, a coffee maker, a chopper, a washing machine and a mixer.
[b] 2 adapters, 2 computers, a two-way radio, a charger, a radio, a stereo, a TV, a video, a screen, a data logger and one undefined.
[c] 2 grinders, a welding machine, a cutter, a circular saw and one undefined.
[d] two temperature cabinets, a vitrine, a mobile temperature cabinet, a warmer and one undefined.
[e] for example an electric board for training.
[f] a water bath, a drop counter, a care table and a bed for the patient.
[g] a voltage aggregate, a frequency converter and a voltage converter
[h] a heat pump and a refrigerating machine.
[i] 9 undefined products, a glazing machine, a hanging globe, a glue gun, a pump, a fan coil unit and an immersion heater.

The most common domestic appliances were an oven/a stove, a toaster, an iron and a vacuum cleaner. It needs to be noticed that the electrical product could not be identified in 9 electrical accidents.

6.2.4. Occupations

Over four fifths of the laymen were not instructed persons (259 persons of 317 laymen). The occupation was not revealed in 23% of electrical accidents of those persons. The occupations are presented in Table 26. One fourth of the employees were technical people including for example mechanics and industrial workers. Pupils and students constituted 20% and construction workers 15%.

Table 26. *Occupations of laymen excluding instructed persons and unknown occupations, (n=199),(%)*

Occupation	**%**
Technical workers (e.g. mechanics and industrial workers)	25
Pupils and students	20
Construction workers	15
Employees at cleaning and real estate management	10
Nursing staff and fire fighters	8
Cooks	8
Drivers	4
Teachers and nannies	3
Employees working with animals	2
Salespeople	2
Employees of the church	1
Employees in the field of research	1
Miscellaneous [a]	4

[a] includes for example an assistant for processing, a sailor, an product specialist and massage therapist

Technical workers were the most common occupational group both in Sweden and Norway (Table 27). In Finland electrical accidents happened most often to construction workers and employees at cleaning and real estate management. Three of the five electrical accidents that occurred to a cleaner occurred when the injured was making the final cleaning at a construction site. In Finland one electrical accident that happened to a pupil or a student was reported in 2011. The occupation was known in four Danish electrical accidents; two of them were construction workers. The Greenlandic injured was a technical worker.

Table 27. *Three largest occupational groups in Sweden, Finland and Norway excluding instructed persons and unknown occupations, (%)*

Sweden (n=154)		**Finland (n=29)**		**Norway (n=11)**	
Order	**%**	**Order**	**%**	**Order**	**%**
1. Technical workers	27	**1.** Construction workers	28	**1.** Technical workers	36
2. Pupils and students	23	**1.** Employees at cleaning…	28	**2.** Pupils and students	27
3. Construction workers	12	**3**. Cooks	10	**3.** Construction workers	18
		3. Technical workers	10		

The number of unknown occupations varied from Finland's 16% to Denmark's 60%. In Norway the occupation was known in over half of the cases and in Sweden 80%.

6.2.5. Location

The majority of the occupational accidents of laymen occurred indoors (Table 28). Denmark and Finland had almost the same percentage value of outdoors electrical accidents, namely 25% and 27%. Least electrical accidents happened outdoors in Norway. The Swedish distribution followed the Nordic distribution but it must be noticed that over 60% of the accidents are from Sweden. The Greenlandic electrical accident occurred indoors.

Table 28. *Grouping of occupational electrical accidents of laymen into indoors and outdoors electrical accidents, (%)*

Country	Indoors	Outdoors	Unknown
Sweden n=193	83	17	0
Denmark n=12	75	25	0
Finland n=37	70	27	3
Norway n=74	88	12	0
Greenland n=1	100	0	0
In total n=317	82	17	0

As it can be noticed from Table 28 one Finnish electrical accident (3% of all the Finnish accidents) could not be classified. The injured was using a circular saw but the information where the injured was working was not revealed.

Indoors

The indoors accident locations were mentioned in 249 of the 262 occupational indoors electrical accidents of laymen. One fourth of the occupational indoors electrical accidents of laymen occurred in industry (Table 29). One fifth of the accidents occurred at schools or kindergartens. Residential buildings had also the proportion over 10%.

Table 29. *Locations of occupational electrical accidents of laymen that occurred indoors excluding unknown locations, (n=249) (%)*

Place	**%**
Industry	25
Schools and kindergartens	20
Residential buildings	12
Public places	6
Office	6
Shops	6
Hospitals and retirement homes	4
Restaurants	4
Construction sites	4
Electricity distribution and production and production of heat	3
Places connected to transport, not rail traffic	2
Places that could not been classified	2
Hotels	2
Railway yards and other places connected to trains and metros	1
Ships	1
Other *	3

* including for example a water treatment plant and a beauty salon

One fourth of the electrical accident occurred in locations related to education and social and health care. 4% of the electrical accidents occurred in locations connected to transport.

One fourth of the occupational electrical accidents of laymen occurred at schools and kindergartens in Sweden (Table 30). The proportion was the highest when compared to Denmark, Finland and Norway. No electrical accident that occurred at school was reported in Denmark and only two in Finland. The most common accident location in Finland was public places which might include e.g. schools, hospitals, offices and shops.

Table 30. *Three most common indoors locations of occupational electrical accidents of laymen in Sweden, Denmark, Finland and Norway excluding unknown locations, (%)*

Sweden (n=157)		**Denmark (n=9)**		**Finland (n=26)**		**Norway (n=56)**	
Order	%	**Order**	%	**Order**	%	**Order**	%
1. Schools and kindergartens	25	**1**. Industry	56	**1.** Public places	27	**1.** Industry	27
2. Industry	24	**2.** Office	22	**2.** Residential buildings	19	**2.** Schools and kindergartens	16
3. Residential buildings	10	**3.** Hospital	11	**3**. Industry	12	**3.** Residential buildings	14
		3. Shops	11	**3.** Construction	12		

Table 30 does not express all the locations in every country expect in Denmark. Almost half of the Norwegian (48%) and two fifths of the Swedish (41%) electrical accidents occurred somewhere else. In Finland 28% of the occupational electrical accidents of laymen did not occur in public places, residential buildings, industry or construction.

Outdoors

The exact outdoors location was known in 45 of 54 occupational electrical accidents of laymen. Almost one fifth (18%) of outdoors electrical accidents occurred at construction sites. The second most electrical accidents were reported in electricity distribution and production and production of heat (13%). The next most (11%) of outdoors electrical accidents occurred at railway yards and other places connected to trains and metros and in industry.

6.2.6. Accident situations

The accident situations of occupational electrical accidents of laymen were revealed in 284 of 317 electrical accidents. One fifth of the 284 electrical accidents occurred during installing, repairing, replacing, modifying or extending of electrical installations (switchgears and control gears and fixed installations excluding installations related to lamps and safety lighting) (Table 31). About 10% of the accidents happened when the injured was connecting/switching on or disconnecting/switching off. Next most electrical accidents (8%) occurred when building and repairing and also when doing work related to lamps. The proportion of work on/with machines and cleaning was 7%.

About one fourth of the 58 *Installing, repair, replacement, modification and extension of electrical installations* accidents involved installing or its opposite demolition as the action. A cable was mentioned in one fifth of those 58 accidents. Less than one fifth of the accidents included coupling as an action and pulling a cable was mentioned in some of the accidents.

Three fourths of the 27 accidents where the injured was *connecting or disconnecting* an electrical product were situations where the injured was connecting something. For example one injured was connecting a power supply cable for a block heater to a car. About one filth of the accidents occurred when the injured was disconnecting an electrical product. There was one accident that could not been classified in more detail.

Building and repairing included different kinds of accident situations for example the renovation of a roof, wallpapering and sanding the floor. Lamps and lighting had the same proportion as building and repairing. More than one third of the 23 accidents related to *lamps and lighting* were situations where the injured was changing the bulb. The rest of the accidents were mainly related to turning the lights on or off and installing a lamp. *Work on or with machines* had the proportion of 7%. Over three fourths of the 21 accidents with machines related to maintenance and less than a fourth to using them.

Table 31. *Accident situations of occupational electrical accidents of laymen excluding unknown accident situations, (n=284), (%)*

Accident situation	**%**
Installing, repairing, replacing, modifying or extending of electrical installations	20
Connecting or disconnecting something	10
Building and repairing	8
Lamps and lighting	8
Work on or with machines	7
Cleaning	7
Industrial works	4
Work at kitchen	4
Touching something or moving something	3
Schooling	3
Heating, plumbing and air-conditioning	2
Testing, measurement and checking of electrical installations	2
Work with electrical products	2
Could not been classified	2
Work at overhead power lines or near pylons	2
Entering or opening a door	2
Outdoor works	1
Welding	1
Ground cables	1
Safety lighting and fire detectors	1
Trains	1
IT	1
Lifts	1
Changing the bulbs into the oven	1
Personal hygiene	1
Care and beauty	1
Single accident situations	3

Accident situations in Sweden, Denmark, Finland and Norway

The three most common accident situations of the Swedish, Danish, Finnish and Norwegian electrical accidents are presented in Table 32.

Table 32. *Three most common accident situations of occupational electrical accidents of laymen in Sweden, Denmark, Finland and Norway when excluding unknown accident situations, (%)*

Sweden (n=164)		Denmark (n=11)		Finland (n=35)		Norway (n=73)	
Order	%	**Order**	**%**	**Order**	**%**	**Order**	**%**
1. Connecting…	15	**1**. Cleaning	18	**1.** Building	29	**1.** Installing..	45
2. Installing…	14	**1.** Work on/with machines	18	**2.** Cleaning	11	**2.** Lamps and lighting	10
3. Lamps and lighting	8	**1.** Lamps and lighting	18	**3**. Industrial works	9	**3.** Work at overhead…	7
3. Work on/with machines	8	**1.** Ground cables	18				

The three most common Norwegian accident situations related to electrical installations which is a difference compared to Sweden, Denmark and Finland. Almost all of the Norwegian accidents situations that were classified into lamps and lighting were situations where the lamp was being installed or removed. The accident situations at overhead power lines or near pylons included for example changing the pylon in Norway. None of the three most common accident situations in Finland related directly to electrical installations. Three fourths of the accident situations related to cleaning were connected to construction sites where the cleaning was done after the actual construction work has been completed.

Natural phenomena and weather

Natural phenomena and weather were mentioned in two descriptions. Heavy snow broke an overhead power line in one accident. In another accident the storm was reaching and it was thus decided to demolish the work.

6.2.7. Causes

The causes of the occupational electrical accidents of laymen were told in 204 electrical accidents. Most of the accidents included problems connected to electrical installations, electrical products and design and problems in electrical work (Table 33). Action of the worker was mentioned as a cause in 23% of the accidents. Other people and the work environment were involved in 17% and live cables, electrical installations and products in 15% of the accidents. Documentation, management and communication were mentioned in 3% of the electrical accidents.

Table 33. *Causes of occupational electrical accidents of laymen, (n=204,) (%)*

Problems connected to electrical installations and products and design		**39**
Damaged electrical installation or product	19	
Faulty electrical installation or product	8	
Mounting fault or fault in installation	6	
Defect in the electrical installation	2	
Loosening from the wall or the ceiling	1	
Short circuit	1	
Earth fault	1	
Defects in an electrical product	1	
Poor insulation	< 1	
Problems in electrical work, related to work at electrical installations		**35**
Not de-energized	9	
Trust there is no voltage	6	
Not measuring voltage	5	
Unauthorized electrical work	3	
Inadequate equipment	2	
Problems in voltage measurement	2	
Inadequate grounding	2	
The installation was live instead of the expectations	2	
Live working instead of dead working	1	
Defective protection	1	
Unexpected live part	1	
Not using PPE	< 1	
All the tension was not gone	< 1	
Action of the worker		**23**
Not obeying the instructions	15	
Hurry, stress, carelessness, oversight or being in a rut	8	
Work environment		**17**
Other people or animals involved	12	
Water	4	
Disorder	1	
Cramped space	< 1	
Live cables, installations and products		**15**
Unconnected, cut or unprotected cables	9	
Live	6	
Other		**10**
Documentation, management and communication		**3**
Poor communication	1	
Inadequate notes or documentations	1	
Defective planning or risk management	1	
Problems in orientation	< 1	
Unclear		**1**
Not found		**1**

The most common single cause was a damaged electrical installation or product (19%). Damaged electrical installations and products mean electrical installations and products that have not been faulty when they were new. A damaged electrical product was mentioned as a cause in 32% of those accidents including electrical products and where causes were mentioned. The proportion of damaged electrical installations was 19% in the accidents including electrical installations.

Other people or animals were involved in 12% of the accidents. Those accidents included for example situations where the rodents had eaten insulating material around the cables. In addition in one accident a screw had hit the cables in the wall. That was the reason for that the fastened object become energized.

There were accidents where the layman was doing electrical work unauthorized. A layman was demolishing production equipment in one accident and another layman was doing electrical work in a cooling plant. A maintenance man was fixing an elevator in another description. Some parts were added to an electrical product by a real estate manager in one accident. In addition a construction worker cut a high voltage cable in one electrical accident.

Different kinds of causes were mixed into the category *Other causes*. In one accident a cable was run over a truck. A spade broke a ground cable in one accident and an iron bar in another. One description described that a gutter to be installed hit an overhead power line. When an angle grinder broke its own cord it was also classified into other causes. In addition an electrical accident that resulted from energized electrolyte was classified into other causes.

The most often mentioned causes when excluding instructed persons

Table 34 presents the most often mentioned causes of the electrical accidents where the injured was not an instructed person. Instructed persons are allowed to perform electrical work in certain situations. The causes of electrical accidents of instructed person may follow the causes of the electrical accidents of the electrical professionals. When the instructed persons are excluded from the sample it is possible to analyze the causes of accidents of those people who are not allowed to perform electrical work. Causes were mentioned in 61% of those accidents.

Table 34. *Most often mentioned causes of occupational electrical accidents of laymen excluding instructed persons, (n=157) (%)*

Cause	**%**
Damaged electrical installation or product	23
Other people or animal involved	14
Other	11
Faulty electrical installation or product	10

6.2.8. Preventive measures

The descriptions included some common advice to prevent electrical accidents. Lamps or switches should not be replaced when they are energized. In another description the employer gave advice that no employee is allowed to move or change the position of the spot lights at the conductor trail in a shop. The description of the accident, where the injured was cutting a fence at a lift cage, tells that the fence is not cut at the lift cage anymore because the overhead power lines are so near at that place. The employer in the accident where the supply cable was damaged stated that the accident could have been prevented if the condition of the supply cable had been checked and the supply cable had been de-energized. In another description the organization underlines in its guidance that live cables must not be touched or moved.

Training and organizational changes were also mentioned in the descriptions. Employees have to be trained and the internal procedures have to be reviewed after the accident. Also the work instructions have been gone through. One accident could have been prevented by more careful actions and better communications among the workers who participated in the action. Some new procedures have also been introduced and some old procedures have been changed to prevent accidents. One example of new procedures is to contact the responsible person before starting to work. In that situation the employee believed that there was no electricity left which was not true. An example of the change of the old procedures is not serving food outdoors anymore.

The need to check the electrical installations by an electrical professional was mentioned as one way to prevent occupational electrical accidents of laymen in the future. Electrical professionals have to ensure that there are no energized cables unconnected. The unconnected ends of electrical wires have to be protected by using for example distributing boxes. In one of the accidents where a cleaner was injured the electrical professional and the overseer responsible for cleaning will go around together in the places that need to be cleaned. They look over the right working methods and in addition the electrical professional makes sure that everything is in condition. The descriptions included also plans to check electrical products regularly.

Damaged electrical products and installations need to be fixed and breakings need to be prevented in different ways. Broken cords shall be changed or insulated. In one accident a cable was probably damaged when it was run over by a digger or when it was moved plugged in. The description guided how to storage the cable when it is unused. The damages and possible damages need to be reported to the overseer. Damaged electrical products should be removed immediately so that there will not be more electrical accidents. In addition faults in electrical installations need to be fixed when they are discovered. To find the faults inspections, analyses and measurements need to be done. When corrective measures are done, the success of the repairs needs to be ensured.

The descriptions included also electrical work related preventive measures. Measuring voltage before starting to work was mentioned in an accident related to electrical installations and also in an accident related to electrical products. In an accident where an electrical student got injured guidelines instruct to inspect the electrical connections and safety of the work de-energized. The permission of the teacher must always be asked prior to switching on voltage. The teacher has to inspect the electrical connections before allowing the work. In addition to that the teacher has to instruct the students to work carefully near live parts because the he/she cannot be monitoring them all the time. The descriptions also included plans to provide reliable information about the structure of the electrical installations, assess the work-related risks and take measures that are necessary to ensure electrical safety. The descriptions underlined also that only electrical professionals are allowed to perform electrical work related to both electrical installations and electrical products. Work has to be stopped until the faults are corrected and checked. One organization is going to include safety at electrical work to safety training that is compulsory to all the workers.

There was one preventive measure mentioned that related to industrial work. That accident included a submersible pump. The problem was that an extension cable was needed to be able to use the pump. If the wiring points could be moved towards the area where the pumps were used the extension cables would not be needed. In addition a mount in order to change the altitude of the submersible pump could be built.

6.3. Leisure time electrical accidents

Leisure time electrical accidents were reported to electrical safety authorities in Sweden, Finland and Norway in 2011. All the reported leisure time electrical accidents happened to laymen according to the electrical accident material.

6.3.1. Consequences and types of accidents

Three persons died of electricity in the Nordic Countries during leisure time in 2011 (Table 35). The fatal electrical accident in Sweden occurred when the victim was fishing and the fishing rod touched the 20 kV overhead power line. The person who died in Finland had climbed on a train and died of the contact lines. In Norway the person had unauthorized entered a substation and touched the 47 kV bushings.

Table 35. *Consequences of leisure time electrical accident in days' absence from work*

Country	0 day or a medical examination	1-30 days	Over 30 days	Death	Unknown
Sweden n= 21	13	5	1	1	1
Finland n=14	8	3	0	1	2
Norway n=6	0	4	0	1	1
In total n=41	21	12	1	3	4

Most leisure time electrical accidents (85%) occurred due to electric shocks. In Finland 93% of the electrical accidents were shocks, 83% in Norway and 81% in Sweden. According to the material all the fatal electrical accidents resulted from electric shocks. An electric shock caused the electrical accident with more than 30 days' absence from work. The type of accident was unknown in a minor electrical accident on railway in Sweden.

6.3.2. Electrical installations and electrical products

Over two thirds of the leisure time electrical accidents involved electrical installations (Table 36). Electrical products were involved in 32% of the electrical accidents. In Finland the proportion of electrical products was higher than in Sweden and in Norway.

Table 36. *Electrical installations and electrical products involved in leisure time electrical accidents*

Country	Electrical installations		Electrical products	
	%	n	%	n
Sweden n=21	76	16	24	5
Finland n=14	57	8	43	6
Norway n=6	67	4	33	2
In total n=41	68	29	32	13

Most leisure time electrical accidents involving electrical installations accidents involved fixed installations (Table 37). In Finland the proportion of fixed installations was the highest. In Sweden there were less overhead power line accidents than on average. There were no accidents involving switchgears and control gears in Finland and no train accidents in Norway.

Table 37. *Different electrical installations in leisure time electrical accidents, (%)*

Electrical installations	In total (n=29)	Sweden (n=17)	Finland (n=8)	Norway (n=4)
Fixed installations	55	53	63	50
Overhead power lines	17	12	25	25
Trains	14	18	13	0
Switchgears and control gears	14	18	0	25

Three people died during leisure time in 2011. Overhead power lines caused the death in Sweden and trains in Finland. The fatal electrical accident in Norway involved switchgears and control gears.

The number of electrical accidents involving electrical products was 13. Four electrical accidents involved lamps and four domestic appliances (a coffee maker, a toaster, a washing machine and a mixer). IT appliances (a portable DVD player and an alarm radio) were involved in two accidents. A power drill, an electrical product used making arts and an undefined electrical product caused one accident.

6.3.3. Location

Most leisure time electrical accidents (71%) occurred indoors in Sweden, Finland and Norway. Half of the six Norwegian electrical accidents occurred indoors. One fourth of the Finnish accidents and 29% of the Swedish accidents occurred outdoors.

Indoors locations

29 electrical accidents happened indoors. Nine accidents happened at home or a house but the exact room could not be identified. Five accidents happened at the bathroom at home and three accidents happened at other rooms including a hall, a washing house and a living room at home. Four accidents occurred in a kitchen at home. Four leisure time electrical accidents occurred in other places consisting of a youth hostel, a train, a boiler room of a farm and a glass-house. Two accidents occurred in a public swimming pool (at the same time at the same place) and in shops.

Outdoors

In 2011 all the three fatal electrical accidents occurred outdoors. In Sweden the victim was fishing. In Finland the dead person was on a train. In Norway the fatal electrical accident occurred at a substation. Two non-fatal electrical accidents occurred also at substations.

6.3.4. Accident situations

The accident situation was told in 31 descriptions of 43 electrical accidents. Five accidents occurred when the injured was touching or moving something. Those situations included situations where the injured touched the lamp, the washing machine and the fridge, and when the victim was switching the pendant on when cooking water and when the victim touched the bore bit and the grounded fridge at the same time. Four accidents occurred during hobbies and playing for example when a kid was playing and a person was flying a powered paragliding or hang-gliding.

Three accidents happened when the injured was connecting or disconnecting, three when the injured was doing things related to personal hygiene and three when the injured was installing a pendant or replacing a lamp of a pendant. The *personal hygiene* accidents included two accidents where the injured was urinating and one accident where the victim was washing hands. The injured was switching on an electrical product in two accidents and switching off in one accident. Cleaning, outdoor works, work at kitchen and issues related to trains caused two electrical accidents each. The accident situation was single in five electrical accidents.

6.3.5. Causes

The causes were mentioned in 22 leisure time electrical accidents. Mounting faults were mentioned in eight descriptions. A towel heater was installed by a former home owner wrongly in one accident and a wall socket in another. There was something wrong in the fixed installation of a new house in one accident. One description told that there had been some other problems in the fixed installation before the accident occurred but the cause of the accident was not known. The resident had installed a washing machine incorrectly in one description and a lay tiler a wall socket at home which resulted in an electrical accident of the home owner. The incorrect electrical installation done by an electrical professional caused two leisure time electrical accidents.

The cover of a DVD player came loose in one accident. It was mentioned in two descriptions that there were two new faulty electrical products. In one accident the fastener of an old lamp was sharp and it was bit into the cord. A fault in a LED light caused two electrical accidents. A non-insulated cable was involved in one electrical accident and a damage fixed installation in another. One electrical product became de-energized possibly from water that leaked in.

A tree fell on an overhead power line in two accidents. A ladder hit a non-insulated cable outdoors when the injured was painting a house. The motor of a powered paragliding stalled in one accident description. The powered paragliding hit an overhead power line which caused a short circuit.

6.3.6. Prevention

Preventive measures were described in four descriptions. Two of those leisure time electrical accidents concerned cutting down of trees. It is worth of consulting the distribution company before starting to fell trees near overhead power lines. In addition to communications good planning is essential.

One of the four leisure time electrical accidents was an accident at a railway yard. In the description the police remind that trespassing at railway yards and as a whole on railways is forbidden. The authority responsible for safety on railways is going to figure out the safety of the railway yard where the accident occurred.

The final of the four accidents with preventive measures was a situation where a layman had made an incorrect electrical connection. The washing machine was connected in such a way that the water supply system became energized. The housing company informs the residents that laymen are not allowed to perform electrical work and every completed electrical work needs to be reported in writing to the housing company.

7. VIEWS ON ELECTRICAL SAFETY

This chapter presents the results of the interviews of the representatives of the Nordic electrical safety authorities. How electrical accident data is collected is presented in Chapter 5. This chapter focuses on the other issues discussed in the interviews. This chapter is based on the views of the representatives of the Nordic electrical safety authorities on the current electrical safety situation. The results are presented mainly in a summary form.

The first two subchapters focus on underreporting and on how electrical accident information is used in the Nordic Countries. Electrical problem areas and emerging risks are dealt with in the next subchapter. Finally, ways to improve electrical safety are gathered in the last subchapter.

7.1. Underreporting of electrical accidents

The Nordic electrical safety authorities do not get information on every electrical accident. Electrical accidents are thus underreported. The authorities believe that they know every fatal electrical accident. They know only a little of leisure time electrical accidents and occupational electrical accidents of laymen. Perhaps only the electrical accidents people find the most dangerous ones are reported to the electrical safety authorities. The problem is how the electrical safety authorities could get information of those electrical accidents which people do not consider hazardous.

In addition to the underreporting of leisure time electrical accidents and occupational electrical accidents of laymen the electrical safety authorities do not know the true number of occupational electrical accidents of electrical professionals. Electrical professionals do not report every electrical accident to their supervisors because most of them might think that an electrical shock is just a part of work. Many people having a minor electrical accident do not think it is necessary to inform about the accident because they did not get hurt. Electrical professionals do not inform minor electrical accidents because they can go on working. Bigger electrical network companies know how to report electrical accidents. Those companies report electrical accidents because they are obligated to do so and the other reason to report the accidents is the aim of not having any electrical accident.

The interviewees were asked to estimate the rate of underreporting. The Swedish representative estimated that 15% of electrical accidents are reported to Elsäkerhetsverket. There can be 4000-5000 electrical accident per year in Sweden based on a report on electrical accidents of small children. The Danes supposed that 3500 electrical accidents might occur in Denmark every year. The estimation was based on a research done earlier and they reminded that Sikkerhedsstyrelsen receives annually information from only about 35 electrical accidents. The Norwegian estimation was also based on an earlier research where it was wanted to know what electrical accidents cause later. According to that study about 10-15% of electrical accidents are reported to DSB. Thus the Norwegian representative estimated that there can be 3000 electrical accidents in Norway every year.

Estimating the rate of underreporting is not always simple. The Finnish interviewees found it almost impossible to estimate the rate of underreporting. The estimation is difficult in particular if an electrical professional experiences he/she has done a mistake which results in not reporting the electrical accident to the supervisor or not visiting the doctor. 400 occupational electrical accidents are reported by insurance companies to the Federation of Accident Insurance Institutions every year. Less than a half, possibly 10%, of occupational electrical accidents is reported to Tukes yearly. The absolute number can be 1000 electrical accidents a year excluding the occupational electrical accidents of laymen and the leisure time electrical accidents.

The Icelandic representative could not estimate the rate of underreporting. According to Mannvirkjastofnun there were two electrical accidents in Iceland in 2011. But according to the Administration of Occupational Safety and Health in Iceland there were nine occupational electrical accidents in 2011.

The Greenlander estimated that the rate of underreporting is the same as in Denmark and Finland. The Faroese stated that the information on the neighboring countries suggests that smaller electrical accidents are also underreported in the Faroe Islands. The Ålandian estimated that a few electrical accidents are not reported to Ålands Landskapsregering yearly.

It was said that too few electrical accident notifications arrive compared to the true number of the electrical accidents. Thus the reported number of electrical accidents tells more about the activeness to inform the electrical safety authorities than the absolute electrical safety situation.

7.2. Utilization of electrical accident information

In Sweden, Elsäkerhetsverket stores electrical accident information in a system called Platina. The system is only for the internal use. The descriptions of the electrical accidents from Platina are not published in the annual report. The annual report includes only statistical information on electrical accidents. Persons reading the annual report are usually teachers or managers of firms. Internally the electrical accident data is used in the biannual or quarterly meetings where it is found out if there are some statistical problems that need to be focused on. In addition to that the database is used for guiding the work of the electrical inspectors.

Danish Sikkerhedsstyrelsen's publications include both statistical and qualitative information on electrical accidents. Sikkerhedsstyrelsen publishes the descriptions partly because they want to show better hazards electricity poses. Technical school teachers, electrical teachers and trainers utilize the publication.

DSB of Norway has a same kind of annual publication like Sikkerhedstyrelsen including statistical and qualitative information. Companies use the publication to improve electrical safety by learning about electrical accidents related to their own electrical professionals. In addition to companies labor unions utilize electrical accident information. DSB's internal use of electrical accident information includes informing and educating specific target groups and considering if the legislation needs changes.

Like Elsäkerhetsverket, Sikkerhedstyrelsen and DSB, Tukes publishes an annual report on Finnish electrical accidents. The annual report includes mainly statistics. The electrical accident information is entered into an accident and damage database called VARO (the abbreviation of *Vaurio- ja onnettomuusrekisteri* in Finnish) and that system has also an external version. The external version of the database includes the classifications and the descriptions of each electrical accident. Information can be searched in many ways. The electrical accident information is used internally and externally. Internally Tukes uses electrical accident information in e.g. supervision, press releases, annual reports and safety indicators. Cases in the database are for learning and the firms likely utilize them in training. The cases are also used in the compulsory training of the standard SFS 6002:2005. Research institutes, thesis workers and authors use also electrical accident information collected by Tukes.

In Iceland Mannvirkjastofnun cannot publish anything related to electrical accidents. Yearly the number of electrical accidents is low which is a limitation to publishing. Mannvirkjastofnun organizes meetings with distribution companies so they know what to focus on. Internally the electrical accident information is used when doing guidelines. Grønlands Elmyndighed has to collect electrical accident information for the government and itself it makes statistics to estimate the electrical safety level in Greenland. Elnevndin use the electrical accident information to form an opinion on the accident. Ålands Landskapsregering uses electrical accident information for issues that need to be concerned.

7.3. Electrical safety problem areas today and in future

"Safety does not interest people and they think electricity is quite safe" was said in one of the interviews. This chapter focuses on electrical safety problem areas, first on problem areas today and after that on emerging risks. "New kind of equipment can cause harm but old things are also a problem".

7.3.1. Electrical safety problems area today

Today's barrier to electrical safety among electrical professionals is cutting corners, not obeying instructions given in the legislation and in the standards. Not obeying instructions was mentioned in five interviews. It was mentioned that not checking if the electrical installation is energized is the main reason of the electrical accidents of electrical professionals. In addition to that electrical professionals tend to trust the measurements they have done and the connection diagrams they have. Sometimes risk assessment is not done.

Some electrical problem areas which exist overall in the society arose in the interviews. These are pressure from above to produce more and hurry. However, "an electrical accident is no excuse: you can always protect yourself if you just take your time. Hurry comes from somewhere." Sometimes electrical professionals are forced to work alone even though they would like to work with someone. Subcontracting can affect electrical safety. The other issues affecting electrical safety are the change of generation (problems in the transfer of know-how) and the increase of foreign labor (language barriers and forcing to do illegal electrical work).

One electrical safety problem area that came up in the interviews was electrical work done illegally and without proper skills which can affect both electrical professionals and laymen. Laymen are unaware of hazards electricity poses and they do not always understand what they are doing. Laymen might fix cords by taping them and change the bulb without concentrating on what they are doing. Small electrical work done by laymen at home can cause electrical accidents or electrical fires. Broken cords and cables, that even the sun can damage, are one electrical safety problem area among laymen. It is hard to tell when the cable is broken or too old. In summary, laymen should always know what they are doing.

Electrical products without CE marks are an electrical safety problem area in the Faroe Islands. The Faroe Islands do not require CE marks but however nearly all the electrical products and appliances are imported from Denmark and are thus CE marked.

7.3.2. Emerging risks

Development of technology was seen as an emerging risk. Electric cars were mentioned in five interviews. Installations are not ready for electric cars and loading stations could be a problem if there are a lot of them. There is a political want for a lot of electric cars within a relatively quick schedule and the development may be just too fast. Solar cells were mentioned three times. The problems related to solar cells are how to turn them off and the fact that they are usually installed by laymen. In addition to electric cars and solar cells the possible shift to using direct current instead alternating current is a risk that needs to be considered.

Industry was mentioned as an emerging risk in two interviews. The expansion of heavy industries might be an emerging risk in one country and mine industry in the other. Industry and the development of technology were not the only mentioned emerging risks. The discount products of uncertain origins can also be emerging risks.

Among other emerging risks social problems might also affect electrical safety in the future. The increase of societal inequality, the increase of organized and international crime might reduce electrical safety. Thieves have already been interested in copper because its high world market price in some countries and that might spread to the other countries as well. In addition extreme weather including for example storms can affect electrical safety.

7.4. Improving electrical safety

The electrical safety situation is already good. A good level has been reached and it would take effort to reduce electrical accidents. Even though electrical accident prevention work has been done for years electrical accidents still occur. It needs to be remembered that electrical safety work is continuous. How the electrical safety authority can affect electrical professionals if when seeing them all they can do is to say "please be careful, it is dangerous".

Communications and spreading information were seen as ways to improve electrical safety in many Nordic Countries. Communications can include for example campaigns about the importance of testing voltage before starting to work or reminding of the costs of electrical accidents. It is important to communicate how work should be done. It is also important to guide people where they can find the instructions. The electrical safety authority could contact employers and companies more and make the professionals more aware of their responsibilities. In addition the mentality of the workers should be changed. They should not do things quickly and they should have no pressure to finish. In summary, the employees should think that everyone's safety is the most important thing at work.

In addition to communications other ways to improve electrical safety were also mentioned. The improvement of standards and legislation can reduce electrical accidents. Also inspections promote safety. To promote safety the electrical safety authorities can make research. Perhaps the authority could also improve its action; electrical accidents could be analyzed more and each electrical accident could be looked into.

7.5. Identified differences

Some differences between the Nordic Countries were mentioned in the interviews. In Norway trains are parked de-energized (the overhead lines are de-energized). In addition to parking trains de-energized it needs to be remembered that there is no railway for example in Iceland and Greenland.

Electrical accidents that happen to pupils and students at schools need to be reported to the Swedish Work Environment Authority in Sweden. Those accidents are considered occupational accidents. In addition to Sweden there is one issue that relates to schools in Denmark. It is not allowed to use a measuring cord with an unprotected end when a metallic end is achievable (*bananstik* in Danish). Only measuring cords with protected ends can be used.

8. DISCUSSION

Cawley and Homce (2003, p. 246) remind that any single preventive measures is not enough in electrical accident prevention but different aspects need to be combined. "Good judgment and common sense are integral to preventing electrical accidents" (Reese 2008, p. 174).

8.1. Electrical accidents

First the definition of the electrical accident is discussed. After that this chapter focuses on electrical accidents from 2011. First it focuses on electrical accidents of electrical professionals and then those of laymen. At last the subchapter the leisure time electrical accidents are presented.

8.1.1. Definition of an electrical accident among electrical safety authorities

The Nordic electrical safety authorities have accepted a common definition of an electrical accident. The definition is "any event electrical power has caused to a person, directly or indirectly, who is injured by an electric shock or an arc" (Statistik over elulykker 2010, p. 4). There is consensus that suicides are not considered electrical accidents in the Nordic Countries. In the interviews all the representatives representing NSS member countries admitted NSS's definition even if it was not spoken out in one of the interviews. NSS's definition says nothing about the consequences of electrical accidents which little sets the national definitions apart from each other. Electrical accidents with one or more days' absence are considered electrical accidents in Iceland and in Åland when a check-up is needed. The other countries consider all the events electrical accidents not depending on the consequences. Telling the number of days' absence from work when reporting electrical accidents is unreliable; no one can know so soon how many days' absence from work there will eventually be. Even minor electrical accidents can cause long-term consequences. This study pointed out that there are differences in interpreting an electrical accident among the Nordic electrical safety authorities.

Some electrical accidents were excluded from the accident analysis. Those accidents did not follow NSS's definition. In addition to the consequences the exclusion pointed also out that the definition is different. However, there might be reasons why the electrical accidents that were excluded in this study were in the material given by the electrical safety authorities. The accidents can tell something about the hazards in the workplace.

It is also possible that the accidents could not be removed from the material before giving it for the purposes of this study.

Resulting from the differences in defining electrical accidents it is difficult to compare the electrical accident statistics of the other countries. Usually only statistics are used when comparing the electrical safety level in the countries. Statistics should be comparable.

8.1.2. Electrical professionals

All the reported electrical accidents of electrical professionals had happened in occupational situations in 2011. However, that is most probably not true. How could it be possible that electrical professionals obey safety procedures during leisure time but not at work? Either the professionalism of the injured of leisure time electrical accidents was not told, which seems far-fetched based on the descriptions of leisure time electrical accidents, or electrical professionals do not report leisure time electrical accidents. It strongly seems that electrical professionals do not report leisure time electrical accidents to the electrical safety authorities.

Consequences and types of accidents

There were no electrical fatalities in Finland but the proportion of over 30 days' absence from work accidents was the highest in Finland. It is possible, although unlikely, that serious non-fatal electrical accidents are not reported as accurately in the other countries as in Finland. The reason behind serious non-fatal electrical accidents might be issues related to safety culture. The sample from one year cannot prove if electrical professionals in Finland act differently than their colleagues in the other Nordic Countries.

Arc accidents caused more over 30 days' absence from work accidents than shock accidents. It seems that arc accidents are more often more serious than electric shock accidents. There were no serious electrical accidents that occurred due to arcs in Norway. Norwegian electrical professionals might know better how to prevent arc accidents or they can reduce consequeces better by wearing PPE. It needs also to be remembered that the proportion of arc accidents was the smallest in Norway (12% versus 21% in the Nordic Countries).

Locations and electrical installations

In Denmark over half of the electrical accidents occurred outdoors and almost one third of the accidents involved ground cables. There were more electrical accidents with overhead power lines in Finland in percentage than in the other countries. The idea was to find out how many kilometers there are overhead power lines and ground cables in total in each country. That information was not found. The lengths of transmission network installations indicate that there might be more ground cables in percentage in Denmark than in the other countries (Statistical Yearbook 2011 2012, p. 106). If that is true it might explain partly the distribution of Danish electrical accidents involving ground cables.

The most common indoors accident location was industry: almost one third of the Nordic electrical accident occurred in industry. Industrial enterprises might have better occupational accident reporting systems than the other places reporting electrical accidents. It was not found out how the work was done in industry. It could be interesting to know if electrical professionals do not work so often alone in industry than in residential buildings and locations related to grids. If electrical professionals work surrounded by other people it might be more probable that someone reports the occurred electrical accident to the employer.

The most common location for accidents occurring outdoors was electricity distribution and production and production of heat. There was also one fatal electrical accident at a 24 kV transformer outdoors. Substations were among the three most common locations in Lindström et al.'s longitudinal study (2006, pp. 1383–1384) among fatal electrical accidents in Sweden. High voltage installations cause hazards and when preventing the realization of the hazards it needs to be remembered that it is difficult to reduce the severity of electrical contact (Soelen 2007, see Albert & Hallowell 2013, p. 119).

Accident situations

Almost half of the electrical accidents occurred when installing, repairing, replacing, modifying or extending electrical installations followed by testing, measurement or troubleshooting of electrical installations. According to Dekker (2002, p. 378) accidents usually occur in normal situations which is true when considering the accident situations of this study. Most accident situations related to different kinds of electrical installations and electrical products but some electrical accidents did not include directly electrical installations or electrical products. Some electrical accidents could also have happened to laymen. This reminds that occupational electrical accidents of professionals do not always need to be related to electrical work.

Causes

Lundberg et al. (2010, p. 2132) state that accident investigation is not usually deep enough which complicates finding the causes of the accidents. The causes mentioned in the descriptions were mainly linked to the actions of the professionals, not to the organizations. Perhaps it is easier to recognize the omissions and commissions the workers have done than to tackle organizational issues. However, Pulkkinen et al. (2009, p. 14) state that most occupational electrical accidents result from errors made by the injured.

Not obeying instructions was the most common immediate cause of the accidents followed by live parts and live electrical installations (meaning something live in them) and hurry, stress or carelessness. Not obeying instruction as the most often mentioned cause confirms that most accidents result from negligence and other actions against instructions (Kartläggning av elolyckor bland 2005, p. 14; Pulkkinen et al. 2009, p. 15). According to Tulonen (2010, p. 86) electrical accidents of electrical professionals result from omissions of safety procedures of the EN 50110-1 standard. Not obeying instructions confirms Tulonen's statement because it may be presumed that those instructions are based on the standard. Using standards is not obligatory but when using them regulatory requirements are met, so in practice they are used (Sähköasennuksia koskevat standardit n.d). It can be said that the most common cause of the electrical accidents of the electrical professionals is that they do not follow the safety procedures mentioned in the EN 50110-1 standard or somewhere else.

Most probably there are different reasons to not obeying instructions. Electrical professionals may not know the safety procedures which is hopefully not true because of the needed education to become an electrical professional. There might not be enough time or proper PPE to do perform the work safely. In the worst case electrical professionals could not care less about working safely.

Time-table related problems, production pressure, insufficient planning and taking shortcuts result in working live, not using PPE and not following safety procedures (Kowalski-Trakofler & Barrett 2007, p. 605). Goffeng and Veiersted (2001, see Goffeng et al. 2003, p. 2458) see that organization of work, time pressure and overtime, availability of equipment, degree of specialization, job rotation, distractions at work and working on multiple tasks simultaneously can cause electrical accidents. The results of this study cannot confirm what Kowalski-Trakofler and Barrett or Goffeng and Veiersted say. The causes were mentioned shortly and as written above they focused more on the actions of the professionals.

When analyzing the causes of accidents it needs to be noticed that the causes were mentioned in 70% of the electrical accidents. If all the descriptions had included the causes the results could have been different. However, the electrical accidents were at least in some way similar so the mentioned causes might indicate the causes of all the electrical accidents that occurred in 2011. All the causes were not written in the descriptions of those cases where some causes were mentioned. For example, all the descriptions did not include the information if voltage was measured or not. However, it needs always to be verified that the electrical installation is dead if dead working is planned (SFS 6002:2005:en, p. 37).

Prevention

Orientation and training were seen as good ways to improve electrical safety among electrical professionals at work in the descriptions. Employees have to be trained on issues related to safety and health at work (89/391/EEC, article 12, 1-2 §). The employer has to assess risks electricity poses. That is also mentioned on a more general level in the Occupational Safety and Health Framework Directive (89/391/EEC, article

9, 1 §). Documents have to be up-to-date and warning signs have to be placed to the places where they are needed. Communications during work is essential because only then everyone knows what the others are doing.

Voltage has to be measured before starting to work in situations where dead working is planned. In addition it needs to be ensured that the whole electrical installation is dead. When working live proper PPE and equipment should be used as mentioned in EN 50110-1-2004 (SFS 6002:2005:en, p. 23). If dead working is planned the work should not be done live. How to perform dead and live working safely is presented in the EN 50110-1-2004 standard and in the national legislation.

Electrical installations and electrical products need to be checked regularly. It is essential to check every work afterwards even though the work would be minor. In addition, electrical accident prevention might sometimes demand technical changes.

8.1.3. Laymen at work

The results of the analysis of laymen consisted of both laymen and instructed persons. The proportion of laymen excluding instructed persons was 82% but that number might include also Swedish instructed persons.

Consequences and types of accidents

No layman died at work of electricity in 2011. Fatal occupational electrical accidents are rare among layman. There has been one fatal occupational electrical accident of a layman between 2007 and 2011 in the Nordic Countries. Among electrical professionals there was 5% of serious (over 30 days' absence from work and deaths) electrical accidents when the proportion was 3% among laymen. The proportion of serious electrical accidents among laymen was the highest in Finland, 8%. It cannot be said why serious electrical accidents occurred or they were reported most in Finland. Most electrical accidents occurred due to electric shocks which is not a surprise.

Electrical installations and products

Two thirds of the electrical accidents resulted from electrical installations. There were more electrical accidents with electrical products in Sweden than in the other countries. But it needs to be remembered that the most common accident location in Sweden was schools and kindergartens where the pupils and students most probably get injured by electrical products than electrical installations. Half of the electrical installations were fixed installations. In Denmark ground cables caused one fourth of electrical accidents which was more than elsewhere. Overhead power lines accidents occurred only in Finland (17%) and Norway (9%).

Six of eight electrical accidents causing more than 30 days' absence from work resulted from electrical installations. Thus it should be noted that electrical products can also cause serious electrical accidents. The majority of electrical products were electrical products for domestics use. There were also some electrical products for professional use.

Occupations and locations

When concentrating on the occupations of the laymen, not on the occupations of the instructed persons, the biggest occupational group was technical workers followed by pupils and students and construction workers. No relevant former study was found on the occupations of the injured laymen. Studies on electrical fatalities and injuries in construction were however found (e.g. McCann et al. 2003 & Chi et al. 2009). American and Taiwanese studies highlighted that construction sites might be dangerous. Only 4% of the indoors electrical accidents were classified into construction sites in this study. The proportion of construction sites was the highest among outdoors electrical accidents.

The most common indoors accident location was industry. The second common indoors accident location was schools and kindergartens which can be explained by that the weight of the Swedish electrical accidents was significant. Swedish schools have to report electrical accidents to the Swedish Work Environment Authority that reports them to Elsäkerhetsverket.

Causes of the electrical accidents

It might seem that people recognize damaged electrical products and installations. According to the results of the accident analysis that was not true because damaged electrical installations or products were the most common cause of occupational electrical accidents of laymen. One third of the electrical accidents involving electrical products resulted from damaged electrical products. And when focusing on the laymen excluding the instructed persons one fourth of the electrical accidents resulted from damaged electrical installations or products. Most often electrical accidents result from unsafe electrical products or installations, unsafe environment or unsafe work practices (Chao & Henshaw 2002). It is not surprising that the most common cause in this study is among the most common causes stated by Chao and Henshaw (2002).

The causes included also other people's involvement. It is surprising that people do not always look after their work and finish them properly. Every worker should take care of the health and safety of others if he/she affects them somehow (89/391/EEC, article 13, 1-2 §). Everyone's occupational safety does not belong only to the worker itself and to the employer but also to other people working in the same place. Responsibility on other people is needed in some Nordic workplaces.

Not following instructions included non-electrical work related breakings of rules and electrical work related omissions and commissions. The sample included both people who were allowed to perform electrical work but there were also people who performed electrical work without permission, unauthorized. Electrical professionals and instructed persons when the professional has guided him/her to work safely are allowed to do electrical work (SFS 6002:2005:en). National legislation describes what laymen can do.

Causes were more worker-centered than management-centered in the descriptions. This might result from the way the descriptions were written or that it is difficult to identify management related causes of accidents. It cannot be said totally sure if not obeying instructions is a primary cause or not because most often the accident resulted from a damaged electrical product or installation.

Prevention of electrical accidents

The descriptions included different ways to prevent occupational electrical accidents of the laymen. Employees should be trained better. According to Casini (1993, p. 37) training at workplaces might be the only source of safety information. In addition to training revising the working instructions might prevent electrical accidents. New procedures and improvement of older ones were also mentioned.

Only electrical professionals are allowed to do electrical work related to electrical installations and electrical products. The conditions of the electrical installations and products have to be checked by electrical professionals. Damaged electrical products and installations need to be fixed and breakages need to be prevented in different ways. A damaged electrical product should be withdrawn immediately after the damage is noticed. In addition damaged electrical installations need to be fixed. When corrective measures are done, the success of repairs needs to be ensured.

Live electrical installations must never be touched or moved. It might be simple to say so but how employees can know if something is energized? Employees might not realize that electrical installations can be energized because they do not know hazards electricity poses. The hazards overhead power lines causes and the right working methods need to be known when working near overhead power lines.

8.1.4. Leisure time

Leisure time electrical accidents were reported to the electrical safety authorities in Sweden, Finland and Norway. This does not mean that leisure time electrical accidents occurred only in those countries. Most probably fatal electrical accidents are reported to the electrical safety authority in each country. The accidents of Sweden, Finland and Norway included also non-fatal accidents. The authorities have done something that makes reporting accidents desirable. It is also possible that the non-fatal electrical accidents were such accidents that needed response from the electrical safety authorities. The reason to report non-fatal electrical accidents to the electrical safety authority might be public health and safety reasons as told in the interviews.

There were three fatal electrical accidents during leisure time in the Nordic Countries in 2011. The Finnish victim had climbed on a train and died of the contact lines. Aerial power lines, mainly at a railway area, caused most of the fatal electrical accidents in Sweden between 1975 and 2000 (Lindström et al. 2006, pp. 1383–1384). In Sweden parking trains de-energized has become more common which has improved electrical safety (Lindström et al. 2006, p. 1386). Trains are parked de-energized also in Norway. However, trains are not parked de-energized in Finland. That might be the reason that there have been electrical accidents at railway area every year between 2009 and 2011 in Finland.

All the fatal electrical accidents occurred outdoors in 2011. The other matter in common between the fatal electrical accidents was the electrical installations: they were high voltage electrical installations. However, low voltage does not mean a low hazard (Reese 2008, p. 167 & 176). The proportion of electrical accidents involving electrical products was the highest in Finland. Reported electrical products were separate products in the Nordic Countries and the reported number of electrical accidents was very small. Therefore it cannot be said which electrical product cause most electrical accidents during leisure time.

Even though the fatal electrical accidents occurred outdoors most electrical accidents occurred indoors. The majority of indoors electrical accidents occurred at home. Only five accidents of 29 indoors electrical accidents occurred somewhere else. In addition almost every electrical accident occurred during normal household activities.

The descriptions included some preventive measures. When felling trees it is good to consult the distribution company and plan the work properly before starting work. It needs to be remembered that trespassing at railway yards and as a whole on railways is forbidden. The Swedish Transport Administration has noticed that information campaigns concerning safety at the railroads are forgotten over the time (Sundvall 2011, p. 6). In addition laymen need to remember that they are not allowed to perform electrical work.

8.2. Views on electrical safety

8.2.1. Underreporting

Most electrical accidents per 100 000 people were reported to DSB in Norway in 2011. This does not indicate that there were more electrical accidents in Norway than elsewhere. Most likely people report electrical accidents more often to the electrical safety authority in Norway than in the other countries. It would be important to find out why people report electrical accidents most often in Norway because the other countries could learn from Norway.

When discussing underreporting of electrical accidents it needs to be remembered that all the electrical accidents do not have to be reported to the electrical safety authorities. The legislation is broader in Norway than in the other Nordic Countries. Different legislation might affect the number of reported electrical accidents. It was said that the reported number of electrical accidents tells more about activeness to inform the electrical safety authorities than the absolute electrical safety situation. That can be true because the authorities estimated that only 10-15% of electrical accidents are reported to them. In Sweden there were 438 electrical accidents in 2011 but the true number might be 4000-5000. The Danish estimation tells about 3500 electrical accidents and the Norwegian about 3000. Sometimes health and safety reasons might affect reporting electrical accidents to the electrical safety authority.

It seems that the electrical safety authorities get information on all the fatal electrical accidents. Every electrical accident of electrical professionals is not reported to the electrical safety authority as well as most occupational electrical accidents of laymen and leisure time electrical accidents. Especially minor electrical accidents are not reported. Hultgren and Rosèn (1988, see Goffeng et al. 1997, p. 9) suspect that reporting routines do not favor reporting minor electrical accidents. Minor electrical accidents might not be reported because nothing really happened; the person involved did not get hurt. Professionals might think that electrical accidents are just a part of work. Professionals do not always report electrical accidents if they consider that the accident resulted from their own mistakes (Pulkkinen et al. 2009, p. 21). It has been said that every professional has been in an electrical accident during his/her career (Tulonen et al. 2006, p. 46). One third of Icelandic electrical professionals have had an electrical accident or a mishap at least once in her/his life (Scope of electrical accidents 2005, p. 9). It is obvious that not all of those accidents are reported to the electrical safety authorities.

Employees should not have to decide themselves which electrical accident is serious and thus to be reported and which one is not (Kartläggning av elolyckor bland 2005, pp. 5–6). If electrical safety authorities want to receive more electrical accident reports it is necessary to define clearer what electrical accidents need to be reported (Goffeng et al. 2003, p. 2458).

8.2.2. Electrical safety problem areas

There are electrical safety problem areas in the Nordic Countries today and new risks can also cause harm in the future. Cutting corners, not following instructions, is one of the problem areas among electrical professionals. Not following instructions means for example situations where the professionals do not measure voltage before starting to work. There are reasons why electrical professional do not measure voltage. However, electrical professionals should always measure voltage and have time to perform it right. Sometimes electrical professionals have to work alone against their wishes which is problematic. They have to work in hurry and produce more all the time.

Laymen do not know the hazards electricity poses. That is also true among electrical professionals (e.g. Kowalski-Trakofler & Barrett 2007, p. 602). Laymen should always know what they are doing and leave the electrical work to the electrical professionals. People do not always know when electrical products are damaged. Cords can be broken and regardless of that electrical products are used.

Technology can pose emerging risks (Improving quality and 2007, p. 6). Electric cars and solar cells were seen as emerging risks in the interviews. The electrical system might not be ready for electric cars and solar cells. In addition there are other unsolved problems related to them. In addition to technology, extreme weather can affect electrical safety. The accident analysis included a couple of accidents where the weather has caused breakages that needed to be repaired.

The change of generation and the increase of foreign labor force can affect electrical safety. It is true that Nordic people are aging and immigration increases (Nordic Statistical Yearbook 2012, p. 38 & 46). Increased immigration can cause language skills problems. Norway, where the proportion of foreigners is the highest (Nordic Statistical Yearbook 2012, p. 48), has written language skills requirements for foreigners in their legislation concerning electrical safety (FOR 1993-12-14 nr 1133, 28 §). The other problem the immigration poses might be that people may be forced to perform electrical work without the qualifications. The foreigners should be made more aware of the electrical safety regulations. But for them saying no to electrical work is not always an option. This qualification problem connects to bigger social problems. However, it cannot be said if the immigrants encounter more electrical accidents.

The increase of societal inequality and the increase of crime are among social problems that might affect electrical safety. Two people died in Sweden in 2010 when they were steeling copper (Kilsgård 2011, p. 2). Electrical accidents related to steeling copper might occur in the other countries as well.

8.2.3. Utilization of electrical safety information

Electrical safety authorities and occupational safety and health authorities collect electrical safety information in the Nordic Countries. Occupational safety and health authorities focus only on occupational electrical accidents. Thus only the electrical safety authorities know about leisure time electrical accidents. It was not asked how the occupational safety authorities use electrical accident information. For example in Sweden, the Swedish Work Environment Authority is responsible for the work injury statistics (Statistics n.d). In Finland the occupational safety and health authority publishes inspections reports of occupational accidents on the web. The police investigate serious electrical accidents but it does not really collect electrical accident information.

National statistics authorities compile statistics on occupational accidents and they use the ESAW classification (European statistics on accidents at work 1999, p. 1). It is possible to use occupational accident information coded in in the ESAW method to get information on electrical accidents when certain corrective actions are made (Hintikka 2007, p. 32). However, all the electrical safety authorities did not know that national statistics authorities collect also electrical accident information. In Finland, the Federation of Accident Insurance Institutions collects also occupational electrical accident data which results from the different kind of occupational accident insurance system compared to the other Nordic Countries.

It was questioned whether the electrical safety authorities can improve the electrical safety level and prevent more electrical accidents. It might be difficult to reduce more electrical accidents. However, electrical accident prevention work is continuous. It might feel that electrical accident prevention does not succeed in because the results cannot be seen directly. The time span of preventing electrical accidents might be longer. For example, according to Lindström et al. (2006, p. 1383) improvements to promote electrical safety have been successful in Sweden in the time period 1975-2000. The results cannot be expected immediately.

The electrical safety authority can guide people to work according to instructions but people decide themselves how they work or act. The electrical safety authority can communicate on how electrical professionals should work safely. It is also essential to inform where instructions can be found. Electrical safety authorities can participate in improving legislation and standards.

The Nordic electrical safety authorities publish electrical safety information differently. Elsäkerhetsverket publishes annually electrical accident statistics without any qualitative information on non-fatal electrical accidents. The yearly report of Sikkerhedsstyrelsen and DSB include both quantitative and qualitative electrical accident information. Sikkerhedsstyrelsen could not publish their yearly report "Ulykkestatistekken" for the years 2011 and 2012 because of the changes in their database (Ulykkesstatistikken for 2011 og 2012). It is unsure if they will publish statistics in the future. However, Sikkerhedsstyrelsen guides to use other material that can be found on their webpages. (Ulykkesstatistikken for 2011 og 2012 2013.) The yearly report of Tukes presents the statistical information related to the occurred electrical accidents. All the accidents reported to Tukes are registered in the VARO database. Only in Finland it is possible to search for electrical accidents online. It can be easier to search by using certain keywords in the database than by reading through the publications from different years to find information. Mannvirkjastofnun does not publish electrical accident statistics as the number of reported electrical accidents is too small to compile the statistics. Grønlands Elmyndighed and Elnevndin do not publish any electrical accident information either. The smaller Nordic countries could benefit from the electrical accident information collected by the other countries if they wanted to show examples of what can occur. Anyway people might be more open to learn about electrical accidents that have occurred in their own country than somewhere else.

All the Nordic electrical safety authorities could utilize the collected electrical accident information more variedly. Collecting and processing electrical accident information demand investments. However, the resources might be limited. The investments are best used when the electrical accident information is used widely. In addition to statistics more qualitative information could be presented. Accident descriptions could tell more in more detail how electrical accidents occur.

The target groups of the electrical accident material might have different information needs. Suominen (2012, p. 42), who studied how the VARO database can be improved, states that teachers in the field of electricity would like to use diagrams and charts most often. Descriptions are also a popular form of the accident information (Suominen 2012, p. 42). The electrical accident information should respond to all the needs of every information user. Electrical safety authorities know more about electrical accidents than the other organizations or authorities. Thus they should be able to answer all the information requests and share their knowledge more widely for preventing electrical accidents.

8.3. Proposals for action for the co-operation of the Nordic electrical safety authorities

Different kinds of electrical accidents are reported to the electrical safety authorities in each Nordic Country and they might have different know-how on electrical accidents. The electrical accident material was the largest in Sweden. Electrical accidents that occur at schools or kindergartens are reported most in Sweden. The Danish electrical accident material was not so large. The Danes may know more about electrical accidents involving ground cables than the others because the proportion of those accidents among electrical professionals was the highest. In Finland the proportion of electrical accidents involving overhead power lines was the highest among electrical professionals and laymen at work. In addition there have been leisure time electrical accidents on a railway yard in Finland last years. The Norwegian electrical accident material was the largest when compared to the population. The material included most electrical accidents that occurred to instructed persons. Iceland and Greenland do not publish their few electrical accidents. The Faroe Island does not collect electrical accident information.

At first NSS’s definition of an electrical accident seemed simple. However, the definition differed in different countries. To be able to compare electrical accidents the material should be uniform. Statistical information needs to be remembered to be compared to different issues. Discussing can reveal new things that affect electrical safety and new ideas to promote electrical safety.

There are reasons why the number of reported electrical accidents differs. Legislation can explain one part. It should also be focused on the reporting practices; whether it is easier to report optional electrical accidents in one country than in another. In addition it would be useful to define from which sources the current electrical accident information comes.

The electrical accident information is at its best when the electrical accident information from all the countries is available. Not so wide electrical accident material can make accident prevention more difficult. It can be difficult to notice new hazards from the smaller electrical accident material but at least it is less difficult from the larger material. The electrical safety authorities could combine their electrical accident knowledge and organize together campaigns on electrical accident prevention. The Nordic electrical safety authorities are each other's colleagues and they might understand each other and the challenges they are facing. Together they can work for changing attitudes towards safety working procedures and making the Nordic Countries even better in electrical safety issues.

8.4. Study evaluation

8.4.1. Limitations

The accident analysis included only one year, year 2011, because of the problems in gaining material from the years 2007-2010. When generalizing the results it needs to be remembered that they present the electrical safety situation in 2011. The sample was small. All the occurred electrical accidents in the Nordic Countries in 2011 could not be taken into the analysis which meant that the sample was even smaller. The reasons included for example unfinished descriptions. In addition it is possible that some electrical accidents should be included but they were not included because of problems in data processing. Even though the description was done some electrical accidents were excluded because the analysis focused only on electrical professionals, instructed persons and laymen. Instructed persons and laymen had to be joined. Perhaps instructed persons and electrical professionals should have been analyzed together because they both perform electrical work. Joining them was not possible. If the instructed persons had been analyzed by themselves new issues could have emerged.

It was considered how to present the Nordic results. It was decided to combine all the electrical accidents. The countries with more electrical accidents had a larger weight than the others. It might have been possible to weight the countries differently for example based on the population distribution.

The electrical accident analysis was planned to be done differently at first. It was meant to analyze all the Nordic electrical accidents from the years 2007–2011 statistically. After that the idea was to choose one year that represents the electrical safety situation best in the Nordic Countries. A statistical analysis followed by a qualitative analysis of one year could maybe have met the objectives better and at least reduce the impact of the yearly variation. However, if the statistical analysis of all the years had been done the material should have been comparable and it should have included only electrical accidents defined by NSS. The accident analysis done showed that the raw data included also accidents that were not electrical accidents in the terms of NSS. All the descriptions between 2007 and 2010 should have been read through to ensure that there were only electrical accidents which would have taken a lot of time to accomplish. In addition the electrical accident material given by different electrical safety authorities was of a different form and the harmonization of them would also have taken a lot of time.

The electrical accident material used included some limitations. It needs to be remembered that the material used in the electrical accident analysis was secondary data. The accident descriptions and classifications did not include all the information needed for the analysis. It was not possible to analyze organizational causes of the electrical accidents because the material did not include that kind of information. There were a lot of categories with unknown options which may influence the results. The information request did not totally meet the analysis done. It was not asked for if the electrical accident involved an electrical installation or an electrical product. In addition the Danish electrical accidents did not originally include the location because it was not asked for to give. The Danish representatives gave the information afterwards. Classifying the electrical accidents demanded choices. If there were conflicts between descriptions and classifications the descriptions were trusted most often. The choice could have been incorrect and partly unreasoned.

The representatives helped when there were unclarities. They helped with difficult technical terminology and especially with jargon terms. Even though help was received there were left some limitations related to languages and cultures. The writer of the study is Finnish-speaking and most of the electrical accident material was written in Swedish, Norwegian and Danish. Speaking English in the interviews might have influenced the quality of the answers. However, the interview situation was wanted to keep pleasant and relaxed. It needs to be admitted that the other Nordic countries than Finland were seen with external eyes. The study can weight towards Finland more than towards the other countries even though it was not meant.

The writer of the study is not an electrical professional and some writers of the descriptions could also be laymen. Some technical issues could be misunderstood by the writer of the study or by the writers of the descriptions. However, in practice only the Finnish descriptions were technology-oriented. The writer of study classified some Finnish electrical accidents and wrote their descriptions. The person responsible for the VARO database checked the cases the writer of the study had made.

The way of the accident analysis was done was piecewise because it took time to read all the electrical accident descriptions written in different languages. It is possible that the classification changed during the analysis. However, the analysis done was observed during the analysis process and corrections were made.

The descriptions included mainly first-hand information on electrical accidents which resulted probably partly from the requirements to report the electrical accident so soon after it has occurred. Information was not improved later. The first-hand knowledge could be seen in the causes of the accidents; "the firm estimates that the causes were…". In addition the person who reported the electrical accident could not be totally sure of the consequences of the electrical accident when he/she reported the accident. Another observation related to the consequences was that consequences were not expressed totally comparable. When observing the consequences of the Norwegian electrical accidents it needs to be noticed that the consequences of a minor injury (*lett skade* in Norwegian) could be either *a medical examination or no medical examination without any days absence from work* or *a medical examination with 1-30 days' absence from work*. The classification of those classes is not totally reliable. In addition it needs also to be noticed that the absence was 2-5 weeks in the classification of one Danish accidents and that was combined with the Finnish classification over 30 days' absence from work. That accident could also have been an electrical accident with 1-30 days' absence from work.

The structures of the descriptions were different. Most Swedish, all the Icelandic and Greenlandic descriptions were shorter. It could be noticed from them that they were not ment to be published. The descriptions of the Danish electrical accidents included various sentences. It could be noticed from the Finnish and the Norwegian descriptions that they were/will be published. However, the cases the Norwegian representative gave during the second interview did not follow the structure of the earlier cases. Most Norwegian electrical accidents included information against which article the work was done. Those were seen as not obeying instructions.

Finding causes behind the accidents has been seen as an important way to prevent electrical accidents. Even though finding causes is important it was not always easy. All the descriptions did not include causes. In addition all the causes were not probably mentioned in the descriptions where some causes were mentioned. Sometimes it was difficult to define what causes were and whose causes were. For example if the cleaner was cleaning and he/she touched unprotected cables, was the cleaner careless or has the electrical professional caused the accident? Most probably firms find causes and suitable preventive measures after they have reported electrical accidents to the electrical safety authority. Causes and preventive measures might not be reported to the electrical safety authorities because electrical accidents need to be reported so soon.

The theory focused more on occupational electrical accidents of electrical professionals than those of laymen and leisure time electrical accidents. It was difficult to compare non-fatal occupational electrical accidents of laymen and leisure time electrical accidents to the theory. Either the relevant theory was not found or there is no relevant theory.

8.4.2. Achievement of the objectives

The objective of this study was to gain deeper knowledge about electrical safety hazards in the Nordic Countries. The electrical accident analysis revealed new aspects on electrical accidents in the Nordic Countries even though the time span was a limitation. The accident analysis and the identified differences can be seen as a basis for accident prevention work of the Nordic electrical safety authorities.

The main research problem was how the electrical safety can be improved in the Nordic Countries. The results were non-specific concerning mainly the Nordic electrical safety authorities. It might have been possible to introduce more specific preventive measures if it had been ensured that the yearly variation would have been smaller.

Electrical safety problem areas were found both in the electrical accident analysis and in the interviews. Emerging risks concerning mainly technological changes were from the interviews. Few best practices were found in the study. It could have been found more best practices that are easy to realize both by electrical safety authorities and employers. Adopting the best practices to other countries was not studied in this study even though it was planned to be studied. The theory, the interviews or the accident analysis did not focus on adopting best practices to other countries. It is possible that best practices and adopting them should have been focused more. But there was not enough time and media to find more of them.

8.5. Future research

This study gave a limited picture of leisure time electrical accidents because of the small number of the reported leisure time electrical accidents and the short time frame. Most leisure time electrical accidents do not most probably need to be reported to electrical safety authorities. It might be that most leisure electrical accidents analyzed in this study were reported to the electrical safety authority because the people wanted the electrical safety authority to react. A lot of leisure time electrical accidents were missing from this study. For getting a larger picture of leisure time electrical accidents the sample should be bigger. Organizing a questionnaire study made out in a specified form in each country could be a simple way to collect leisure time electrical accident information. The questionnaire could include, for example, questions related to damaged electrical products and electrical work laymen are allowed to do.

A longitudinal statistical study could help to find the changes in the electrical safety situation and best practices in electrical accident prevention. If the source material for the study comes from the Nordic electrical safety authorities certain issues will need to be remembered. They collect different kind of information and focus on different kinds of aspects. The data collection is different in each country and there might be even differences resulting from changes in the data collection or the database over the years in one country. If it is possible all the descriptions used in the study should include all the causes behind the accidents. Most probably it is not possible. Somehow the causes behind electrical accidents should be found out better, especially those of occupational electrical accidents of laymen and leisure time electrical accidents. In addition it would be interesting to know how aging affects electrical safety.

Electrical accidents of electrical professionals have been studied in the Nordic Countries. New aspects could be introduced to those studies. It could be possible to study what the electrical safety situation is in the small firms working in the field of electricity. In addition it would be interesting to know what kinds of electrical accidents occur when electrical professionals are working alone.

This study presented certain differences in the Nordic Countries. The field was wider than expected when starting the study. If more differences were presented it could be simpler to explain the differences in electrical safety in the Nordic Countries. Possible themes for future research include for example differences in legislation, how the electrical safety authorities can affect (for example bans of sales and communications) and attitudes of citizens towards electrical safety and electrical accident reporting.

This study pointed out that electrical accidents are reported both to electrical safety authorities and the occupational safety authorities. A co-operation study with occupational safety authorities could reveal some new aspects. Also estimating the functionality and effectiveness of electrical safety communications could reveal new aspects. Estimating the functionality of the communications could highlight the areas where more preventative measures could be introduced. It is essential to find out what kind of information is needed in electrical accident prevention work because the Nordic electrical safety authorities cannot do all the accident prevention work themselves.

9. CONCLUSIONS

The Nordic electrical accidents from the year 2011 were analyzed in this study. The rate of under-reporting was high. It could be unclear what electrical accidents need to be reported to the Nordic electrical safety authorities. The number of the reported electrical accidents varied a lot country by country. Different kinds of electrical accidents were reported to the electrical safety authorities and the authorities know about different kinds of electrical accidents based on this study. The difference of the number of the reported electrical accidents might result from the legislation, the electrical accident reporting practices or the yearly variation. The electrical accident reporting practices include for example how electrical accidents are reported and how people find reporting them.

The electrical accident information could be used better in electrical accident prevention in the Nordic Countries. The Nordic electrical safety authorities could for example organize campaigns on electrical accident prevention together. The Nordic electrical safety authorities could also use information on electrical accidents that occur in the other countries better because the electrical accident material is different. For example, electrical accidents that occur at schools are reported most in Sweden. In addition, the electrical safety authorities could share more their best practices on electrical accident prevention. Leisure time electrical accidents were not reported to every Nordic electrical safety authority in 2011 and thus the material was small in this study. By combining their knowledge especially on leisure time electrical accidents the electrical safety authorities would know better what kinds of hazards people are facing during leisure time and how those electrical accidents could be prevented. Even though electrical accident prevention might seem difficult from time to time it needs to be remembered that electrical accident prevention is continuous work all the time.

Current electrical safety problem areas may not disappear even though new emerging risks arise. Damaged electrical products and installations caused most occupational electrical accidents of laymen and not obeying instructions those of electrical professionals in this study. Attitudes of electrical professionals should be changed towards working safely. However, it needs to be remembered that organizational causes were very rarely reported in the material of the study even though they most likely exist. In addition, electrical professionals do not report leisure time electrical accidents even though they most probably also occur. Emerging risks can concern for example technological and demographic changes.

This study revealed few best practices explaining differences in electrical safety between the Nordic Countries. For example, trains are parked de-energized in some countries. More occupational electrical accidents of laymen were reported to the Nordic electrical safety authorities than those of electrical professionals in 2011. Occupational electrical accidents do not affect only the electrical safety authorities but also the occupational safety and health authorities why co-operating more with them could be useful in occupational electrical accident prevention.

REFERENCES

89/391/EEC. Council directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.

89/391/EEG. Rådets direktiv av den 12 juni 1989 om åtgärder för att främja förbättringar av arbetstagarnas säkerhet och hälsa i arbetet.

89/391/EØF. Rådets direktiv av den 12. juni 1989 om iværksættelse af foranstaltninger til forbedring af arbejdstagernes sikkerhed og sundhed under arbejdet.

89/391/ETY. Neuvosteon direktiivi, annettu 12 päivänä kesäkuuta, toimenpiteistä työntekijöiden turvallisuuden ja terveyden parantamisen edistämiseksi työssä.

A 28.6.1996/498. Sähköturvallisuusasetus.

Albert, A. & Hallowell, M.R. 2013. Safety risk management for electrical transmission and distribution line construction. Safety Science. 51, pp. 118–126.

American Medical Association (AMA). (1998). A tale of two stories: contrasting views of patient safety. Report from a workshop on assembling the scientific basis for progress on patient safety. Chicago, IL: National Patient Safety Foundation at the AMA.

Anmälan av elolycka och tillbud. 2012. Elsäkerhetsverket. Updated 19.9.2012, [cited 23.11.2012]. www.elsakerhetsverket.se/sv/Elolyckor/Anmalan-av-elolycka-och-tillbud/

Ansvarig svensk kommitté [www]. n.d. Svensk elstandard. [cited 7.2.2013]. www.elstandard.se/standarder/visa.asp?IDnr=889601

Arbetsmiljöförordning 1977:1166.

Attwood, D., Khan, F. & Veitch, B. 2006. Occupational accident models - Where have we been and where are we going?. Journal of Loss Prevention in the Process Industries. 19, pp. 664–682.

Aven, T. 2011. On risk governance deficits. Safety Science. 49, pp. 912–919.

Bekendtgørelse om administration m.v. af stærkstrømsloven, nr 177 af 20. marts 1995.

Bekendtgørelse om anmeldelse af arbejdsulykker m.v. til Arbejdstilsynet nr 615 af 08/06/2010.

Capelli-Schellpfeffer, M., Landis Floyd II, H., Eastwood, K. & Liggett, D.P. 2000. How We Can Better Learn from Electrical Accidents. IEEE Industry Applications Magazine. 6, pp. 16–23.

Casini, V.J. 1993. Occupational electrocutions: Investigation and prevention. Professional Safety. 34, 1, pp. 34–39.

Cawley, J.C. & Brenner, B.C. 2012. Occupational Electrical Injuries in the US, 2003-2009. 2012 IEEE IAS Electrical Safety Workshop (ESW), Hilton Daytone Beach Oceanfront Hotel Daytona Beach, FL, USA, 31.1.-3.2.2012, IEEE, 5 p.

Cawley, J.C. & Homce, G.T. 2003. Occupational electrical injuries in the United States, 1992-1998, and recommendations for safety research. Journal of Safety Research. 24, pp. 241–248.

Cawley, J.C. & Homce, G.T. 2008. Trends in Electrical Injury in the US., 1992-2002. Transactions on Industry Applications. 44(4), pp. 962–972.

Cawley, J.C. 2001. Electrical accidents in the Mining Industry, 1990-1999. Industry Applications Conference, 2001. Thirty-Sixth IAS Annual Meeting. Conference Record of the 2001 IEEE. 8 p.

Cawley, J.C. n.d. Occupational Electrical Accidents in the U.S., 2003-2009 [www]. An ESFI White Paper. [cited 13.2.20132]. www.esfi.org/index.cfm/pid/10272/cdid/11510. 9 p.

Chao, E.L. & Henshaw, J.L. 2002. Controlling electrical hazards [www]. OSHA 3075. [cited 19.2.2013]. www.osha.gov/Publications/3075.html

Chi, C.-F., Lin, Y.-Y. & Ikhwan, M. 2012. Flow diagram analysis of electrical fatalities in construction industry. Safety Science. 50, pp. 1205–1214.

Chi, C.-F., Yang, C.-C. & Chen, Z.-L. 2009. In-depth accident analysis of electrical fatalities in the construction industry. International Journal of Industrial Ergonomics. 39, pp. 635–644.

Definition and description of "emerging risks" within the EFSA's mandate [www]. 2007. European Food Safety Authority. EFSA/SC/415 Final. Parma. www.efsa.europa.eu/en/scdocs/doc/escoemriskdefinition.pdf. 2 p.

Dekker, S.W.A. 2002. Reconstructing human contributions to accidents: the new view on error and performance. Journal of Safety Research. 33, pp. 371–385.

Denscombe, M. 2007. The Good Research Guide. 3rd edition. Buckingham, Open University Press.

DS/EN 50110-1:2005 [www]. n.d. Dansk standard. [cited 7.2.2013]. webshop.ds.dk/product/51884/standard.aspx

DSB som organisasjon [www]. 2009. DSB. Published 3.11.2009, updated 5.11.2012, [cited 28.11.2012]. dsb.no/no/toppmeny/Om-DSB/DSBs-organisasjon-/

Electrical Safety Code of Practice 2010 Risk Management [www]. 2010. Electrical Safety Office Queensland. [cited 22.3.2013]. www.justice.qld.gov.au/__data/assets/pdf_file/0015/25404/cop-risk-management.pdf. 60 p. + 14 app.

Elinstallatörsförordning 1990:806.

Ellag 1997:857.

ELSÄK-FS 2006:1. Elsäkerhetsverkets föreskrifter och allmänna råd om elsäkerhet vid arbete i yrkesmässig verksamhet.

ELSÄK-FS 2007:2. Elsäkerhetsverkets föreskrifter om behörighet för elinstallatörer.

ELSÄK-FS 2012:1. Elsäkerhetsverkets föreskrifter om anmälan av olycksfall, allvarliga tillbud och driftstörningar.

Elsikkerhet [www]. n.d. DSB. [cited 28.11.2012]. www.dsb.no/no/Ansvarsomrader/EL-sikkerhet/

Elsikkerhet nr. 73 [www]. 2008. DSB. Juni 2008, 01/08, årgang 37. [cited 29.3.2013]. http://www.dsb.no/Global/Publikasjoner/Andre/Elsikkerhet/73.pdf. 55 p.

Elsikkerhet nr. 75 [www]. 2009. DSB. Juni 2009, 02/09, årgang 38. [cited 10.3.2013]. www.dsb.no/Global/Publikasjoner/Andre/Elsikkerhet/Elsikkerhet%2075.pdf. 59 p.

Elsikkerhet nr. 77 [www]. 2010. DSB. Juni 2010, 2/10, årgang 39. [cited 10.3.2013]. www.dsb.no/Global/Publikasjoner/Andre/Elsikkerhet/Elsikkerhet_77.pdf. 75 p.

Elsikkerhet nr. 79 [www]. 2011. DSB. Juni 2011, 1/11, årgang 40. [cited 10.3.2013]. www.dsb.no/PageFiles/4731/el-sikkerhet%2079.pdf. 71 p.

Elsikkerhet nr. 81 [www]. 2012. DSB. Juni 2012, 02/2012, årgang 41. [cited 10.3.2013]. www.dsb.no/Global/Elsikkerhet/Elsikkerhet/Elsikkerhet%2081.pdf. 55 p.

ENTSO-E Member Companies [www]. 2012. ENTSO-E. [cited 27.4.2013]. www.entsoe.eu/about-entso-e/member-companies/

European Statistics on Accidents at Work (ESAW). 2013. Luxembourg, Publications Office of the European Union. 59 p.

European statistics on accidents at work. 1999. Luxembourg, European communities. 54 p.

Fischer, L.K. 2004. The Dangers of Arc Flash Incidents. Maintenance Technology. February, 5 p.

Floyd, H.L. II. 2012. Facilitating Application of Electrical Safety Best Practices. Electrical Safety Workshop (ESW), 2012 IEEE IAS, Wilmington, DE, USA, Jan. 31 2012-Feb. 3 2012. IEEE. Paper No. ESW 2012-07. 6 p.

FOR 1993-12-14 nr 1133: Forskrift om kvalifikasjoner for elektrofagfolk.

FOR 1998-11-06 nr 1060: Forskrift om elektriske lavspenningsanlegg.

FOR 2001-12-04 nr 1450: Forskrift om maritime elektriske anlegg.

FOR 2005-12-15 nr 1690: Forskrift om medisinsk utstyr

FOR 2005-12-20 nr 1626: Forskrift om elektriske forsyningsanlegg.

FOR 2006-04-28 nr 458: Forskrift om sikkerhet ved arbeid i og drift av elektriske anlegg.

FOR 2011-01-14 nr 36: Forskrift om elektrisk utstyr.

Föreskrifter. 2012. Elsäkerhetsverket. Updated 28.9.2012, [cited 22.11.2012]. www.elsakerhetsverket.se/sv/Lag-och-ratt/Foreskrifter/

Generelt. Elnevndin. n.d. [cited 30.11.2012]. www.elnevndin.fo/dk/0_0_1/Forside/Forside.php

Goffeng, L.O. & Veiersted, K.B. 2011. Ulykkesrapportering, oppfatning av ulykkesårsaker og mulige forebyggingsstrategier i elektrobransjen. Abstrakt. I: Skyberg K, Kjuus H, Bredrup AJ, Siguenza E, red. 48. Nordiske arbeidsmiljømøte Trondheim, 3.–5. september 2001: Oslo: Statens arbeidsmiljøinstitutt. pp. 219–220.

Goffeng, L.O., Haugen A. & Melheim, O. 1997. Karlegging av arbeidsoppgaver og strømstøt blant ansatte i et energiverk [www]. Statens arbeidsmiljøinstitutt. HD 1079/97 FaD. [cited 22.3.2013]. bilder.bibits.no/stami/Gamle%20HD/1997/HD%201079%201997.pdf. 49 p.

Goffeng, L.O., Veiersted, K.B., Moian, R., Remo, E., Solli, A. & Erikssen, J. 2003. Forekomst og forebygging av strømulykker i arbeidslivet. Tidsskrift for Den norske legeforening. 123, 17, pp. 2457–2458.

Gravseth, H.M., Wergeland, E. & Lund, J. 2003. Underrapportering av arbeidsskader til Arbeidstisynet. Tidsskrift for Den norske legeforening. 123, 15, pp. 2057–2059.

Grønlands Elmyndighed. n.d. Nukissiorfiit. [cited 30.11.2012]. www.nukissiorfiit.gl/dk/om_nukissiorfiit/groenlands_elmyndighed/

Hämäläinen, P., Takala, J. & Saarela K.L. 2006. Global estimates of occupational accidents. Safety Science. 44, pp. 137–156.

Hansen, F.A. 2012. Grønlands Elmyndighed. Interview 9.10.2012.

Hansen, J.S. 2012. Secretary, Elnevndin. A written interview by email 21.11.2012.

Heinä-elokuun 2010 rajuilmat. 2010. Onnettomuustutkintakeskus, S2/2010Y. [cited 18.12.2012].www.turvallisuustutkinta.fi/Satellite?blobtable=MungoBlobs&blobcol=urldata&SSURIapptype=BlobServer&SSURIcontainer=Default&SSURIsession=false&blobkey=id&blobheadervalue1=inline; filename=Tutkintaselostus_S2-2010Y_VALMIS_nettiin.pdf&SSURIsscontext=Satellite Server&blobwhere=1330439898659&blobheadername1=Content-Disposition&ssbinary=true&blobheader=application/pdf. 149 p. + 9 app.

Heinsalmi, K. & Mattila, M. 2008. Toimialan onnettomuudet 2007 [www]. Turvatekniikan keskus, Helsinki. Tukes-julkaisu 2/2008. www.tukes.fi/Tiedostot/julkaisut/2_2008.pdf. 59 p. + 23 app.

Hintikka, N. 2007. Tapaturmatilastojen hyödyntäminen sähköturvallisuutta kuvaavan indikaattorin kehittämiseksi TUKESissa. Tutkimusraportti 18.1.2007. [cited 22.3.2013]. www.tukes.fi/Tiedostot/varoasiat/TUTRaportti%20180107.pdf. 34 p. + 3 app.

Hollnagel, E. 2004. Barriers and Accident Prevention. Burlington, VT Ashgate. 226 p.

Hollnagel, E. 2006. Resiliece - the Challenge of the Unstable. In Hollnagel, E., Woods, D.D. & Leveson, N. Resilience Engineering : Concepts and Precepts. Abington, Ashgate Publishing. pp. 9–18.

Hovden, J., Albrechtsen, E. & Herrera, I.A. 2010. Is there a need for new theories, models and approaches to occupational accident prevention?. Safety Science. 48, pp. 950–956.

Hultgren, M. & Rosèn, G. 1988. Hälsorisker i arbete vid elprodukion och eldistribution. Delrapport 5: Exponering för kemiska belastningsfakorer. Arbetsmiljöinstitutet, Solna. Undersökingsrapport 1988 :22.

Iceland Construction Authority. n.d. [cited 30.11.2012]. www.mannvirkjastofnun.is/um-stofnunina/english/iceland-construction-authority/

Improving quality and productivity at work: Community strategy 2007-2012 on health and safety at work. 2007. The European Commission. 21.2.2007, [cited 12.3.2013]. COM(2007) 62 final. 15 p. eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0062:FIN:en:PDF

Introduction [www]. 2011. Eurostat. Updated 11.11.2011, [cited 31.3.2013]. epp.eurostat.ec.europa.eu/portal/page/portal/ess_eurostat/introduction

Janicak, C.A. 2008. Occupational fatalities due to electrocutions in the construction industry. Journal of Safety Research. 39, pp. 617–621.

Kartläggning av elolyckor bland elyrkesmän [www]. 2005. Elsäkerhetsverket. [cited 9.11.2012]. www.elsakerhetsverket.se/Global/PDF/Elolyckor/Unders%C3%B6kningar/Kartlaggning_av_elolyckor_bland_elyrkesman_2005.pdf. 33 p (+ 34 p. app).

Kilsgård, L. 2008 (ed.). Elolycksfall 2007 [www]. [cited 9.3.2013]. www.elsakerhetsverket.se/Global/PDF/Elolyckor/Elolycksfallsrapporter/Elolycksfall_2007_webb.pdf. 35 p.

Kilsgård, L. 2009 (ed.). Elolyckor och elbränder 2008 [www]. [cited 9.3.2013]. www.elsakerhetsverket.se/Global/PDF/Elolyckor/Elolycksfallsrapporter/Elolyckor_2008_webb.pdf. 85 p.

Kilsgård, L. 2010 (ed.). Elolyckor och elbränder 2009 [www]. [cited 9.3.2013]. www.elsakerhetsverket.se/Global/PDF/Elolyckor/Elolycksfallsrapporter/Elolycksrapport2009.pdf. 77 p.

Kilsgård, L. 2011. Rapport elolyckor 2010, Redovisning av statistik uttagen från Elsäkerhetsverkets databas [www]. [cited 9.3.2013]. www.elsakerhetsverket.se/Global/PDF/Elolyckor/Elolycksfallsrapporter/Rapport%20elolyckor%202010.pdf. 47 p.

Kjellén, U. 2000. Prevention of Accidents Through Experience Feedback. London, Taylor & Francis.

Kleter, G.A. & Marvin, H.J.P. 2009. Indicators of emerging hazards and risks to food safety. Food and Chemical Toxicology. 47, pp. 1022–1039.

Körvers, P.M.W. & Sonnemans, P.J.M. 2008. Accidents: A discrepancy between indicators and facts! Safety Scienece. 46, pp. 1067–1077.

Kowalski-Trakofler, K. & Barrett, E. 2007. Reducing non-contact electric arc injuries: An investigation of behavioral and organizational issues. Journal of Safety Research. 38, pp. 597–608.

KTMp 5.7.1996/516. Kauppa- ja teollisuusministeriön päätös sähköalan töistä.

Kuolemansyytilasto on Suomessa ainoa kattava tilasto kuolemansyistä. 2011. Tilastokeskus. Updated 22.2.2011. [cited 16.11.2012]. www.stat.fi/til/ksyyt/2009/01/ksyyt_2009_01_2011-02-22_laa_001_fi.html

L 14.6.1996/410. Sähköturvallisuuslaki.

L 20.1.2006/44. Laki työsuojelun valvonnasta ja työpaikan työsuojeluyhteistoiminnasta.

L 20.8.1948/608. Tapaturmavakuutuslaki.

Lindström, R., Bylund, P.-O. & Eriksson, A. 2006. Accidental Deaths Caused by Electricity in Sweden, 1975-2000. Journal of Forensic Sciences. 51, 6, pp. 1383–1388.

List of CENELEC national committees (NCs) [www]. n.d.. CENELEC. [cited 7.2.2013]. www.cenelec.eu/dyn/www/f?p=104:5:761156871599397

Lög nr. 146/1996 um öryggi raforkuvirkja, neysluveitna og raffanga. Used the English translation called Act on the Safety of Electrical Installations and Electrical Equipment sent by J. Ólafsson 13.11.2012.

López, M.A.C., Fontaneda, I., Alcántara, O.J.G. & Ritzel, D.O. 2011. The special severity of occupational accidents in the afternoon: “The lunch effect”. Accident Analysis and Prevention. 43, pp. 1104–1116.

Lov 1929-05-24 nr 4: : Lov om tilsyn med elektriske anlegg og elektrisk utstyr (el-tilsynsloven).

Lov om autorisation af elinstallatører m.v., nr, 314 af 5.maj 2000.

Lov om elektriske stærkstrømsanlæg og elektrisk materiel, nr. 251 af 6. maj 1993.

Lundberg, J., Rollenhagen, C. & Hollnagel, E. 2009. What-You-Look-For-Is-What-You-Find - The consequences of underlying accident models in eight accident investigation manuals. Safety Science. 47, pp. 1297–1311.

Lundberg, J., Rollenhagen, C. & Hollnagel, E. 2010. What you find is not always what you fix - How other aspects than causes of accidents decide recommendations for remedial actions. Accident Analysis and Prevention. 42, pp. 2132–2139.

Lundberg, J., Rollenhagen, C., Hollnagel, E. & Rankin, A. 2012. Strategies for dealing with resistance to recommendations from accident investigations. Accident Analysis and Prevention. 45, pp. 455–467.

Main activities [www]. n.d. Mannvirkjastofnun. [cited 30.11.2012]. www.mannvirkjastofnun.is/um-stofnunina/english/main-activities/

Manuele, Fred A. 2000. Behavioral safety: looking beyond the worker. Occupational Hazards. October 2000, pp. 86–88.

Mattila, H. 2012. Sähkötuotteet [www]. [cited 26.11.2012]. Tukes's intra [not available in public].

McCann, M., Hunting, K.L., Murawski, J., Chowdhury, R. & Welch, L. 2003. Causes of Electrical Deaths and Injuries Among Construction Workers. American Journal of Industrial Medicine. 43, pp. 398–406.

Mearns, K. & Yule, S. 2009. The role of national culture in determining safety performance: Challenges for the global oil and gas industry. Safety Science. 47, pp. 777–785.

Medarbejdere [www]. 2009. Grønlands Elmyndighed. 01.09.2009, updated 18.10.2012, [cited 30.11.2012]. www.elmyndighed.gl/medarbejdere1

NEK EN 50110-1:2005 [www]. n.d. Standard Norge. [cited 7.2.2013]. www.standard.no/no/Sok-og-kjop/produktkatalogen/Produktpresentasjon/?ProductID=131952

New trends in accident prevention due to the changing world of work [www]. 2002. European Agency for Safety and Health at Work. [cited 12.3.2013]. Luxembourg, Office for Official Publications of the European Communities. 34 p. osha.europa.eu/en/publications/reports/208

Nordberg, S. 2013. Ålands Landskapsregering. A written interview via email 7.5.2013.

Nordic Statistical Yearbook 2012 [www]. 2012. Nordic Council of Ministers. [cited 5.3.2013]. Nord 2012:001, 50 volume. www.norden.org/fi/julkaisut/julkaisut/2012-001. 158 p.

Om DSB [www]. n.d. DSB. [cited 28.11.2012]. dsb.no/no/toppmeny/Om-DSB/

Om Nukissiorfiit [www]. n.d. Nukissiorfiit. [cited 30.11.2012]. www.nukissiorfiit.gl/dk/om_nukissiorfiit/

Om verket [www]. 2012. Elsäkerhetsverket. Updated 10.10.2012, [cited 21.11.2012]. www.elsakerhetsverket.se/sv/Om-verket/

Organisation [www]. 2012. Elsäkerhetsverket. Updated 13.6.2012, [cited 21.11.2012]. www.elsakerhetsverket.se/sv/Om-verket/Var-organisation/

Organisation [www]. n.d a. Mannvirkjastofnun. [cited 30.11.2012]. www.mannvirkjastofnun.is/um-stofnunina/english/organisation/

Organisation [www]. n.d b. Sikkerhedsstyrelsen. [cited 23.11.2012]. www.sik.dk/Global/Om-os/Organisation

Pate-Cornell, M.E. & Murphy, D.M. 1996. Human and management factors in probabilistic risk analysis: The SAM approach and observations from recent applications. Reliability Engineering and System Safety. 53, pp. 115–126.

Probst, T.M. & Estrada, A.X. 2010. Accident under-reporting among employees: Testing the moderating influence of psychological safety climate and supervisor enforcement of safety practices. Accident Analysis and Prevention. 42, pp. 1438–1444.

Produktsäkerhet [www]. 2012. Elsäkerhetsverket. Updated 11.11.2012, [cited 21.11.2012]. www.elsakerhetsverket.se/sv/Produktsakerhet/

Project [www]. n.d. CENELEC. [cited 8.2.2013]. www.cenelec.eu/dyn/www/f?p=104:110:822147468659982::::FSP_PROJECT,FSP_LANG_ID:21676,25

Pulkkinen, J., Tappura, S. & Knuutila, O. 2009. Vaarallisten työskentelytapojen ennaltaehkäisy sähkötöissä. Loppuraportti. Tampereen teknillinen yliopisto, teollisuustalouden laitos. 28 p.

Reason, J. T. 2000. Grace under fire: compensating for adverse events in cardiothoracic surgery. Paper presented at the 5th Conference on Naturalistic Decision Making, Tammsvik, Sweden.

Recording and notification of occupational accidents and diseases and ILO list of occupational diseases [www]. 2002. International Labour Organization. [cited 24.3.2013]. www.ilo.org/public/english/standards/relm/ilc/ilc90/rep-v-1.htm#National notification systems

Reese, C.D. 2008. Industrial Safety and Health for Infrastructure Services. Boca Raton, Taylor & Francis Group. 560 p.

Reglugerđ um raforkuvirki nr. 678/2009. Used the English translation called Regulations for electrical installations sent by sent by J. Ólafsson 13.11.2012.

Rehmeier, K. 2013. Sikkerhedsstyrelsen. Email 7.5.2013.

Saari, J. 2001. Accident prevention today. Magazine of the European Agency for Safety and Health at Work. 4, pp. 3–5.

Sähköasennuksia koskevat standardit [www]. n.d.. Sesko ry. [cited 15.11.2012]. www.sesko.fi/portal/fi/standardeja_ja_direktiiveja/sfs_6000_2012/sahkoasennuksia_koskevat_standardit/

Samarbete [www]. 2011. Elsäkerhetsverket. Updated 15.9.2011, [cited 11.9.2012]. www.elsakerhetsverket.se/sv/Om-verket/Samarbete/

Sarup, J. 2013. Sikkerhedsstyrelsen. Email 3.1.2013.

Saunders, M., Lewis, P. & Thornhill, A. 2009. Research methods for business students. (5th edition), Essex, Pearson Education Limited. 614 p.

Savola, A. 2011. Sähkölaitteistot-ryhmä [www]. [cited 26.11.2012]. Tukes's intra [not available public].

Scope of electrical accidents. 2005. Consumer Agengy. [cited 21.3.2013]. 25 p. www.neytendastofa.is/lisalib/getfile.aspx?itemid=667

SFS 6002:2005. 2005. Sähkötyöturvallisuus.Suomen standardisoimisliitto SFS. 57 p.

SFS 6002:2005:en. 2005. Safety at electrical work. Finnish Standards association. 113 p.

SFS-OPAS 73. 2011. Riskienhallinta. Sanasto. Suomen standardoimisliitto SFS. 19 p.

Sigurdarson, S. 2013. Icelandic Standards. Email 7.2.2013.

Spangenberg, S., Baarts, C., Dyreborg, J., Jensen, L., Kines, P. & Mikkelsen, K.L. 2003. Factors contributing to the differences in work related injury rates between Danish and Swedish construction workers. Safety Science. 41, pp. 517–530.

Starfsmenn [www]. n.d.. Mannvirkjastofnun. [cited 30.11.2012]. www.mannvirkjastofnun.is/um-stofnunina/starfsmenn/

Starkströmsförordning 2009:22.

Statistical Yearbook 2011 [www]. 2012. ENTSO-E. [cited 27.4.2013]. https://www.entsoe.eu/publications/general-reports/statistical-yearbooks/. 132 p.

Statistics [www]. n.d. Arbetsmiljöverket. [cited 4.4.2013]. http://www.av.se/inenglish/statistics/

Statistik over elulykker 2010 [www]. Sikkerhedsstyrelsen. Updated 28.3.2012, [cited 7.11.2012]. www.sik.dk/Global/Publikationer/Statistikker/Statistik-over-elulykker/Ulykkesstatistikken-for-2010. 15 p.

Sundvall, K.-G. 2011. Elolyckor på järnväg, Redovisning av regeringsuppdrag [www]. Elsäkerhetsverket. [cited 29.10.2012]. www.elsakerhetsverket.se/Global/Publikationer/Elolyckor%20p%C3%A5%20j%C3%A4rnv%C3%A4g.pdf. 22 p.

Sundvall, K.-G. 2012. Elolyckor 2011Rapport [www]. Elsäkerhetsverket. [cited 13.3.2013] www.elsakerhetsverket.se/Global/Publikationer/Elolycksrapport%202011.pdf. 28 p.

Suominen, M. 2012. Vaurio- ja onnettomuusrekisterin hyödynnettävyyden kehittäminen. Diplomityö. Tampereen teknillinen yliopisto. 74 p. + 11 App.

Taylor, A.J., McGwin, C. Jr., Valent, F. & Rue III L.W. 2002. Fatal occupational electrocutions in the United States. Injury Prevention. 8, pp. 306–312.

The Emergence of Risks: Contributing Factors. 2010. International Risk Governance Council. Geneva. 59 p.

The European Network of Transmission System Operators for Electricity (ENTSO-E) [www]. 2012. ENTSO-E. [visited 27.4.2013]. www.entsoe.eu/about-entso-e/

The Government of Åland. 2013. Updated 7.3.2013, [cited 7.5.2013]. http://www.regeringen.ax/.composer/upload//kansli/Org_eng_2013.pdf

Tietoa meistä [www]. 2012. Tukes. Updated 12.11.2012, [cited 26.11.2012]. tukes.fi/fi/Tietoa-meista/

Toimialan onnettomuudet 2009 Osa 7 Sähkö ja hissit [www]. 2010. Turvatekniikan keskus. [cited 29.3.2013]. www.tukes.fi/Tiedostot/varoasiat/2009%20kalvosarjat/Toimialan%20onnettomuudet%202009%20osa%207%20s%c3%a4hk%c3%b6%20ja%20hissit%20muistiinpanoineen.pdf. 25 p.

Toimialan onnettomuudet 2010 Osa 7 Sähkö ja hissit [www]. 2011. Turvallisuus- ja kemikaalivirasto. [cited 29.3.2013]. www.tukes.fi/Tiedostot/varoasiat/2010%20kalvosarjat/Toimialan%20onnettomuudet%202010%20osa%207%20muistiinpanot.pdf. 25 p.

Toimialan onnettomuudet 2011 Osa 7 Sähkö ja hissit [www]. 2012. Turvallisuus- ja kemikaalivirasto. [cited 29.3.2013].. www.tukes.fi/Tiedostot/varoasiat/2011%20kalvosarjat/Toimialan%20onn%202011%20osa%207%20s%c3%a4hk%c3%b6%20notes.pdf. 25 p

Toimialan onnettomuudet 2011, Osa 7 Sähkö ja hissit [www]. 2012. Tukes. [cited 9.3.2013]. www.tukes.fi/Tiedostot/varoasiat/2011%20kalvosarjat/Toimialan%20onn%202011%20osa%207%20s%c3%a4hk%c3%b6%20diat.pdf. 25 p.

Tulonen, T. 2010. Electrical accident risks in electrical work. Doctoral thesis. Tampere, Tampere University of Technology. Tukes-julkaisu 3/2010. 125 p. + 36 app.

Tulonen, T., Pulkkinen, J. & Nousiainen, H. 2006. Sähköalan ammattilaisten sähkötapaturmien ennaltaehkäisy. Helsinki, Turvatekniikan keskus, TUKES-julkaisu 6/2006. 66 p.

Ulykkesstatistikken for 2007 [www]. n.d. Sikkerhedsstyrelsen. Updated 15.1.2009, [cited 9.3.2013]. www.sik.dk/Global/Publikationer/Statistikker/Statistik-over-elulykker/Ulykkesstatistikken-for-2007. 42 p.

Ulykkesstatistikken for 2008 [www]. n.d. Sikkerhedsstyrelsen. Updated 16.6.2010, [cited 9.3.2013]. www.sik.dk/Global/Publikationer/Statistikker/Statistik-over-elulykker/Ulykkesstatistikken-for-2008. 42 p.

Ulykkesstatistikken for 2009 [www]. n.d. Sikkerhedsstyrelsen. Updated 1.10.2010, [cited 9.3.2013]. www.sik.dk/Global/Publikationer/Statistikker/Statistik-over-elulykker/Ulykkesstatistikken-for-2009. 42 p.

Ulykkesstatistikken for 2010 [www]. n.d. Sikkerhedsstyrelsen. Updated 28.3.2012, [cited 9.3.2013]. www.sik.dk/Global/Publikationer/Statistikker/Statistik-over-elulykker/Ulykkesstatistikken-for-2010. 15 p.

Ulykkesstatistikken for 2011 og 2012 [www]. 2013. Sikkerhedsstyrelsen. Updated 4.3.2013, [cited 9.3.2013]. www.sik.dk/Global/Publikationer/Statistikker/Statistik-over-elulykker/Ulykkesstatistikken-for-2011-og-2012

Vår vision och vårt uppdrag [www]. 2010. Elsäkerhetsverket. Updated 29.4.2010, [cited 21.11.2012]. www.elsakerhetsverket.se/sv/Om-verket/Var-vision-och-vart-uppdrag/

VARO database. Searched for the locations of fatal electrical accidents. [cited 12.4.2013]. Tukes internal version, not available in public.

Visjon og virksomhetside [www]. 2012. DBS. Published and updated 5.11.2012, [cited 28.11.2012]. dsb.no/no/toppmeny/Om-DSB/Visjon-og-virksomhetside/

Who we are. n.d. CENELEC. [cited 27.3.2013]. www.cenelec.eu/aboutcenelec/whoweare/index.html

Williamson, A. & Feyer, A.-M. 1998. The Causes of Electrical Fatalities at Work. Journal of Safety Research. 29 (3), pp. 187–196.

Williamson, A. & Garg, U. 2002. Analysis of the causes of electrical shock incidents in mining in NSW [www]. The University of New South Wales, Injury risk management research centre. [cited 19.10.2012]. http://www.resources.nsw.gov.au/__data/assets/pdf_file/0006/81465/Electric-shock-Analysis-report.pdf. 15 p.

Østbye, I.E. & Gilje, K.O. 2000. Risiko ved strømgjennomgang [www]. NELFO. [cited 22.3.2013]. Rapport ST-7156-WE-1-rev01. www.elsakerhetsverket.se/Global/PDF/Elolyckor/Litteratur_andras/Stromgjennomgang.pdf. 13 p.

APPENDICES (2 pieces)

APPENDIX 1. Fatal electrical accidents in the Nordic Countries in 2007-2011

APPENDIX 2. Interview themes

APPENDIX 1. Fatal electrical accidents in the Nordic Countries in 2007-201

Year	Sweden	Denmark	Finland	Norway
2011	– two professionals – one layman ○ fishing	– one professional (from the electrical accident material)	– one layman ○ on train	– one professional – one layman ○ at a transformer substation
2010	– four laymen ○ two on train ○ two steeling copper – two professionals	– one laymen ○ on station	– two laymen ○ one on train – one professional	None
2009	– four laymen ○ one on train – one professional	– five laymen ○ two on train ○ tractor driver , overhead power lines ○ faulty hot water dispenser ○ electric fence	– one layman ○ on train – one professional	– one layman at work ○ fisher
2008	– four laymen ○ two on train – two professionals	– one layman ○ on train	None	– one layman
2007	– six laymen ○ four on train – two professionals	– one professional	– one layman ○ was renovating	– one layman ○ Powered paragliding towards overhead power lines

(Kilsgård 2008, p. 1; Kilsgård 2009, p. 1; Kilsgård 2010, p. 1, Kilsgård 2011, p. 2; Sundvall 2012, p. 5; Ulykkesstatistikken for 2011 och 2012 2013; Ulykkesstatistikken for 2007 n.d., p. 10; Ulykkesstatistikken for 2008 n.d., p. 9; Ulykkesstatistikken for 2009 n.d., p. 10 & 22; Ulykkesstatistikken for 2010 n.d., p. 8 & 15; Toimialan onnettomuudet 2012, p. 13; Heinsalmi & Mattila 2008, p. 48 & 51; Toimialan onnettomuudet 2009 Osa 7 Sähkö ja hissit 2010, p. 12; Elsikkerhet nr. 81 2012, p. 9; Toimialan onnettomuudet 2010 Osa 7 Sähkö ja hissit 2011, p. 12; Toimialan onnettomuudet 2011 Osa 7 Sähkö ja hissit 2012, p. 19; VARO database; Elsikkerhet nr. 77 2010, p. 15 & 59; Elsikkerhet nr 75 2009, p. 10; Elsikkerhet nr. 73 2008, p. 21)

APPENDIX 2. Interview themes

Background questions

1. What does your authority do?
2. What is your official title?
3. For what kinds of tasks are you responsible in electrical safety issues?
    a. statistics
    b. collecting information
    c. spreading information in- and outside the organization
4. What else do you do in your work?

Electrical data collection

5. How is the data collected?
6. Where does the data come from?
    a. forms?
    b. other authorities?
    c. media?
7. Why is the data collected?
    a. Laws (name the laws, are they translated into English, Danish, Swedish, etc)?
8. What kind of data is collected? Define an electrical accident.
    a. Are suicides electrical accidents?
9. Who uses the data?
10. How is the data used?
11. What kind of information do not you get?
12. Estimate the rate of underreporting of electrical accidents.
    a. What is the estimation based on?
13. Name the other authorities/organizations in your home country that collects electrical accident data (descriptions and statistics) and their registers
    a. other authorities
        i. the occupational health and safety authority
        ii. the police
        iii. the fire and rescue services
    b. national statistics center
    c. insurance companies
        i. alone/together
    d. hospitals
    e. labor unions

Electrical safety

14. From your point of view, what are the biggest electrical safety problem areas in your home country?
    a. Overall in the society?
15. Emerging risks are new or familiar risks that become apparent in new or unfamiliar conditions. What emerging risks related to electrical safety can you identify in your home country?
16. How can electrical safety be improved in your country?

Open question

17. Have you something else to say about the electrical accident data acquisition or electrical safety?