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Resilience in the context of Finland's water, energy and comprehensive security

Master's thesis, which has been given in for a degree of Master of Science in Technology.

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Abstract of master's thesis

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Abstract

The world is shaped by global phenomena, which catalyze changes on multiple scales and in numerous and sometimes surprising ways. It is thus necessary to understand how well we are prepared against both known and unknown threats. One option is to focus on increasing a system's resilience, which in general means a system's ability to endure and overcome change. Depending on the discipline, resilience is defined in diverse ways, and therefore also varying ways of analyzing resilience exist.

This thesis focuses on resilience in the context of Finland's water, energy, and comprehensive security. First, the aim is to study how the concept of resilience should be understood in the context of national security. This is followed by analyzing the functionality of a resilience analysis framework in the research context, and studying the related governing systems.

A literature review is used as a basis to define the study context, as well as to decide the actual focus of the semi-structured interviews. Based on the literature review, a resilience matrix was selected to be tested by interviewing the researchers of the Winland research project. The interviews also focused on the governance in the context of the thesis with the aim of providing a general understanding of the current governing systems.

The thesis concludes that resilience will likely be a key concept for both security and sustainable development. Both are broad concepts that encompass various disciplines, each with their own views on resilience. Instead of stating that any definition of resilience is all-encompassing, it would be more constructive to embrace the diverse nature of resilience, and use a definition (or measurement) based on the context.

The results of the semi-structured interviews showed that the resilience matrix is a good starting point in structuring systemic resilience, but as such it is not adequate to holistically analyse the resilience of Finland's water, energy, or comprehensive security. The feedback from the semi-structured interviews can assist further development of the resilience matrix to make it more functional in assessing the resilience of security on a national scale.

Keywords resilience, water security, energy security, comprehensive security, resilience matrix

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Tiivistelmä

Tänä päivänä maailmaa muokkaavat globaalit ilmiöt, joiden myötä muutoksia tapahtuu useilla skaaloilla ja monin ajoittain yllättävinkin tavoin. Tästä syystä on tärkeää ymmärtää, kuinka hyvin olemme valmistautuneet sekä tunnettuja että tuntemattomia uhkia vastaan. Eräs vaihtoehto on keskittyä parantamaan systeemin resilienssiä, jolla yleisesti tarkoitetaan systeemin kykyä sietää muutosta ja selviytyä siitä. Resilienssi määritellään tieteenalasta riippuen eri tavoin, minkä vuoksi eroavaisuuksia löytyy myös resilienssin analysoinnissa.

Tämä diplomityö keskittyy resilienssiin Suomen vesi-, energia- ja kokonaisturvallisuuden kontekstissa. Ensin tavoitteena on tutkia, miten resilienssin käsite tulisi ymmärtää kansallisen turvallisuuden yhteydessä. Tämän jälkeen resilienssin arviointikehikon toimivuutta analysoidaan tutkimuksen kontekstissa ja tutkitaan siihen liittyviä hallintajärjestelmiä.

Kirjallisuuskatsauksen myötä muodostetaan tutkimuksen konteksti ja valitaan puolikonstruoidun haastattelun painopiste. Resilienssimatriisi valittiin kirjallisuuskatsauksen perusteella testattavaksi haastattelemalla Winland-tutkimushankkeen asiantuntijoita. Lisäksi haastattelut keskittyvät kuvaamaan tutkimuksen kontekstin hallintoa ja antamaan yleisen käsityksen hallinnon nykyisestä tasosta.

Johtopäätös on, että resilienssi tulee todennäköisesti olemaan yksi kestävän kehityksen ja turvallisuusajattelun avainkäsitteistä. Näitä laajoja käsitteitä käsitellään useiden tieteenalojen yhteydessä, joista jokaisella on oma määritelmä resilienssille. Sen sijaan, että jokin resilienssin määritelmä todettaisiin kaiken kattavaksi, olisi rakentavampaa hyödyntää resilienssin moninaista luonnetta ja käyttää kuhunkin kontekstiin parhaiten sopivaa määritelmää (tai mittausmenetelmää).

Puolikonstruoidun haastattelun tulokset osoittavat, että resilienssi-matriisi on hyvä alkupiste systeemisen resilienssin jäsentelylle. Sellaisenaan matriisi ei kuitenkaan ole riittävä Suomen vesi-, energia- ja kokonaisturvallisuuden resilienssin kokonaisvaltaista tarkastelua varten. Haastatteluista saatu palaute voi edesauttaa resilienssi-matriisin jatkokehitystä, kun tavoitteena on tehdä matriisista toiminnallisempi kansallisen tason turvallisuuden resilienssin arviointia varten.

Avainsanat resilienssi, vesiturvallisuus, energiaturvallisuus, kokonaisturvallisuus, resilienssi-matriisi

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I would also like to thank the experts of the Winland research project, who spent their time and took part in the semi-structured interviews. Without their participation and input, the qualitative research could not have been conducted.

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Jussi Laine

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1 Introduction: Providing security in a changing world

"A resilient system must be both prepared,
and be prepared to be unprepared."

-Hollnagel et al. 2010

We live in a world which can be characterized by growing globalization, population growth, increased consumption, and a changing climate. In addition to shaping our world, these phenomena also shape our connection with the surrounding environment, which can quite understandably create a lost sense of control and insecurity. It is therefore relevant to understand how we can influence the direction of development, and how we should prepare for the challenges posed by the changing environment.

The aforementioned phenomena are often explained and discussed on a global scale due to their inherently global and intertwined nature. However, as their effects materialize on a local level, the variety of ways in which the local and global levels are connected are pertinent objects for research. In the context of Finland, we are interested in studying the ability of Finnish society to thrive amid the changing conditions.

In this thesis, the term society is defined as including the public sector, private sector, and the civil society. In addition to the Finnish society, it is appropriate to study how Finland's critical infrastructure and natural resources are affected by global systemic changes, and how existing frameworks and regulations support Finnish governing systems in providing security to the Finnish society.

Risks and threats to security can be "natural or man-made, external or systemic, single agent or multiagent, and short-lived (i.e., transient) or enduring" (Madni & Jackson 2009). Somehow, the most relevant ones should be identified and managed to prepare for future stress and change, but in a globally interconnected world, this task can be demanding and resource intensive (Hollnagel et al. 2010).

As the world is constantly undergoing change, it seems like an impossible task for any society to successfully identify all possible risks. It is thus necessary to develop proactive measures, which increase both security and the ability to react to unknown risks. One option is to emphasize systemic capacities and increase *resilience*, which in general means a system's ability to endure and overcome change (Fox-lent et al. 2015; Hollnagel et al. 2010; Madni & Jackson 2009).

Depending on the discipline, resilience is defined in diverse ways, and these varying definitions focus on a diverse set of system characteristics (Ayyub 2014; Bhamra et al. 2011; Brand & Jax 2007; Francis & Bekera 2013). However, it is not clear how resilience should be interpreted considering national (or comprehensive) security, if one considers both the variety of stakeholders on national and global levels, and the complexities of an interconnected world.

First, one needs to understand the context of comprehensive security, and then study how do the existing resilience definitions support the construction of a comprehensive security centered approach. A key aspect of such an approach would be to find a way of analyzing resilience with a wide scope that considers the mix of relevant disciplines and dimensions.

The research problem of this thesis focuses on understanding how the concept of resilience should be interpreted regarding matters of national security, and how resilience thinking supports the concept of Finland's comprehensive security.

The research problem is synthesized in the following overarching research question (RQ):

- *RQ 1: How can resilience and its different definitions help in promoting comprehensive security?*

One goal of this Master's thesis is to find a viable way of measuring resilience on a systemic level, and to study whether the identified method could be utilized to assess the resilience of Finland's water, energy, and comprehensive security. Linkov et al. (2013b) have created a tool which is called the *resilience matrix*, and it was selected based on the literature review as the key resilience method to be studied in this thesis.

The matrix is said to be scalable to any system (Fox-Lent et al. 2015), and therefore it could be a viable option for analyzing the resilience of Finland's comprehensive security. Besides comprehensive security, this thesis will focus on analyzing the resilience of Finland's water and energy security separately.

As the first step of a resilience analysis is to define the system under analysis, testing the functionality of the resilience matrix requires defining the system boundaries and the governing system of each thematic analysis. In this thesis, the governing system refers to the connections and power relations between the most relevant actors and stakeholders on a specific theme (water, energy, and comprehensive security).

These notions led to two further research questions:

- *RQ 2: How applicable is the resilience matrix presented by Linkov et al. (2013b) to analyze the resilience of Finland's water, energy, and comprehensive security, and what kind of constraints and possibilities does the matrix entail?*
- *RQ 3: How are the governing systems regarding the resilience of Finland's water, energy, and comprehensive security characterized?*

In this thesis, resilience and comprehensive security are studied in the context of the Winland research project (2016-2019), which aims to identify the most relevant security threats and their management options to Finnish society through the combined use of interdisciplinary research, scenario planning, and co-creation (Winland 2017a). In Winland, comprehensive security is looked through the themes and processes illustrated in Figure 1.

More specifically, Winland is guided by the questions of "how do the shocks and pressures to our energy and food system and their related policy measures affect Finland's comprehensive security in the future, and how can we improve the resilience of our society?" (Winland 2017a). The project also takes into account systemic long term pressures which are linked to, for example, water use and climate change (Winland 2017a). On a global level, climate change impacts the hydrological cycle, which in turn hampers water and food security (Winland 2016).

In the context of Winland, resilience is studied from different viewpoints based on the themes and processes affecting Finland's comprehensive security (Figure 1), which include analysing resilience in conjunction with learning (Pirinen 2017; Pirinen et al. 2016).

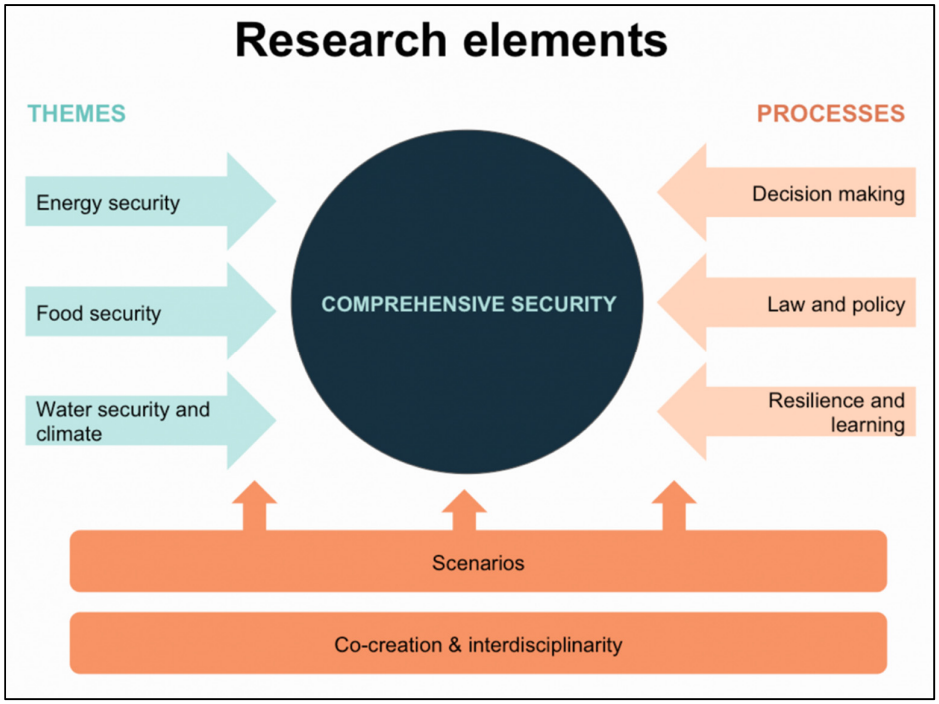


Figure 1. Research elements of Winland research project (Winland 2017a).

Winland has brought together a multidisciplinary group of researchers, who understand the concept of resilience through varying perspectives. The group of researchers consists of experts from diverse fields, which cover the research elements presented in Figure 1. By interviewing the experts on water, energy, and comprehensive security, valuable insights can be obtained on the functionality of the resilience matrix to analyze the resilience of each theme. In addition, the interviews will focus on the governance of each theme with the aim of providing a general understanding of the current governing system and its link to resilience.

By answering the research questions, the main objective of the thesis is to identify relevant insights on the connection of resilience with Finland's water, energy, and comprehensive security discourse. The results of the thesis can concurrently aid and streamline the resilience analysis which is conducted inside Winland in the future.

This thesis is structured in the following way. First, the materials and methods applied in the thesis are described and then the results of the literature review are presented. After the literature review, results of the semi-structured interviews are presented in chapters focusing on water, energy, and comprehensive security separately. Finally, the main findings are discussed and the conclusions on the novelty of the thesis are provided.

2 Research materials and methods

2.1 Literature review

2.1.1 Data gathering and analysis

Literature review was used as a basis to define the study context and the related research questoins, as well as to decide the actual focus of the semi-structured interviews. The literature review starts by comparing the concepts of risk and resilience. However, the focus is on multiple definitions of resilience, the connection of resilience with Finnish comprehensive security, and the task of measuring resilience in general. Hence, the literature review presents key insights which are needed to answer the first research question.

The literature review focused on published scientific articles and on material published by the Government of Finland. The analysis started by focusing on the material provided by Winland. In the analysis, key concepts and terminology of the provided material were marked and added to a search diary. The search diary was then gone through by searching journal databases and subject specific professional websites for published articles. Articles and material were selected based on the relevance to the context of the thesis and the number of citations.

First the focus was on the definition of resilience, and more specifically on ways resilience can be defined on a systemic level. Secondly, ways of analysing, managing, and measuring resilience were searched. Lastly, material focusing on the concepts of water, food, energy, and comprehensive security were obtained.

As ample literature regarding the definition of resilience is available, the literature review focused on gathering the ones which presented the diverse resilience definitions in a concise form. The literature on measuring resilience was often found being case specific, and it was decided that the vast published material on those cases were not reviewed, as it would have issued difficulty in finding a homogenous synthesis on the subject. Instead, the literature review focused on identifying general characteristics of resilient systems, and on resilience measurement tools, which could be utilized on a systemic level.

2.2 Qualitative semi-structured interviews

2.2.1 Data gathering

One goal of this Master's thesis was to find a viable way of measuring resilience on a systemic level, and to study whether the identified method could be utilized to assess the resilience of Finland's water, energy, and comprehensive security.

Based on the literature review, a resilience analysis framework was selected to be tested by interviewing the researchers of Winland. As the resilience matrix by Linkov et al. (2013b) is said to be applicable for analyzing the resilience of varying sized systems, it was considered a potential way of analyzing the resilience of Finland's water, energy, and comprehensive security.

Prior to the literature review, members of Winland had already considered the resilience matrix to be a possible option for measuring systemic resilience. However, the matrix had only been implemented in limited case studies which were not directly comparable to a national level security analysis. Hence, further feedback of the functionality of the

matrix was needed and it was decided that the feedback would be collected through qualitative semi-structured interviews.

Semi-structured interviews were guided by an interview guide. All the questions of the interview guide were asked from every interviewee, but additional probing questions were also presented to focus on replies that are significant to the research. (Bryman 2008; Merriam 2009.) As the objective of the interviews was to collect practical feedback of the resilience matrix, it was seen best to conduct the interviews using a co-creation (or co-design) approach.

Co-design is a participatory approach, where the roles of product users, researchers, and designers are merged in the co-designing process. A user is considered "an expert of his/her experience, who plays a large role in knowledge development, idea generation and concept development". A researcher aids the user by providing tools for ideation, and a designer assists in the development of the tools. (Sanders & Stappers 2008.)

In the context of this thesis, the interviewees acted as users, the author acted as a researcher, and the role of a designer was shared between them. The reflections on the resilience matrix can be considered as the product. In this way, the author could take part in the conversation and clarify the context to the interviewees to make sure that the collected feedback was as useful as possible.

It should be noted that the involvement of the author in the co-creation process increased the subjectivity of the obtained results. To minimize subjectivity, the author followed the interview guide and aimed to limit directing the course of the discussion.

To test the suitability of the resilience matrix in the selected context the interviewees were selected from the researchers working for Winland. The experts from water, energy, and comprehensive security sub-projects were identified as key interviewees, and it was decided that regarding water security, a group interview would be more suitable, as it would benefit the future work of the group in question.

Regarding energy security, two separate 1-on-1 interviews were seen beneficial, as there were clear differences in the expertise and disciplinary background between the two sub-project directors. With comprehensive security, one face to face interview was conducted. Food security was left outside the scope of this thesis, as the researchers of food security in Winland are focused on global trends, and not as much on Finland's national level.

The interview questions focused on the applicability of the resilience matrix in assessing resilience on a national level in Finland. In addition, questions were asked regarding the governing system of each thematic field in Finland, and on the definition of resilience in general. The questions were formulated in Finnish and they are presented in Appendix 3 in the original format. In Appendix 4, the interview questions are presented in English as translated by the author.

Before the actual interviews, a pilot interview was conducted with one of the advisors. The pilot interview was conducted to test the quality and order of the interview questions, to measure the duration of the interview, and to provide the interviewer experience on the practicalities of the interview process. After the pilot interview, the questions were finalized, and they were sent to the interviewees together with a Finnish summary written by the author, which describes the concept of resilience and the background of the resilience matrix (Appendix 5).

Like all communication with the interviewees, the interviews were conducted in Finnish. The interviews were conducted on the following dates:

- 8th of June, 2017: Energy security A
- 14th of June, 2017: Water security
- 15th of June, 2017: Energy security B
- 28th of July, 2017: Comprehensive security

The interviews lasted between 1h 30min and 2h 10min, and they were recorded with a dictation machine with the consent of the interviewees.

Additional probing questions were presented during the interview on matters deemed relevant. The author also presented the sent Finnish summary (Appendix 5) via presentation slides to make sure that the interviewees understood the content under analysis as well as possible.

To test the suitability of the resilience matrix, during each interview a short exercise was conducted where the interviewees tried to produce useful indicators which could be used to evaluate the resilience of the subject under review. The interviewees conducted the exercise based on the provided instruction in the form of the Finnish summary and translation of the matrix.

2.2.2 Data analysis

The aim of the data analysis was to obtain feedback on the applicability of the resilience matrix and to understand the governing systems of water, energy, and comprehensive security in Finland.

First the recorded material was transcribed by the author. It was then analysed one security theme at a time. The analysis focused on the transcribed content by applying the methodology of content analysis (Bryman 2008). It started by focusing on each interview question separately, and underlining in the transcription the answers by the interviewees which corresponded with the presented questions. In addition to the precise interview questions, the relevance of the answers to the research questions were also considered in the analysis.

After repeatedly reviewing the transcripts alongside the audio recordings, key themes and results could be identified from the marked answers. These findings were grouped based on two of the research questions, and they were then translated to English by the author.

3 Literature review results: research context

3.1 From risk analysis to resilience thinking

The processes of risk and resilience analysis include similarities, but there also clear distinction between the two approaches (IRGC 2016). Thus, before the concept of resilience is reviewed, one should understand how risk is defined and what are the fundamental differences between risk analysis and resilience analysis.

Risk is commonly explained as a product of probability and consequence regarding an identified hazard (Kaplan & Garrick 1981; Sheridan 2008). Instead of comparing risks based purely on the products of different scenarios, one should compare also the probabilities and consequences separately, as a high-probability low-damage scenario might not be as serious as a low-probability high-damage scenario (Kaplan & Garrick 1981).

An alternative definition of risk connects the consequences of a hazard with uncertainty instead of probability. A key difference is, whether probability is considered as an objective or subjective factor. In other words, should we use self-calculated numerical probabilities as objective parameters, or should we focus on the uncertainty of the used probability measures and challenge the limits of our knowledge. (Steen & Aven 2011.)

Regarding the notion of uncertainty, it is suggested that we separate the subjective and objective dimensions of probability, and use different concepts for each. The term probability should be understood to include the notion of uncertainty, and it is therefore subjective. The objective dimension should be described with measured frequency. (Kaplan & Garrick 1981.)

Risk analysis is said to consist of identifying vulnerabilities to expected threats (or hazards), and then proceeding to study the possible consequences (Linkov et al. 2014). Vulnerability can be seen to describe the combination of consequences and uncertainty (Steen & Aven 2011), but in can also be understood to include exposure to an event and the probabilities of system failure and negative consequences (Francis & Bekera 2013).

To summarize the slightly overlapping definitions, risk analysis is in this thesis understood as consisting of figuring out what could go wrong, examining the likelihood and consequences of such a disruption, and considering the uncertainty of the used parameters. To manage a risk, it would therefore be intuitive to either reduce the probability of a hazard, or to minimize the damage it could cause. This sounds feasible, if one operates in a familiar environment with knowledge on the frequencies and consequences of past misfortunes.

However, if one considers the modern world and the rapid change that has occurred during the past century, and especially during the past decades, it has become more and more difficult to acquire all the available information to support risk analysis on a global level (Linkov et al. 2014; Yodo & Wang 2016). This is partly due to characteristics of global socio-ecological systems, which are shaped by globalization (Young et al. 2006).

Globalization has both constructive and destructive qualities, and on one hand it can be explained by the increase in connectedness and in the speed of global interactions, but on the other hand by the decreased diversity and widened scale of processes and activities (Young et al. 2006). As a result, the changing global inter-dependencies make it problematic to rely on traditional risk analysis, which is best used in a scenario with known variables and collected data (Folke 2006; Hyvönen & Juntunen 2016).

A complex operating environment can cause unexpected failures even in simple systems (Davies 2015), and it is said that risk assessment and risk management are no longer sufficient to tackle the various threats against inter-connected systems (Linkov et al. 2014; Park et al. 2013; Rosati et al. 2015). The point here is not that risk analysis was useless, as we are not able to predict and calculate every possible risk in a complex world. Rather, is it adequate to continue identifying risks, and minimize their probabilities and resulting consequences? If we decide to focus on managing solely known risks, is the system's ability to react to unknown risks hampered?

One idea is to move from risk analysis to resilience analysis (IRGC 2016; Park et al. 2013). While the aim of risk management is to prevent adverse events by preparing against known risks, resilience analysis acknowledges that there are known and unknown threats, and the focus should be placed on whether the system has the sufficient knowledge and capacity to bounce back (or forward) after a disruptive event (Hollnagel et al. 2010; IRGC 2016; Park et al. 2013; Sikula et al. 2015).

Both resilience and risk analysis start from identifying threats and planning countermeasures, and the main differences are in the temporal scale of analysis and in the focus of the proactive measures (IRGC 2016). While risk analysis tends to assume that background processes and operations function normally, and the countermeasures against a hazard can be planned accordingly, resilience analysis identifies crucial supporting processes, and focuses on them instead of just the ones aimed at preventing a hazard (Rosati et al. 2015).

Where traditional risk management methods promote strengthening vulnerable components of a system against the most severe identified risks, resilience management is a systematic approach with the aim of making sure that a disruptive event would not afflict permanent damage to the critical functionality and efficiency of a given system. They both work towards securing a system, but besides the time periods before and immediately after an external shock, resilience management is interested in how long it takes for a system to regain its functionality. (IRGC 2016.)

One critical difference is that resilience is a property of the system (Meadows 2009), whereas risk is something that can affect the system externally. To be more precise, while materials and simple systems can be said to have resilience (static property), it is more fitting to describe the resilience of complex systems as a process and by focusing on agency (dynamic property) (Madni & Jackson 2009).

In conclusion, both risk and resilience analysis have positive aspects, and they can in fact complement each other (Baum 2015; Park et al. 2013). If we are to improve the system and secure its critical functions, we should first identify the possible risks and then proceed to study the system's resilience. In this way, we can benefit from the wide array of analytical tools of risk analysis (Sheridan 2008), and continue with resilience analysis to widen the understanding of necessary processes on a systemic level.

3.2 Security through resilience

This chapter defines the concept of Finland's comprehensive security, and studies the aspects, which need to be considered if one desires to increase its resilience. Comprehensive security is a relatively new concept in Finnish national policy discourse, as in 2012 it replaced the concept of 'comprehensive national defence' as the goal of Finland's security policy (Turvallisuuskomitea 2015).

The comprehensive security of Finnish society is defined as denoting "a target state where the vital functions of the society are secured. It enables us to guarantee the well-

being and security of Finnish citizens in all circumstances. The comprehensive security of Finland is created through a joint effort by the administration, business life, NGOs and individual citizens" (Turvallisuuskomitea 2015; Valtioneuvosto 2012).

The above definition highlights the security of vital functions, which are defined as the "management of Government affairs, international activity, Finland's defence capability, internal security, functioning of the economy and infrastructure, the population's income security and capability to function, and psychological resilience to crisis" (Valtioneuvosto 2010b).

The definition encompasses a broad spectrum of national matters, which concurrently makes the analysis of comprehensive security, and its resilience, a demanding task. Instead, this thesis borrows the approach from Winland, where comprehensive security is studied from the points of view of water, energy, food, and resilience (Winland 2017b). Thus, the concepts of water, energy, and food security need to be defined for us to be able to determine how resilience fits in the comprehensive security discourse.

Water security is seen as the main objective of water governance (Winland 2017b), and more broadly it is defined after UN-Water "as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water 2013).

Energy security can be described by four As, which are commonly listed as availability, accessibility, affordability, and acceptability of energy (Cherp & Jewell 2014). In a similar manner, food security is seen to consist of four dimensions, which are food availability, economic and physical access to food, and food utilization and stability over time (FAO et al. 2017).

Besides shaping comprehensive security, Winland is based on the notion that water, energy, and food security are linked to each other in numerous ways. Food and energy production are water intensive industries, but just as well energy is needed to support food production, water treatment, and the distribution networks of both. On a global level, climate change impacts the hydrological cycle, which in turn hampers global water and food securities. Indirectly, this can increase global migration and eventually increase the demand of water, food, and energy on a local level through increased population. (Winland 2016.)

So, in the context of comprehensive security, we are in a 'system of systems', where decreased functionality of one system can have a cascading effect on others. In this sense, we should favour functional autonomy of systems, which means that the resilience of vital systems should be isolated as well as possible (Linkov et al. 2014).

More precisely, one should focus on the critical functions of a system, which are essential to the functionality and resilience of other systems (Linkov et al. 2014; Park et al. 2013). As an example, one can consider the power grids, which have an important role in providing electricity to the critical infrastructure that supports the modern way of life (DiMase et al. 2015). A disruption in the power grid can decrease the resilience of communication network and data transfer, which in turn can hamper the resilience of various other systems.

To analyse the applicability of resilience thinking in strategies aimed at increasing national security, one needs to have an understanding of the operating environment of governments, and the implications of using a concept such as comprehensive security to guide the decision-making process.

The role of nation-states has changed due to globalisation (Fjäder 2014), and concurrently governments need to provide national security in an interconnected and changing world, which is viewed as more uncertain and unsecure than before (Fjäder 2014; Hyvönen & Juntunen 2016). The concept of resilience has recently been adapted in national policy discourse, and therefore Hyvänen & Juntunen (2016) suggest that governments will begin to direct more focus on securing continuity and resilience instead of focusing only on securing borders and sovereignty.

As resilience integrates with national security policy, issues such as privatization of critical infrastructure, regional and industrial prioritization, and securitisation of non-traditional threats forces governments to consider, for example, restricting foreign investment and subsidising specific industries (Fjäder 2014; Hyvönen & Juntunen 2016).

Resilience thinking can also be seen to shift the responsibility of providing security from the centralized public sector to the private sector and individual citizens, without necessarily transferring any actual power (Hyvönen & Juntunen 2016). This raises such problematic questions as which means are justified to improve societal resilience politics, and when can it be declared successful (Juntunen 2014).

Resilience discourse has been integrated into EU's foreign policy, where in a similar way responsibility is localized, but the agency to dictate, which course of action is beneficial for the resilience of the whole of EU, is centralized (Juncos 2016). In Europe, the relationship of resilience and security politics is viewed from two opposing schools of thought: one views resilience as a tool of neoliberal politics and governance, while the other sees good in diversifying and localising agency, and in this way empowering the society (Hyvönen & Juntunen 2016).

Before 2015, the direct Finnish translation of resilience (resilienssi) was not seen in national guiding documents of Finland (Juntunen 2014), but it was used in the 2010 document 'Security Strategy for Society' where the Finnish concepts of '*kriisinkestävyys'* and '*toiminnan palautuvuus'* were translated as *crisis resilience* and *resilience of functions*, respectively (Valtioneuvosto 2010a; Valtioneuvosto 2010b). An updated version of the document is being prepared at the time of writing this thesis, and it is scheduled to be published in October 2017 (Turvallisuuskomitea 2017).

In the Finnish 'Vocabulary of Comprehensive security', resilience has been translated as '*resilienssi*', and it has been incorporated with *crisis tolerance* (SPEK 2014). Resilience is partly used as a synonym for *crisis resilience*, and it describes both the "capacity of individuals and communities to sustain the ability to perform under changing conditions", and the "preparedness to confront disturbances and crises, and to recover from them" (translated by the author from SPEK 2014).

Since then, resilience is mentioned only a few times in the documents 'National Risk Assessment 2015' and 'Secure Finland: Information on comprehensive security in Finland', in which resilience is coupled with psychological crisis resilience and individual resilience in aviation (Ministry of the Interior 2016; Turvallisuuskomitea 2015). However, in 2016 the Finnish term '*resilienssi*' is used with conjunction to '*yleinen kriisinsietokyky*', which is translated by the author of the thesis as the *capacity to withstand crises* (Valtioneuvoston kanslia 2016).

The concept of resilience seems to be slowly appearing in Finland's comprehensive security discourse. As it does, it is relevant to consider, what is the quality of information regarding resilience that is provided to policy makers (IRGC 2016)? In other words, where is the used data derived from, how is knowledge regarding resilience met-

rics constructed, and how should the uncertainty in the used data be explained to the policy makers, whose aim is to create a resilient Finland?

To summarize, if the aim is to increase the resilience of national security, one should focus on the concept of agency and the balance between responsibilities and power in decision-making. The role of the public sector is central in national security discourse, but also the interaction and communication between the public sector, private sector, and civil society should be analysed. As governments have the ability to monitor and control the big picture, it is relevant to study how resilient their national governing systems are.

3.3 Defining resilience

The concept of comprehensive security is in this thesis seen to construct of multiple security themes, which are in turn shaped by multiple factors from the national to local level. Instead of focusing on resilience on each level separately, the aim is to present general characteristics, which support the analysis of systemic resilience.

To conduct functional resilience analysis, a clear definition of resilience needs to be selected. In this thesis, the following definition given by the National Academy of Sciences (NAS) is used: (NRC 2012)

> "Resilience is the ability to prepare and plan for, absorb,
> recover from, and more successfully adapt to adverse events".

It is, however, important to understand that different disciplines and sectors understand resilience in different ways. The concept of resilience is said to have evolved from psychology and psychiatry in the 1940s (Manyena 2006), but many consider Holling's definition of ecological resilience in 1973 as the stepping stone, from which the evolution of later definitions has sprung (Bhamra et al. 2011; Folke et al. 2010; Park et al. 2013; Young et al. 2006).

In his work focusing on ecology, Holling (1973) stated that "resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist.". Holling also brought up the notion of multiple stable states in ecological resilience, as opposed to a single stable equilibrium, which is associated with engineering resilience (Folke 2006; Holling 1973).

With engineering resilience, one can either focus on the time it takes to return to a steady state after a system is no longer affected by a stressor, or alternatively measure how much stress a system can endure before it is no longer able to return at all (Holling 1996; Pimm 1984).

Since then, various definitions have been given to resilience, and they differ based on disciplines and the context of research (Ayyub 2014; Bhamra et al. 2011; Brand & Jax 2007; Francis & Bekera 2013; Quinlan et al. 2016). Multiple compilations of the definitions are available, and the definitions seen as most central vary based on the author (see Tables 1 & 2).

Outside the descriptions provided in Tables 1 & 2, there are also distinctions between disaster, economic/financial, community, institutional, industrial, urban, network, political, evolutionary, and development resilience (see Bhamra et al. 2011; Davoudi et al. 2013; Madni & Jackson 2009; Quinlan et al. 2016).

Table 1. The connection of resilience features of four domains with the phases of resilience, as described by the National Academy of Sciences (NAS) (adapted from IRGC 2016).

NAS phase of resili-ence	Resilience Feature	Description by Application Domain			
		Socio-ecological	**Psycho-logical**	**Organiza-tional**	**Engineering & Infra-structure**
Plan	**Critical function**	A system function identified by stakeholders as an important dimension by which to assess system performance.			
		Ecosystem services provided to society	Human psychologi-cal well-being	Goods and services provided to society	Services provided by physical and technical engineered systems
Absorb	**Thresh-old**	Intrinsic tolerance to stress or changes in conditions where exceeding a threshold perpetuates a regime shift.			
		Used to identify natural breaks in scale.	Based on sense of community and personal attributes.	Linked to organiza-tional adap-tive capacity and to brit-tleness when close to threshold.	Based on sensitivity of system functioning to changes in input variables.
Recover	**Time**	Duration of degraded system performance.			
		Emphasis on dynamics over time.	Emphasis on time of disruption (i.e., devel-opmental stage: child-hood vs adulthood).	Emphasis on time until recovery.	Emphasis on time until recovery.
Adapt	**Memory/ Adaptive Manage-ment**	Change in management approach or other responses in anticipation of or enabled by learning from previous disruptions, events, or experiences.			
		Ecological memory guides how ecosystem reorganizes after a disruption, which is maintained if the system has high modularity.	Human and social memory, can enhance (through learning) or diminish (e.g., post-traumatic stress) psy-chological resilience.	Corporate memory of challenges posed to the organization and man-agement that enable modi-fication and building of responsive-ness to events.	Re-designing of engineer-ing systems designs based on past and potential future stressors.

A compilation of various definitions is presented in Appendix 1. The list is not exhaustive, but it gives an understanding of the available diversity. Also, many national and international organisations have their own definitions (Ayyub 2014; Keating et al. 2017; Larkin et al. 2015; Rosati et al. 2015), and although the differences between used definitions are at times minor, each one tends to be shaped by the context or discipline in question.

Table 2. Characteristics, focus, and context of systemic resilience concepts (adapted from Folke 2006).

Resilience concepts	Characteristics	Focus	Context
Engineering resilience	Return time, efficiency	Recovery, constancy	Vicinity of a stable equilibrium
Ecological/ecosystem resilience **Social resilience**	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibria, stability landscapes
Social–ecological resilience	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity, transformability, learning, innovation	Integrated system feedback, cross-scale dynamic interactions

Through the review of available definitions, certain general characteristics, properties, and attributes of systemic resilience can be identified. Resilient systems are said to be characterized by the four Rs: robustness, redundancy, resourcefulness, and rapidity to recover (Ayyub 2014; Ganin et al. 2016), as well as diversity, innovation, adaptive capacity, cohesion, and flexibility (Bhamra et al. 2011; Francis & Bekera 2013; Larkin et al. 2015; Park et al. 2013; Quinlan et al. 2016).

A general feature of systemic resilience analysis is to define the system thresholds and its critical functions (Fox-lent et al. 2015; IRGC 2016; Resilience Alliance 2010). Critical functions "must be maintained at close to full capacity, in order to continue providing the essential services of the system through an adverse event and to support the resumption of other functions after the event." (Fox-lent et al. 2015).

For each critical function, there is a threshold, which states the level, above which the functionality is attempted to be kept (IRGC 2016). The level of predicted loss in critical functionality is determined by a risk analysis, and focus is placed on the speed of recovery, after the system starts to regain its functionality (Linkov et al. 2014; IRGC 2016).

Attention is put on the temporal dimension, and especially on the different phases a system goes through before and after an adverse event (Henry & Ramirez-Marquez 2012; Teodorescu 2015). Figures 2 illustrates how a system's functionality is effected by different levels of risk and resilience, and Figure 3 shows the connection of the critical functionality with the temporal phases of an adverse event.

Depending on the literature, the naming of the phases varies, but they can be generalized into a phase before an adverse event (to plan, prepare, and anticipate), declining functionality after an event (to absorb, resist, withstand, and sustain), regaining functionality after an event (to recover, restore, and adjust), and returning to a steady state (to adapt, learn, and transform) (Bhamra et al. 2011; Francis & Bekera 2013; Madni & Jackson 2009; Rosati et al. 2015; Yodo & Wang 2016).

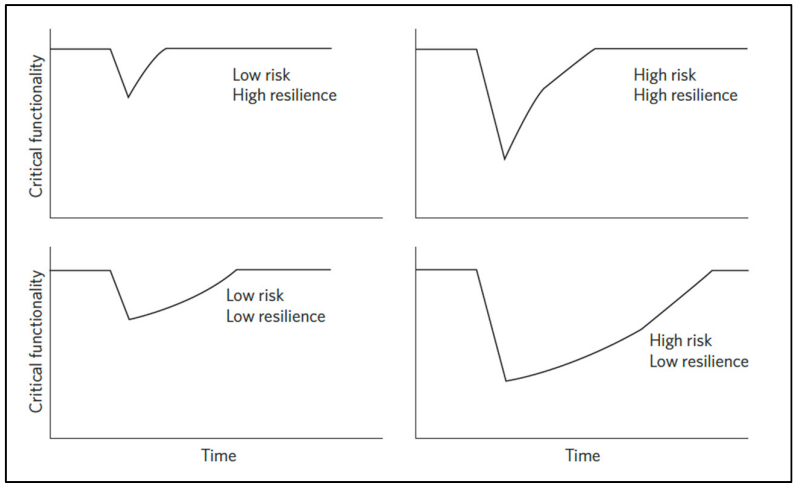


Figure 2. The effect of risk and resilience to a systems functionality as a function of time (Linkov et al. 2014).

Each phase entails a certain level of agency, and hence resilience can be understood "as the outcome of a recursive process that includes sensing, anticipation, learning, and adaptation" (Ayyub 2014). The continuous nature of resilience management is presented in the cyclical illustration of Figure 4, which is developed by the author and based on the connection of resilience features and phases shown in Table 2.

It is relevant to keep in mind that the simplistic illustration (Figure 4) does not depict the stochastic nature of resilience cycles, which occur on varying temporal, and spatial scales (Park et al. 2013). The many scales, which affect a system's resilience are illustrated well with the concept model of adaptive cycles (see Holling 2001). The model connects resilience with the adaptive capacity of systems, and it demonstrates that change can occur gradually or rapidly, change can be a result of connected adaptive cycles, and that both instabilities and stabilities affect the level of resilience (Folke 2006; Holling 2001).

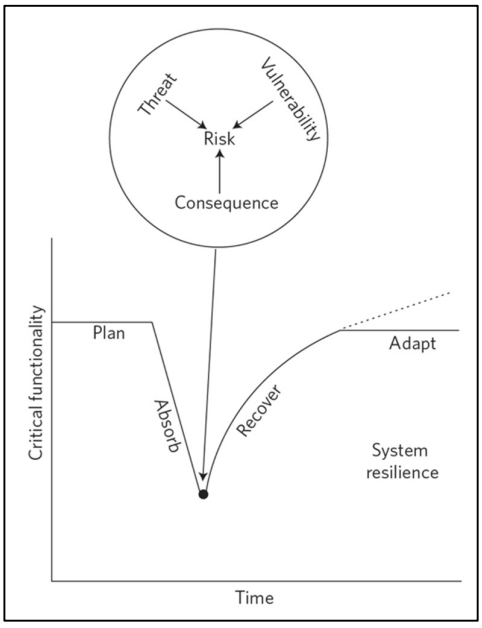


Figure 3. The connection between the phases of systemic resilience and the main attributes (Linkov et al. 2014).

Resilience can be considered a boundary object, as by having multiple meanings, it facilitates communication between groups, who do not necessarily share a disciplinary background nor a common vocabulary. As a drawback, the vague and ambiguous definition of the term can complicate scientific progress, but on the other hand, it can support interdisciplinary work. (Brand & Jax 2007.)

The concept of resilience can be a unifying concept between environmental and ecological disciplines, but there are issues when adding social sciences to the same pool. Resilience vocabulary does not work well with social sciences, and additionally concepts such as agency, conflict, knowledge, and power suffer from lack of attention in the resilience literature. Therefore, resilience can turn into a depoliticizing concept. (Olsson et al. 2015.)

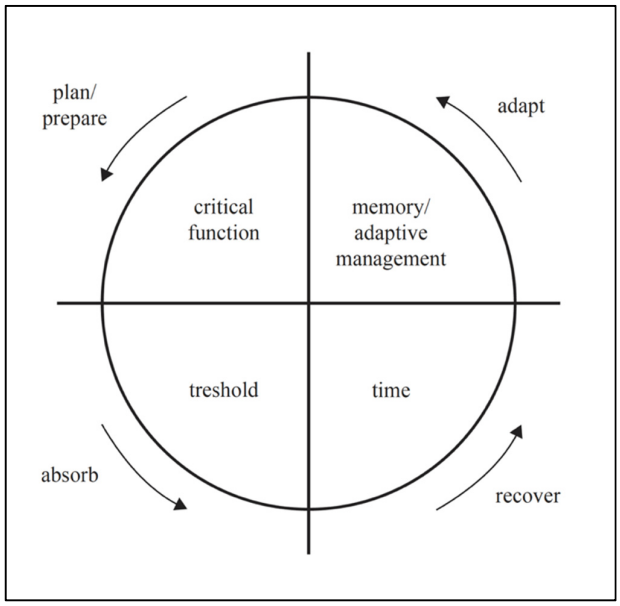


Figure 4. An illustration, which shows the continuous nature of resilience management, and the key resilience features under focus during the resilience management process (based on IRGC 2016).

Finally, even though crisis and disruptions are often seen negative, a resilient social-ecological system can make use of such a shock or change, and transform into a more desired state (Folke et al. 2005). However, one must be careful and observant when learning from things that have gone wrong as the learnt explanations to observed misfortunes can be affected by false assumptions on cause and effect (Hollnagel et al. 2010).

If learning is not supported, there is a possibility that resilience is seen merely as bouncing back to the previously held system state. If a system has negative properties, for example power imbalances and inequality, an argument can be made that sustaining the current state would be undesired, and hence the system's resilience might prevent favourable change (Nuorteva et al. 2010).

3.4 Measuring resilience

When analysing the resilience of any system, one should start by defining the system (Francis & Bekera 2013; Hollnagel et al. 2010; Linkov et al. 2014; Resilience Alliance 2010), and clarify the used definition of resilience due to the varying available definitions.

Resilience engineering (or management) contains the actions, which establish and enhance the characteristics of resilient systems. Besides focusing on what could be done better, it is also relevant to identify the properties of a system, which are currently increasing resilience (Hollnagel et al. 2010). After references to specific resilience analysis tools, this chapter will focus on measuring resilience on a general systemic level.

Uniform tools and metrics for measuring resilience have not sprung from the many definitions given to resilience, or from the various attributes that are said to increase the resiliency of a system (Cutter 2016). In the context of the thesis, it is seen important that clear metrics should support the decision-making between alternative resilience engineering options, because the decisions and actions regarding national security need to be justified (Ayyub 2014; Francis & Bekera 2013; Madni & Jackson 2009).

Most available tools or frameworks have been created for specific purposes such as disaster resilience (Cutter 2016), which is one of the recurring topics in resilience literature. Several action plans and analytical tools have been designed to measure specifically resilience related to disaster risks (Cutter et al. 2014), as besides fatalities, disasters tend to cause substantial direct damages and concurrently large annual financial losses (Ayyub 2014).

Winderl (2014) offers an extensive list and overview of disaster resilience measures both on national and sub-national level. A part of these measures is already being implemented, but most of them are used only in selected areas. Cutter (2016) adds to the list with several disaster resilience assessment measures, one of which is the baseline resilience indicators for communities (BRIC), created by Cutter et al. (2014).

Whereas most of the offered measures have a discipline specific approach, the BRIC incorporates social, economic, community, institutional, housing/infrastructure, and environmental dimensions using 49 indicators from available datasets in the United States of America (Cutter et al. 2014).

Whether faced with a disaster or smaller scale hazards, it is necessary for any society that the critical infrastructure and key supply chains stay in good shape and resilient. In the domain of engineering resilience, there are several metrics through which the state of nodes and links is observed and compared to the performance of a given network or functionality of an infrastructure system (Ayyub 2014; Ganin et al. 2016; Yodo & Wang 2016).

The offered metrics are often provided in the form of mathematical equations, which represent the critical functionality of a selected system as a function of time, and which produce graphics as indicators of resilience (See Figure 5) (Ayyub 2014; Ganin et al. 2016). As can be seen from Figure 5, the focus in resilience engineering is to minimize the drop in critical functionality, shown in Figure 5 as the area of "1-R".

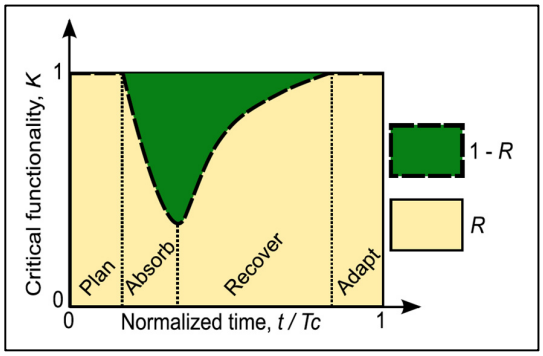


Figure 5. Resilience measured in critical functionality as a function of time (Ganin et al. 2016).

Time dependency is considered a key element in metrics, which focus on systems and networks (Francis & Bekera 2013; Henry & Ramirez-Marquez 2012), while some focus more on thresholds of critical functionality (Linkov et al. 2014), and others on the probabilities of recovering from a hazard within an acceptable timeframe (Teodorescu 2015).

As we are interested in measuring and improving the resilience of the Finnish society (Winland 2017a) alongside with Finland's critical infrastructure, natural resources, and existing frameworks and regulations it would also be useful to have tools and frameworks which are more general in nature. Quinlan et al. (2016**)** provide a list of social-ecological, ecological, and development resilience metrics, but also more general and systemic approaches to resilience engineering are available.

Two such options were identified during the literature review, and they are called the resilience analysis grid (RAG) (see Appendix 2) and the resilience matrix (Hollnagel et al. 2010; Linkov et al. 2013b).

The resilience matrix (Table 3) combines the chosen definition of resilience by the NAS with the four dimensions of a network from the doctrine of Network Centric Warfare (Linkov et al. 2013b). It has been applied to assess cyber security (Linkov et al. 2013a), and it has also been used as a rapid screening-level assessment (Tier 1) of a three-tiered analysis by the US Army Corps of Engineers and the Coastal Engineering Research Board to assess coastal and community resilience (Rosati et al. 2015).

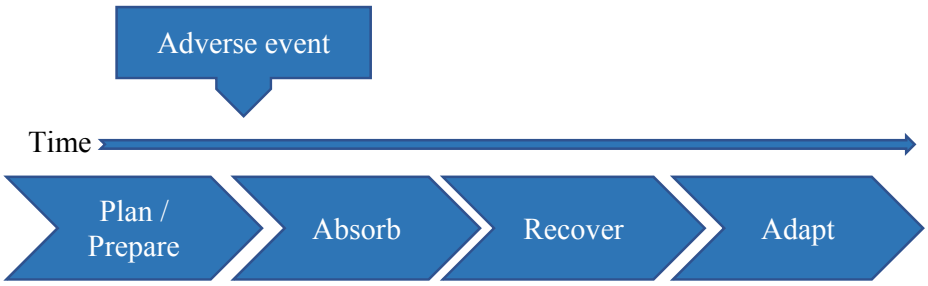
Using the resilience matrix starts by geographically defining the system boundary and establishing the range of threats. Then three to five critical functions are selected, and for each critical function, scoring indicators are chosen. After generating scores for each indicator, separate matrices can be aggregated. Additionally, the agencies and actors, who have either expertise or authority to manage the selected indicators, can be depicted in the same matrix format to identify possibilities for collaboration. (Fox-lent et al. 2015.)

The indicators can be quantitative or qualitative in nature, and their specificity is relative to the selected system scale. An indicator can be a single metric, combined metric, checklist, or it can be based on expert judgement. When selecting the indicators, one should favor those that are in line with the general characteristics of resilient systems. (Fox-lent et al. 2015.)

In general, the selected indicators can be categorized by their nature as either leading (future state), current (present state), or lagging (past state) (Hollnagel et al. 2010). Current and lagging indicators are most common, and one should acknowledge the subjectivity of the ones selected (Hollnagel et al. 2010; Madni & Jackson 2009). Guidance on selecting proper indicators for the resilience matrix is provided in Table 4 by clarifying the meaning of each dimension and phase of the resilience matrix.

The researchers of Winland detected that as such the resilience matrix does not consider the power relations and responsibilities between stakeholders, nor the synergies and conflicts that might affect the resilience management process. Thus, it was initially proposed that these features would be analysed on a fifth dimension named 'political' that would be added to the matrix.

Table 3. The resilience matrix. Descriptions given in the cells aids in selecting the resiliency indicators (adapted from Linkov et al. 2013b).



Physical	State and capability of equipment and personnel, network structure	Event recognition and system performance to maintain function	System changes to recover previous functionality	Changes to improve system resilience
Information	Data preparation, presentation, analysis, and storage	Real-time assessment of functionality, anticipation of cascading losses and event closure	Data use to track recovery progress and anticipate recovery scenarios	Creation and improvement of data storage and use protocols
Cognitive	System design and operation decisions, with anticipation of adverse events	Contingency protocols and proactive event management	Recovery decision-making and communication	Design of new system configurations, objectives, and decision criteria
Social	Social network, social capital, institutional and cultural norms, and training	Resourceful and accessible personnel and social institutions for event response	Teamwork and knowledge sharing to enhance system recovery	Addition of or changes to institutions, policies, training programs, and culture

Table 4. Further guidance for the selection of indicators for the resilience matrix (adapted from Rosati et al. 2015; Linkov et al. 2013a).

Dimension / phase	Focus
Physical	Physical resources and their capabilities: facilities, equipment, sensors.
Information	Information about the physical domain: data creation, data manipulation, data storage.
Cognitive	Make decisions based on information and physical domains: understanding and analyzing data.
Social	The governing structure for making cognitive decisions: interaction and collaboration.
Plan / Prepare	Create the foundation to keep services available and assets functioning during a disruption.
Absorb	Maintain the most critical functions, while isolating the disruption.
Recover	Restore services and assets to full functionality.
Adapt	Gather knowledge from the event to modify the system, train personnel.

4 Semi-structured interview results

4.1 Presenting the results

The results from the semi-structured interviews are divided into three chapters, which focus separately on the themes of water, energy, and comprehensive security. In the chapter focusing on energy security, the results of the two separate interviews are combined to describe the field with a wider view. The chapters are divided into two sections according the second and third research questions which focus on the resilience matrix and the governing systems, respectively. The results contain only answers and insights given by the interviewees, and the key findings are highlighted with a cursive font style.

It was decided before the interview on water security that issues regarding the quality of drinking water, the water supply sector, and the water treatment sector were left outside of the interviews scope. This was done due to the expertise of the interviewees, which is focused on water resources management, floods, and droughts.

4.2 Water security

4.2.1 Governing system: A clear hierarchy amid uncertainty

In Finland, different dimensions of water security are managed by multiple stakeholders, which range from municipalities to ELY Centres (Centres for Economic Development, Transport and Environment) and AVIs (Regional State Administrative Agencies), and from multiple ministries to hydropower plants and the local emergency services departments. A key actor is the Flood Centre, which is a virtual organisation, where the Finnish Meteorological Institute and Finnish Environment Institute (SYKE) join forces.

Currently, *the governing system related to water security has a clear hierarchy*, where the ministries control the ELY Centres, who again control their designated areas. SYKE coordinates the actions of, and provides instruction to relevant stakeholders. This system may change due to the regional government reform, which had not yet been agreed upon in the Finnish Parliament at the time of writing the thesis.

In an emergency, responsibilities shift from the ELY Centres to the local emergency services departments. Yet, *it is not clear how the actual moment when this shift takes place is defined*. The *important role of the emergency service departments* was highlighted several times during the interview, as they often are first to detect the damages, and are also the 'safety net', which aids the public.

The governing system is said to be well organized regarding floods, and it is guided by the Flood Risk Management Act (620/2010). However, *in the case of rare droughts the division of responsibilities is not as clear*. The responsibilities depend also on the type of flood, as even though floods are generally under the authority of the ELY Centres, urban floods are the responsibility of municipalities.

The use of flood insurances was considered a problematic issue regarding the governing system of Finnish water security, as there is no statutory instruction which says that information on flood damages needs to be collected. Also, *for an insurance to cover damages caused by a flood the flood must be 'rare enough' so the customer can never know in advance whether the damages will be compensated or not*. This is an unrecognized problem, and so far, not many people have bought an insurance against agricultural damages.

Because floods and droughts are rare in Finland, people quickly forget to consider them as threats. The same goes for the civil society and the public sector, where it is decided how much funding is allocated for flood risk management. This poses a dilemma, as short-sighted decision making provides little attention to necessary long-time preparation.

One driving force in decision making is *the lack of available funds.* For this reason, the public sector needs to prioritize between actions and between separate sectors of water security. In conclusion, a question was presented that *should the funds be used to protect the society against a rare and uncertain threat, or alternatively to repair and maintain a deteriorating water supply infrastructure?*

4.2.2 The resilience matrix: A viable and puzzling option

The interviewees defined resilience in numerous ways, and noted that there are different ways of approaching the concept. Resilient systems were seen to be linked with features such as adaptive capacity, elasticity, tolerance, ability to learn, and absorptive capacity. As the resilience matrix focuses on threats and adverse events, it was noted that *changes occurring slowly should also be considered*.

If the resilience matrix (Table 3, p. 15) was used to analyze water security in Finland*, SYKE would be one actor who would define the functions and indicators on national level, and ELY Centres and the local emergency services departments should partake in the regional analysis.* The incorporation of local stakeholders is important, but it is not clear, whether the critical functions and indicators should be directed top-down, or bottom-up.

One option is to provide *a basic set of indicators for the same critical functions,* and let the regional level continue from there. This would save time, as *several groups would not have to figure out self-evident indicators,* and it would also *empower the local stakeholders and actors,* who have valuable knowledge of the region.

In any case, multiple indicators would likely arise, and hence the emphasis, or value of each indicator should be somehow determined. Here, *the multiple-criteria decision analysis (MCDA) method* would be useful, and it could be used to emphasize indicators differently depending on the region.

As the suitability of the resilience matrix was considered for a national analysis, it became clear that *the water security of a country was too broad of a subject to be placed in one matrix.* As the flood risk management is conducted in a common way nationally, it might be an exception, but the *matrix would work best in a regional analysis, and on separate sectors of the wider concept of water security.* The regional results could then be combined for a national grade.

When the columns (phases) and rows (domains) of the resilience matrix were discussed, it was noted that it can be *challenging to differentiate between the planning phase and the adaptive phase*, which was seen crucial to "bounce forward". In general, *the division between phases was seen easier than between the dimensions. The meaning of each row* should be explained better, but also *the headlines of each column* would benefit from more clarity.

As one views the matrix as a whole, the connections between the rows and columns should be more intuitive to make the working process fluent. Participants noted that in the end, it is probably not so relevant, in which cell of the matrix one places an important indicator, if all the key indicators are written down.

Regarding the five domains, it was noted that the cognitive domain might bring new points of view to flood risk management, as *the level of flood risk awareness in the society is extremely important, and it affects how people prepare themselves,* and *how they act during an adverse event*.

As suggestions on improvements, it was said that adaptation could be also explained by lessons learned, or learning from an event in general. The newly added row, which was named as *'political' was seen to be too vague* and it would be better divided into separate rows, if both legislation, and the connections and power relations between actors are to be covered.

The *order of filling the matrix* seemed rational, and it felt *functional to be used with flood risk management*. The first step, where the system and threats are defined, is crucial, because *the first selections dictate the entire analysis*, and adequate time should be reserved for it. As critical functions regarding floods, one suggestion would be to avoid the five adverse consequences, which are listed in the §8 of the Flood Risk Management Act (620/2010).

The aim of the resilience analysis should be to identify the cells, or indicators, where most improvement for water security can be made, but an issue was raised with the reporting of improvements and justifying any prioritization to the civil society. If no quantitative measure is available, it might prove difficult to justify the use of public spending to improve the resilience against an unlikely threat.

To properly analyze the actual resilience matrix, a short exercise was conducted where the matrix was used to analyze the resilience of road transport against flooding. Focusing on the suggested topic of reducing flood-induced damages was seen too broad, and hence more specific options from the §8 of the Flood Risk Management Act (620/2010) were contemplated. Road transport is one of few indispensable services which are listed in the act.

Other adverse consequences were listed as:

- adverse consequence to human health or safety;
- long-time interruption of indispensable services, such as water and wastewater services, energy supply, communications, (road transport) or other similar activities;
- interruption of economic activity which ensures the functions vital to society;
- long-term or extensive adverse consequence to the environment; or
- irreparable adverse consequence to cultural heritage.

It was pointed out that these are not commensurate functions, and one should not give the same emphasis for human safety and cultural heritage. Additionally, financial losses are not listed on their own, and they are only mentioned in the third adverse consequence.

When filling out the matrix, it was *easier to figure out relevant indicators than it was to decide to which cell,* and especially *to which row, each indicator should be placed.* The *plan/prepare and absorb phases were the easiest to fill, and it was difficult to separate between recovery and adaptation, or between political and social.* Also, *the cognitive domain should be better explained.*

To summarize, the Finnish translation of the matrix is needed and used throughout the process, if one fills out the matrix the first time. As the used terminology guides the selection of indicators, the instructions should be more clear and intuitive. To make the

process more fluent, *an additional row could be added with the title 'other',* where one can place relevant indicators and not get stuck on figuring out the right cell.

The short exercise was considered useful and functional, and it was said that the exercise showed that *the resilience matrix is a useful tool,* and it *supported the idea of moving forward with matrix regarding water security*.

4.3 Energy security

4.3.1 Governing system: Strong domestic governance

Energy security has many definitions, and the key actors in the governing system vary depending on the definition. A common definition is to focus on the concepts of availability, accessibility, affordability, and acceptability. In Finland, a key requirement of the system is to make sure that there is *enough electrical power in the power grid during the cold winter*. During the coldest time of the year, there is *a known deficit between the demand and the domestic production capacity,* and thus imports are needed.

Securing the supply of electricity and heat is essential for any functioning society, and it was noted that the Finnish society is more and more dependent on electricity through automatization and the Internet of Things. As most data and information is shared online, *the availability and transfer of information is a cross-sectional theme in comprehensive security,* and it relies on *steady supply of electricity*.

Finland has very clear legislation, which dictates *the roles and responsibilities of providing energy security*, and *the industry is well regulated*. The supply and demand define the price of electricity in the virtual electricity market called Nord Pool, through which electricity is bought and sold over national borders in the area covering most of the Nordics and Baltics. It should be noted that Russia is not a part of Nord Pool, and hence it is often more convenient to purchase electricity from another country in the same market, for example Sweden.

The *system is well controlled technically,* but respondents noted that *energy security has also social and political dimensions*. During the interview the interviewees posed such questions as, how important is it for the society that Finland is self-sufficient, or that we shift to carbon-free energy? Should we rely on nuclear power instead of coal, gas, and oil?

If we confine the area of analysis to the borders of Finland, key actors in the system are Fingrid, the National Emergency Supply Agency, the Ministry of Economic Affairs and Employment, large energy companies such as Neste, Fortum, and Gasum, and also smaller local energy companies. However, *one should not set such geographical borders due to the cross-national nature of the energy flows*, which makes it also relevant to include foreign actors in the analysis.

EU is a central actor due to EU legislation, and Finland is also linked to foreign actors and markets through Nord Pool, and the energy flows of oil, gas, coal, and uranium. As two thirds of the imported energy comes from Russia, we should also consider Gazprom, Rosneft, and Rosatom, which are practically controlled by the Russian Government.

The dependency on Russian energy is a recognized issue, but it is not clear, how the same amount of energy would be supplied, if for some reason the Russian exports were halted. As electricity needs to be continuously supplied to match the demand, *Fingrid and the Energy Authority control strategic reserves,* which are needed to uphold the

power grid during a disruption. In the worst case, controlled rolling blackouts would be applied.

An interesting connection between water and energy security comes through hydropower and Nord Pool. Even though a severe drought in the Nordic region would not paralyze the Finnish power market, it would indirectly affect Finland via reduced electricity imports from Sweden and Norway which have significantly higher shares of hydropower than Finland.

Regarding improvements to the governing system of Finland's energy security, it was suggested that the energy sector could benefit from clarifying overlapping subsidies and taxes. This could be done by focusing more on taxing emissions and pollution instead of subsidizing certain electricity production modes.

The global reality is that climate change should be slowed down, and this should be reflected in the way Finland's energy sector is governed. Optimally, *the governing system would be a neutral body,* which focuses only on *environmental and energy politics,* and it would *not be guided by the economic interests of upholding the current energy mix.*

4.3.2 The resilience matrix: A challenge posed by imported energy

The concept of resilience was seen to describe a system that is prepared to react to disruptions, and more specifically how the system can prevent disruptions and recover from them. It is a good thing that concepts like resilience are presented to which people from many disciplines can relate to. One should however be careful that in the context of security the interpretation of the military is not given too strong of a foothold, as this can lead to securitization of for example the natural resources and the environment.

The interviewees considered *the resilience matrix to be useful in detecting deficiencies in a system,* and the *phasing seemed functional,* as one should be able to describe any event within the four columns. *The labelling of the rows was not seen as intuitive,* and especially *the difference between the social and political domains was not clear*. It should be specified, whether the social domain focuses on the social sphere of the society, or alternatively of the identified main actors.

It is good that the political dimension is being recognized, but if the purpose of the row is to describe the power relations between actors, can we state that all power relations are political? Further, *it should be clear, whose political views we are considering*. Some might not see any issues with being dependent on Russian exports, whereas others might favour domestic renewable energy production. One option would be to *fill the matrix from different political standpoints and see how the results differ.*

The matrix was seen *more suitable to analyse the technical sector of energy security,* as one can define the system within the national borders. But if *the entire energy security is considered, there are too many interlinked phenomena,* and one might have to do *trade-offs with matters that are not comparable.* It would be a good idea to *divide the analysis to smaller sections,* for example regionally. However, one should remember that in the energy sector, the global and national level affect the local and regional levels, and therefore a "closed" analysis would not consider all relevant factors.

The work order of the resilience matrix was seen problematic, as *defining the system with the national borders would leave out the foreign actors and processes*. If we focus solely on technical solutions, such a system definition would be adequate, but when we analyse electricity supply or the supply of fossil fuels, we should define the system to also include the Nordics or Russia.

A couple of issues with the matrix were highlighted. One is that *the matrix suffers from a lack of focus to the possible costs of success*. If the goal is to guarantee successful adaptation, the costs of increasing the probability would likely rise exponentially towards a "safe-to-fail" state. Another issue is *incorporating the externalities of for example fossil fuel consumption*. Even though CO_2 emissions might not cause direct problems for Finland, global population is affected through climate change, and in the end this can result in increased migration to Finland among other countries.

Despite the difficulty of fitting all relevant factors and linkages in an analysis where only three to five critical functions are selected, *the matrix has the advantage of providing a way of showing decision-makers and the society different options to understand and increase resilience*. *The critical functions would most likely be selected by the Finnish Government with its different ministries,* but also the most relevant actors, which were listed above, should take part in the process.

It was mentioned that in addition to the governing system, the process should also include the civil society and NGOs who should be offered a possibility of challenging the decisions made by the core actors. Gathering such information democratically would require a lot of resources, and in the end the discussion would somehow need to be restricted to find a realistic consensus.

After a short exercise which focused on analysing the electricity infrastructure with the resilience matrix, *it was seen that the cognitive, social, and political domains were closely connected,* and that *working on one row at a time was not the most fluent method*. The rows and columns aid in understanding the big picture, but instead of filling one row or column at a time, it was seen *more practical to continue thinking of the most relevant indicators, and find suitable cells for them*.

The matrix was considered useful, and due to the interlinked nature of energy security, it would be interesting to analyse resilience with complex scenarios as adverse events. *The matrix would benefit from considering such economic issues as how much funding is available, and on what basis is the use of funds decided*. Finally, it is relevant to note that *besides built infrastructure, the physical domain includes also the ecosystems and environment in general*.

Reviewing the resilience matrix strengthened the viewpoint of one interviewee that the dimensions of the matrix are based on the military's definition of systems. For the other, the understanding of resilience was broadened to also include the phase of adaptation after recovery. Prioritization between the different phases remained challenging, as one needs to decide whether to place more effort in preparation or in absorbing, and then justify the decisions.

4.4 Comprehensive security

4.4.1 Governing system: Providing security via two administrations

Governing comprehensive security is the responsibility of the Finnish Government, and its relevant organizations and offices. It was said that when Matti Vanhanen was the acting Prime Minister, there was a discussion on how the comprehensive security should be governed within the central government. At that time, the result was to continue governing comprehensive security in a similar manner as was done with the former concept of comprehensive national defence.

Thus, the role of Ministry of Defence remained strong, and the interviewee saw that this can cause friction among other ministries, who could argue that the responsibility

should be more centralized to the Finnish Government. A relevant issue is *the position of the Security Committee*, to which three options were presented. Should it continue being *a part of the Ministry of Defence,* should we create *a Ministry of Security with the Security Committee,* or should it comprise of *an expert body within the Finnish Government?*

This very much depends on *the interest of key ministers to modify the current structure,* and currently most ministers concentrate more on other themes, than those of comprehensive security and national defense. Further, *there is an embedded problem with the relationship of the military and civil administrations,* as they tend to be *regarded as two entirely separate entities*.

From the point of view of comprehensive security, these two are strongly linked to each other, and hence *both administrations should interact and understand each other more*. On the civilian side, ELY Centres and AVIs have been created, and recently efforts have been made to move forward with the regional government reform. It was suggested that after the reform, the newly formed regions would partly have responsibility of providing security for the society, and *hence it would be beneficial,* if these *regions were better linked with the organizational structure of the military*.

From the point of view of comprehensive security, it would therefore be favourable, if this issue of separate and spatially differing (military and civil) administrations would be taken into consideration in the larger discourse of the regional government reform. The Finnish Government should clarify the situation on both sides, but doing this and connecting the two sides is a substantial task.

It was noted that as the Finnish Government is renewed every four years, *the attention of the members of parliament, and of the ministers, is directed towards issues which attract voters*. The 'big picture' would benefit from a holistic consensus on the improvements that are necessary to develop the comprehensive security of the Finnish society.

An improvement in the governance of comprehensive security would be to active the Finnish citizens more effectively. *The special knowledge and skills of the Finnish civil society could be better mapped and registered*, and *instead of a national military service register we could have a security register*. The register would contain the abilities, which are beneficial to aid the society when faced with a crisis, and it would not have to be directly linked with the military.

4.4.2 The resilience matrix: A starting point for a productive process

Before working for Winland, the interviewee affiliated the concept of resilience mostly with psychological resilience. When resilience was discussed the focus was on individual citizens and their value in securing a society and increasing its resilience. Instead of focusing on individuals' duty to defend the nation, why not frame the concept as a duty to take part in comprehensive security?

The resilience matrix itself was considered logical, and it benefitted from the addition of the political domain. The importance of the 'plan/prepare' phase was highlighted, as the above-mentioned issues, of the governing system and the activation of individual citizens, requires a lot of time and work. This kind of *focus on everyday preparation differs from interpretations which focus on overcoming conflicts and crises,* and its role was seen *essential in improving the governing system's resilience*.

Considering the work order of the resilience matrix, it was noted that the current comprehensive security thinking was preceded by focusing on the concept of comprehensive

national defence, which was threat-centred. But a question was posed that *do we still need to see resilience through threats, or could we focus more on the abilities of the society in general*?

It was proposed that the vital functions, as defined in the 'Security Strategy for Society' (Valtioneuvosto 2010b), could be used as the critical functions in the matrix analysis. The 'Security Strategy for Society' is a document prepared by the Finnish Government, and hence the Government would be the one who sets the scope of the resilience analysis.

In the context of Winland Finland's comprehensive security is seen through water, food, and energy, and this makes is easier to communicate the subject to the civil society as these are something we think of daily. As these three themes are analyzed separately within Winland, it was decided that a separate exercise analysis on comprehensive security outside these themes would not be conducted.

The decision was based partly on reducing redundant work, but also it was seen that *the vital functions were seen difficult to analyze in the matrix without classifying them to smaller sections*. As a next step, it was suggested that *the actors of the governing system should select one candidate tool, which would be used to structure the viewpoints on the resilience of comprehensive security.* The presented *resilience matrix would be a good and justified starting point,* and it would be good to get more feedback of it.

As the Finnish translation of the matrix will most likely play a role in how people understand the matrix and the nature of the cells/indicators, *more attention should be placed to the translation of key concepts*. For example, as the differences between information, knowledge, and data need to be clear, it would be beneficial to *define them more clearly in the provided instructions*.

When resilience and comprehensive security are discussed, one should not aim to find best solutions and discard the rest. Somehow *differing points of view need to be integrated,* and using *the resilience matrix with the right actors* could be one option. However, tools such as the resilience matrix need to be reviewed critically. It can be *risky to copy and embrace tools which were designed in a different social and political culture,* if one does not keep in mind the geopolitical status and history of Finland.

A tool, such as *the resilience matrix, can assist in detecting flaws in the current governing system,* and by tackling those flaws, *the Finnish system can evolve and move forward.* To succeed in this, we should *start by figuring out, how do we find and attract the "right people" to partake in the process. The process itself can be just as important, as the solutions it produces.* The matrix is a peer reviewed option, and it should be compared with other ones, but as such, *it provides a good starting point and framework for a successful co-creation process.*

5 Discussion

5.1 Resilience: Making the most of a diverse concept

If one considers the uncertainties of a complex world and the change which seems embedded in global interconnected systems, the continuous process of resilience analysis seems like a more flexible and proactive option than the traditional risk analysis. When we focus on the resilience of a system, critical system functionalities which are key to bouncing back (or forward) are highlighted. Concurrently, the system's ability to withstand various adverse events can be improved.

Related to the first research question, the plethora of available resilience definitions could arguably be considered as a challenge for actionable policy. Yet, regarding the concept of Finnish comprehensive security, they can also be seen to provide opportunities for a multifaceted national approach that includes various sectors and actors.

The concept of comprehensive security is in the thesis seen to construct of multiple security themes, which are shaped by multiple factors from the national to local level. Alternatively, the official definition of the Finnish Government focuses on a broad spectrum of national matters, which would prove to be difficult to analyse with any single disciplinary approach.

If a diverse concept such as comprehensive security would be analysed using an inflexible definition and simplistic tools, the analysis would likely not consider all the relevant aspects. Instead, one can consider the general characteristics of systemic resilience which were identified in the literature review, but at the same time keep in mind that they should be understood as guiding themes and concepts, and not as objective 'truths'.

Considering the first research question, if one aims to analyse the resilience of a whole society, and the critical infrastructure and natural resources that support it, one should acknowledge the challenges of using the concept of resilience in such a broad context. With comprehensive security, concepts such as agency, responsibility, and power should be kept in mind, but these are the very concepts which tend not to be used in resilience literature (Olsson et al. 2015).

These findings do not suggest that resilience could not be used in promoting comprehensive security. They rather highlight the need of emphasizing the above concepts and diversity of comprehensive security and resilience when resilience analysis is conducted regarding security on a national level.

If we are clear on which definition for resilience is used, and what we leave outside of the analysis, it is easier for people to take part in the dialogue. After all, increasing resilience is a process and it benefits from an educated discussion from multiple disciplines. Alternatively, if we would go on to declare a certain viewpoint as the 'right' one, instead of a discussion we could be faced with opposition. Instead of benefitting from synergy and co-creation, a firm opposition might lead towards confrontation.

If we consider resilience and its multifaceted nature, we cannot apply the same metrics for every object which we are interested in measuring. When the goal is to increase comprehensive security and we move from top to bottom in the system hierarchy, our focus shifts from the Finnish Government and its ministries to water treatment plans and private housing on river banks.

When one studies the resilience of a governing system, a tool such as the presented resilience matrix is well suited, but if the object of analysis is for example a water treatment plant or the power grid, it might be reasonable to utilize a tool designed for engi-

neering resilience. Thus, the scope and the way of measuring resilience are not static, and neither is the disciplinary approach. According the object of analysis, one can move from a social-ecological system oriented view on resilience towards engineering and psychological resilience.

In summary, to define the resilience of Finland's comprehensive security one needs to first understand the diversity of such a concept. Then, the many themes through which it is constructed should be analyzed using varying and context specific tools and definitions. Instead of focusing solely on threat scenarios, we could focus on resilience as a property of a system (Meadows 2009), and study how we could increase our agency in steering the Finnish society towards a more secure future.

5.2 The resilience matrix: Increasing the understanding of systemic resilience

This chapter focuses on the second research question and discusses the feedback obtained from the semi-structured interviews. Comprehensive security proved to be too broad of a concept to be analyzed in the resilience matrix. Therefore, most feedback on the resilience matrix was obtained regarding the themes of water and energy security. The themes of water security and energy security were also seen too broad, and they had to be divided into more precise sections for a functional analysis. Such a division could be done geographically or thematically.

The resilience matrix itself was considered useful, and it seems to aid well to understand the whole system under analysis. In their work, experts and researchers might tend to focus on specific sections of broad concepts such as water security. Analysing the whole concept through the resilience matrix can therefore open new insights and areas for improvement.

The work order of the resilience matrix fits water security better than energy security, as water security can be governed domestically, but energy security is more influenced by foreign actors and imported energy. However, the governance of the domestic energy infrastructure could be analysed with the resilience matrix.

If the resilience matrix is utilized in practice, more emphasis should be placed on clarifying the differences between the phases and dimensions and on the guidance regarding suitable indicators. The separation between the phases was seen more intuitive than between the dimensions, which makes sense as most definitions and measures of resilience use some similar version of the four phases (Bhamra et al. 2011; Francis & Bekera 2013; Ganin et al. 2016; Madni & Jackson 2009; Rosati et al. 2015; Yodo & Wang 2016).

Selecting proper indicators can be challenging as they should denote the general characteristics of a resilient system and preferably be objective in nature. On the other hand, one could argue that the whole process of filling out the resilience matrix is inherently subjective, and the process would likely differ depending on the group of people conducting the analysis.

When the resilience matrix was tested during the interviews, identifying suitable indicators seemed most fluent regarding water security. This could be a result of the selected critical function, or it could be that the group interview spurred more indicators as people with different backgrounds co-operated in the process. The short exercise itself was useful, and it was a fluent way of obtaining practical feedback on the matrix.

As a next step, the matrix could be used to pinpoint possibilities for collaboration between different agencies and actors (Fox-lent et al. 2015), and by doing so many over-

lapping activities could be streamlined, or alternatively unknown deficiencies could be identified.

In some cases, as with Finnish water security, defining the critical functions according the Flood Risk Management Act is justified, but still selecting the precise indicators can prove to be difficult. The selected indicators need to be justified, and if one aims to use the resilience matrix for regular reviews, the same set of indicators should be in place to support following up the progress. It is a challenge to select the 'right ones', as they should support proactivity, and they should be as objective as possible (Hollnagel et al. 2010).

In general, difficulties with using the matrix can be a result of poor instructions, but also of the lack of good known indicators. This could in turn indicate that some relevant characteristic of the system is not known or measured. For assistance on finding proper indicators which truly consider the resilience of a system, one could read the probing questions of the RAG presented in Appendix 2. The proposed questions can work as indicators themselves, but using them might increase the subjectivity of the analysis itself.

If the resilience matrix is utilized to assess national systems, a key challenge is to communicate also the decisions which are made before the resilience matrix is used. Besides justifying the system boundaries, critical functions, and indicators, it should be acknowledged that people might have political views on local and national matters. Unless these are addressed, the process might be clogged with hidden agendas which can conflict with each other. Ideally, the process would follow statutory guidance and scientific reasoning, but in the end, the decisions on trade-offs and prioritization will include some level of political conviction.

Even though the need to acknowledge power relations in the matrix was recognized before the interviews, it became apparent that the proposed way of adding the 'political' dimension was not functional. The use of 'legislation' instead of a 'political' row sounds like a practical suggestion, and it might be that political dimension simply does not work in such a matrix framework.

Political views are explicitly subjective, and even though the concepts of agency, power, and equality need to be considered (Olsson et al. 2015), grading the political dimension in a matrix might prove to be infeasible. Alternatively, the resilience matrix could be filled from different political viewpoints, and it could be studied how the results differ.

Regarding the second research question, many improvements were suggested during the interviews, and by taking them into account the matrix could prove to be a good way of mapping out the systemic resilience of governing systems. As filling out the matrix should be designed as fluent as possible, it was a useful suggestion to add the row 'other' for important indicators that are difficult to place in the matrix.

It would also be a good improvement to consider the economic dimension in the analysis. One should consider the prioritization of different dimensions and phases on a general level, but also the impact, which can be made with the allocated funding, should play a role. As an example, it might be that available funds could be used to improve the resilience score of a single cell in the 'absorb' phase, or alternatively for three cells in the 'adapt' dimension.

In any case, as the different dimensions and temporal phases of a system are analysed, many relevant issues can arise from the conversation. One of the biggest advantages which the matrix approach can offer is precisely the conversation it sparks. One could

argue that such conversation is part of the process that is called resilience engineering, and instead of merely learning of occurred adverse events learning could occur already in the 'plan/prepare' phase.

5.3 Governing national security in Finland

In the context of the thesis, energy and water security influence comprehensive security directly. It can thus be said that if their resilience is increased, the resilience of comprehensive security is increased as well. In relation to the third research question, it can be said that both energy and water security seem to be supported by a strong governing system, whether it is due to a clear hierarchy or strong legislation. They might however be tested in the future, as the frequency of floods, droughts, and issues regarding imported energy are not known.

The official definition of comprehensive security places responsibility to "business life, NGOs and individual citizens", so should also the key actors of the private sector share a common definition on resilience? Or what about the civil society? It can portray a sense of unity and a strong society when it is said that we all do our part in securing comprehensive security, but at the same time, if the responsibility is multipolar so should be the ability to vote on the courses of action.

As we try to find a way to make a society more resilient, it is extremely important to keep in mind the prevalent power relations, and the politics which can affect them. Even though the quality of life in Finland is valued as one of the highest in the world, it seems fitting that issues such as inequality and poverty should be taken into consideration when decisions are made on diversifying the responsibility for comprehensive security.

At least, we should view the resilience of our comprehensive security from the point of view of stakeholders in different positions in the Finnish society. The same should be done with different political views. How is the functionality of the system seen and experienced from the point of view of different stakeholders? In other words, what would be the effects of a non-functional system?

Using vague rhetoric on the definition of resilience is one problem, but just as well one should refrain from using vague justifications on the means of action. If resilience is embraced as the process towards security, the Finnish society needs to be informed about the practical changes to the ways in which security is provided, and how it might affect them on a local or individual level.

The idea of comprehensive security poses also the question of increased securitization. Should the Finnish Government really secure everything, and can they be expected to succeed in this? It is comforting that Fingrid and the Energy Authority keep an eye on the big picture regarding energy security and they aim to make sure that for example every home in Finland is heated during the cold winter. At the same time, it would be comforting to hear about long term plans which dictate the strategy regarding the reliance on imported fossil fuels from Russia.

But if Finland switched from fossil fuels to renewable energy and nuclear energy, how would this affect the Finnish society, and would it increase or decrease the society's resilience? A diversified energy mix sounds like a resilient option, but relying on renewable energy does not, as the biggest issue in Finland is to supply energy during the times when renewable energy is most difficult to harvest.

As stated, energy security is a relevant topic due to its supporting role in almost every aspect of a functioning society. The dependence on imported energy sources makes it a tricky subject to analyze, and it does not seem that we can be self-sufficient regarding

energy anytime soon. We are, on the other hand, extremely self-sufficient when it comes to water resources, and hence studying water security and its resilience seems more straightforward.

In Winland, water is paired with climate (Figure 1), and this makes sense as the climate change is the biggest driver affecting the hydrogeological water cycle globally. The changes in annual water cycle are observed to predict floods, but regardless of Finland's water resources, it is also relevant to prepare for dry years. If one considers climate change and Finland's water security, it seems like a good idea to study the resilience of the governing system which needs to manage with the uncertainties regarding the frequencies of future floods and droughts.

Floods and droughts do not necessarily pose relevant threats for people who live in the capital region of Finland, but for some they can cause dramatic financial and infrastructural losses. Hence, the equality in water security should be highlighted when decisions are made on the national level of resilience.

5.4 Future challenges

The notion of adaptive cycles (Holling 2001) on different scales seems fitting to describe the processes which affect a system, especially when we discuss matters on the national level. As an example, the proactive co-creation process conducted within Winland aims to affect the resilience of the Finnish society, but it is also affected by larger scale global processes which are more difficult to observe.

We should somehow spot relevant signals of the global processes, and based on them select proper indicators to guide our attempts to increase systemic resilience. Moving forward, it would be beneficial to be active in the evident transformation to a more sustainable society, and arguably this calls for proactive measures, such as incorporating resilience thinking in strategic planning.

As Finland is centrally governed, one way to increase the resilience of the Finnish society is to aid the Finnish Government and its understanding on resilience engineering. In doing so, a relevant task is to communicate the uncertainties in the used data and models which are used in resilience analysis.

It was also noted during the interviews that there is a dilemma in managing long term uncertainty, as the national governing body changes every four years. Coming outside of the political sphere, the Winland research project could be one actor which provides guidance that extends over the relatively short governing term.

The issue of politics regarding national strategic planning is a key challenge, and therefore it is critical that the process of analysing resilience is well documented and justified so that reasoning behind the used process can be back-tracked. Politics is closely tied to affecting legislation and the way public funding is used, so another challenge is to argue in favour of using funds to increase resilience in general. Hence, measuring the success or failure of resilience engineering is key, and this in turn requires validated processes and frameworks.

Additionally, if the results of a resilience analysis show that most improvement could be made in the 'adapt' phase, should it automatically favoured as the focus of future actions? Or can a case be made that planning and preparing against threats is still more important?

To summarize, decision-making regarding water, energy, and comprehensive security should be supported by tools and frameworks which have been tested and validated. The resilience matrix would benefit from further development if it is to be used in the

context set in this thesis, but it has proven to be a very potential way of structuring the concept of resilience regarding security on a national level. Hopefully the results of this thesis will support developing the matrix further so that it could be used for analysing resilience on the national level in Finland and abroad.

6 Conclusions

In this thesis, multiple definitions of resilience were presented and the suitability of using resilience with the concept of Finland's comprehensive security was analysed. The Finnish Government has a distinct definition of comprehensive security, but in the context of this thesis, the it was analyzed by focusing on water and energy security.

Measuring resilience is a key phase in resilience analysis. Yet, it suffers from the same lack of consensus as does defining the concept. After reviewing ways of measuring resilience, the resilience matrix (Linkov et al. 2013b) was selected as the most promising way of analysing resilience in the context of national security. The matrix was tested by interviewing the experts of the Winland research project.

The semi-structured interviews focused on water, energy, and comprehensive security. As the first step of resilience analysis is to define the system under analysis, testing the functionality of the resilience matrix required defining the system boundaries and the governing system of each thematic analysis.

The aim of the thesis was to answer the following three research questions:

- *RQ 1: How can resilience and its different definitions help in promoting comprehensive security?*
- *RQ 2 How applicable is the resilience matrix presented by Linkov et al. (2013b) to analyze the resilience of Finland's water, energy, and comprehensive security, and what kind of constraint and possibilities does the matrix entail?*
- *RQ 3: How are the governing systems regarding the resilience of Finland's water, energy, and comprehensive security characterized?*

Regarding the first research question it can be concluded that instead of stating that any definition of resilience as being all-encompassing, it would be more constructive to embrace the diverse nature of resilience, and use a definition (or measurement) based on the context.

As comprehensive security is a diverse concept which covers for example social, technical, and environmental dimensions, its resilience cannot be defined unequivocally. Since the social sciences do not integrate seamlessly with the resilience literature, one should emphasize such concepts as agency and power when conducting resilience analysis.

In relation to the second research question, the results of the semi-structured interviews showed that the resilience matrix is a good starting point in structuring systemic resilience, and that the phases and dimensions included in the matrix widen the systemic understanding of security on a national level. However, as such the resilience matrix is not adequate for analysing the resilience of water, energy, or comprehensive security holistically.

The semi-structured interviews provided good insights, which can assist further development of the resilience matrix to make it more functional in assessing the resilience of security on a national scale. The first key step would be to carefully select the right people to start working with the resilience matrix and reserve time for educating them on the concept of resilience and the particularities of the security themes under analysis. Besides detecting flaws in the current governing system, such a process would in fact improve the resilience of the 'plan/prepare' phase regarding comprehensive security.

As for the third research question, the results of the interviews indicate that Finland's water, energy, and comprehensive securities are currently supported by strong governance. However, it remains to be seen how the governing systems will be affected by Finland's regional government reform, or how the governance will react to changes caused by the climate change.

Further analysis of the resilience of Finnish society would benefit from a more thorough research on the governing systems of water, energy, and comprehensive security in Finland. As the concept of comprehensive security has recently been adopted as the goal of security policy in Finland, one could also study the effect it has had in securitisation of the natural resources.

In summary, resilience seems to be a key concept of future sustainable strategic planning, and hence the use of resilience engineering as a process would benefit from a coherent set of definitions for each disciplinary approach. In the field of comprehensive security, actors with varying disciplinary background interact so one should aim to define clearly how they understand the concept of resilience, because in this way it also becomes clear what is left outside of a resilience analysis.

Interdisciplinary research and co-creation seem like fitting methods to find ways to increase a society's resilience. This thesis does not provide a definitive definition of resilience, but rather emphasizes its context-specificity. Yet, the feedback from the semi-structured interviews can assist further development of the resilience matrix to make it more functional in assessing the resilience of security on a national scale.

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List of Appendices

Appendix 1. A compilation of resilience definitions by multiple disciplines.

Table A1-1. A Compilation of resilience definitions by multiple disciplines (adapted from Bhamra et al. 2011; Brand & Jax 2007).

Author	Context	Definition
Holling (1973)	Ecological systems	The measure of the persistence of systems and of the ability to absorb change and disturbance and still maintain the same relationships between state variables.
Tilman & Downing (1994)	Ecological systems	The speed at which a system returns to a single equilibrium point following a disruption.
Gunderson (2000)	Ecological systems	The magnitude of disturbance that a system can absorb before its structure is redefined by changing the variables and processes that control behaviour.
Walker et al. (2004)	Ecological systems	The capacity of a system to absorb a disturbance and reorganise while undergoing change while retaining the same function, structure, identity and feedback.
Bodin & Wiman (2004)	Physical systems	The speed at which a system returns to equilibrium after displacement, irrespective of oscillations indicates the elasticity (resilience).
Hollnagel et al. (2006)	Engineering	The ability to sense, recognise, adapt and absorb variations, changes, disturbances, disruptions and surprises.
Carpenter et al. (2001)	Socio-ecological systems	The magnitude of disturbance that a system can tolerate before it transitions into a different state that is controlled by a different set of processes. Resilience of what to what?
Walker et al. (2002)	Socio-ecological systems	The ability to maintain the functionality of a system when it is perturbed or the ability to maintain the elements required to renew or reorganise if a disturbance alters the structure of function of a system.
Adger et al. (2005, p. 1036)	Social-ecological systems	The capacity of a social-ecological systems to absorb recurrent disturbances (...), so as to retain essential structures, processes and feedbacks.

Adger (2000, p. 347)	Sociological	The ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change.
Folke et al. (2002)	Ecosystem-services-related	The underlying capacity of an ecosystem to maintain desired ecosystem services in the face of a fluctuating environment and human use.
Brock et al. 2002:273	Ecological-economic	Transition probability between states as a function of the consumption and production activities of decision makers.
Perrings 2006:418	Ecological-economic	The ability of the system to withstand either market or environmental shocks without losing the capacity to allocate resources efficiently.
Horne & Orr (1998)	Organisational	Resilience is the fundamental quality to respond productively to significant change that disrupts the expected pattern of event without introducing an extended period of regressive behaviour.
Hamel & Välikangas (2003)	Organisational	Resilience refers to the capacity to continuous reconstruction.
McDonald (2006)	Organisational	Resilience conveys the properties of being able to adapt to the requirements of the environment and being able to manage the environments variability.
Cumming et al. (2005)	Operational	The ability of the system to maintain its identity in the face of internal change and external shocks and disturbances.
Paton et al. (2000)	Disaster Management	Resilience describes an active process of self righting, learned resourcefulness and growth. The concept relates to the ability to function at a higher level psychologically given an individual's capabilities and previous experience.
Bruneau et al. (2003)	Disaster management	The ability of social units to mitigate hazards, contain the effects of disasters when they occur and carry out recovery activities that minimise social disruption and mitigate the effects of future earthquakes.
Luthans et al. (2006)	Psychology	The developable capacity to rebound from adversity.
Coutu (2002)	Individual	Resilient individuals possess three common characteristics. These include an acceptance of reality, a strong belief that life is meaningful and the ability to improvise.

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Appendix 2. Probing questions of the resilience analysis grid (RAG).

With RAG, it is seen that a resilient system is comprised of the four abilities, and that these should be analysed separately. The abilities are "the ability to respond to events, to monitor ongoing developments, to anticipate future threats and opportunities, and to learn from past failures and successes alike". (Hollnagel et al. 2010.)

After defining the system, one should select relevant questions for each of the four abilities (see Tables A2-1, A2-2, A2-3, and A2-4), and provide answers by rating them excellent, satisfactory, acceptable, unacceptable, deficient, or missing. The result can be illustrated on a star chart (see Figure 6) by drawing a polygon according the answers. (Hollnagel et al. 2010.)

Naturally, the level of resilience, as measured by the RAG, is directly affected by the setting of probing questions, and the provided qualitative answers.

Table A2-1. Probing questions for the ability to respond (adapted from Hollnagel et al. 2010).

	Analysis item (ability to respond)
Event list	*Is there a list of events for which the system has prepared responses? Do the events on the list make sense and is the list complete?*
Background	*Is there a clear basis for selecting the events? Is the list based on tradition, regulatory requirements, design basis, experience, expertise, risk assessment, industry standard, etc.?*
Relevance	*Is the list kept up-to-date? Are there rules/guidelines for when it should be revised (e.g., regularly or when necessary?) On which basis is it revised (e.g., event statistics, accidents)?*
Threshold	*Are there clear criteria for activating a response? Do the criteria refer to a threshold value or a rate of change? Are the criteria absolute or do they depend on internal/external factors? Is there a tradeoff between safety and productivity?*
Response list	*How is it determined that the responses are adequate for the situations they refer to? (Empirically, or based on analyses or models?) Is it clear how the responses have been chosen?*
Speed	*How soon can an effective response begin? How fast can full response capability be established?*
Duration	*For how long can an effective response be sustained? How quickly can resources be replenished? What is the 'refractory' period?*
Resources	*Are there adequate resources available to respond (people, materials, competence, expertise, time, etc.)? How many are kept exclusively for the prepared responses?*
Stop rule	*Is there a clear criterion for returning to a 'normal' state?*
Verification	*Is the readiness to respond maintained? How and when is the readiness to respond verified?*

Table A2-2. Probing questions for the ability to monitor (adapted from Hollnagel et al. 2010)

	Analysis item (ability to monitor)
Indicator list	*How have the indicators been defined? (By analysis, by tradition, by industry consensus, by the regulator, by international standards, etc.)*
Relevance	*When was the list created? How often is it revised? On which basis is it revised? Is someone responsible for maintaining the list?*
Indicator type	*How appropriate is the mixture of 'leading', 'current' and 'lagging' indicators? Do indicators refer to single or aggregated measurements?*
Validity	*For 'leading' indicators, how is their validity established? Are they based on an articulated process model?*
Delay	*For 'lagging' indicators, what is the duration of the lag?*
Measurement type	*How appropriate are the measurements? Are they qualitative or quantitative? (If quantitative, is a reasonable kind of scaling used?) Are the measurements reliable?*
Measurement frequency	*How often are the measurements made? (Continuously, regularly, now and then?)*
Analysis / interpretation	*What is the delay between measurement and analysis/interpretation? How many of the measurements are directly meaningful and how many require analysis of some kind? How are the results communicated and used?*
Stability	*Are the effects that are measured transient or permanent? How is this determined?*
Organisational support	*Is there a regular inspection scheme or schedule? Is it properly resourced?*

Table A2-3. Probing questions for the ability to anticipate (adapted from Hollnagel et al. 2010)

	Analysis item (ability to anticipate)
Expertise	*Is there expertise available to look into the future? Is it in-house or outsourced?*
Frequency	*How often are future threat and opportunities assessed? Are assessments (and re-assessments) regular or irregular?*
Communication	*How well are the expectations about future events communicated or shared within the organisation?*
Assumptions about the future (model of future)	*Does the organisation have a recognisable 'model of the future'? Is this model clearly formulated? Are the model or assumptions about the future explicit or implicit? Is the model articulated or a 'folk' model (e.g., general common sense)?*
Time horizon	*How far does the organisation look ahead? Is there a common time horizon for different parts of the organisation (e.g., for business and safety)? Does the time horizon match the nature of the core business process?*
Acceptability of risks	*Is there an explicit recognition of risks as acceptable and unacceptable? Is the basis for this distinction clearly expressed?*
Aetiology	*What is the assumed nature of future threats? (What are they and how do they develop?) What is the assumed nature of future opportunities? (What are they and how do they develop?)*
Culture	*To which extent is risk awareness part of the organisational culture?*

Table A2-4. Probing questions for the ability to learn (adapted from Hollnagel et al. 2010)

	Analysis item (ability to learn)
Selection criteria	*Is there a clear principle for which events are investigated and which are not (severity, value, etc.)? Is the selection made systematically or haphazardly? Does the selection depend on the conditions (time, resources)?*
Learning basis	*Does the organisation try to learn from what is common (successes, things that go right) as well as from what is rare (failures, things that go wrong)?*
Data collection	*Is there any formal training or organisational support for data collection, analysis and learning?*
Classification	*How are the events described? How are data collected and categorised? Does the categorisation depend on investigation outcomes?*
Frequency	*Is learning a continuous or discrete (event-driven) activity?*
Resources	*Are adequate resources allocated to investigation/analysis and to dissemination of results and learning? Is the allocation stable or is it made on an ad hoc basis?*
Delay	*What is the delay between the reporting the event, analysis, and learning? How fast are the outcomes communicated inside and outside of the organisation?*
Learning target	*On which level does the learning take effect (individual, collective, organisational)? Is there someone responsible for compiling the experiences and making them 'learnable'?*
Implementation	*How are 'lessons learned' implemented? Through regulations, procedures, norms, training, instructions, redesign, reorganisation, etc.?*
Verification/ maintenance	*Are there means in place to verify or confirm that the intended learning has taken place? Are there means in place to maintain what has been learned?*

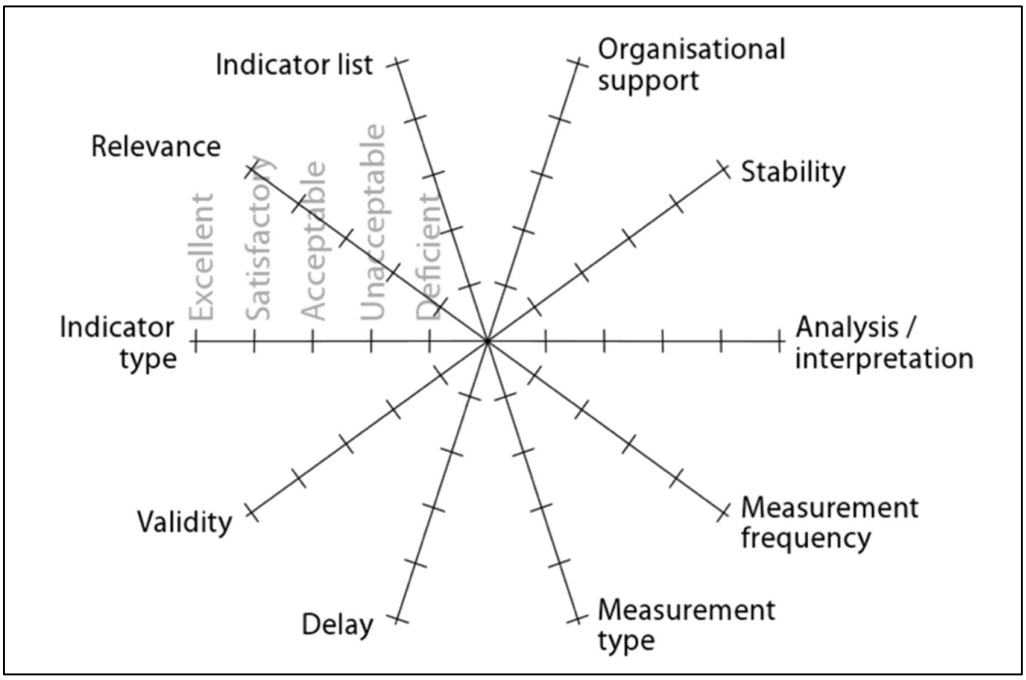


Figure 6. A RAG star chart for questions regarding monitoring (adapted from Hollnagel et al. 2010).

Appendix 3. Interview questions in Finnish.

Tausta:

1. **Ketkä ovat mielestänne Suomen vesi-/energia-/kokonaisturvallisuuden hallinnan oleellisimmat toimijat? Miksi?**

JL: -Vesiturvallisuutta on kuvattu Winlandin tutkimuskatsauksessa vesivarojen hallinnan tavoitetilana. Tutkimuskatsauksessa lisäksi todetaan, että "YK on määritellyt vesiturvallisuuden elinkeinojen, terveyden ja hyvinvoinnin sekä sosioekonomisen kehityksen kannalta riittävänä veden määränä ja laatuna. Se kattaa vesistöjen saastumisen ehkäisemisen, veteen liittyviin katastrofeihin ja uhkiin varautumisen, ekosysteemien monimuotoisuuden säilyttämisen sekä oikeudenmukaisen vesivarojen hallinnan.". (Winland 2017b, p.8)

-Energiaturvallisuutta on kuvattu Winlandin tutkimuskatsauksessa seuraavan laisesti: Sen on perinteisesti nähty koostuvan energian saatavuudesta (varannot), saavutettavuudesta (logistiikka), kustannustehokkuudesta (talous) ja hyväksyttävyydestä (yhteiskunta). (Winland 2017b, p. 6.)

-Winland-hanke (2016–2019) tarkastelee Suomen kokonaisturvallisuutta energian, ruoan ja veden sekä resilienssin näkökulmasta. Painopisteenä ovat suomalaisen yhteiskunnan elintärkeät toiminnot sekä kriittinen infrastruktuuri ja tuotanto. (Winland 2017b, p. 2).

Tässä on tavoitteena pyrkiä kartoittamaan vesiturvallisuuden toimijakenttää analysoitavan systeemin rajaamiseksi.

2. **Miten luonnehtisitte vesi-/energia-/kokonaisturvallisuuden hallintajärjestelmän rakennetta ja dynamiikkaa Suomen tasolla? Muuttuuko hallintajärjestelmän dynamiikka häiriötilanteen aikana?**

JL: Hallintajärjestelmällä tarkoitetaan tässä yhteydessä toimijoiden välisiä yhteyksiä ja valtasuhteita. Keskustelun aikana pyritään hahmottamaan, miten esimerkiksi tieto ja vastuu siirtyvät hallintajärjestelmän sisällä.

Ensin keskitytään varautumisen vaiheeseen, minkä jälkeen keskustellaan häiriön aikaisen toiminnan vaiheesta ja mahdollisista muutoksista päätöksenteossa ja toimintavastuussa.

3. **Onko resilienssi terminä teille entuudestaan tuttu? Miten määrittelisitte sen?**

JL: Tässä diplomityössä resilienssiä käsitellään erityisesti systeemien ja hallinnan järjestelmien tasolla. Resilienssin määrittely muuttuu, kun lähestytään käytännön tasoa ja esimerkiksi teknisiä järjestelmiä. Työn yhtenä tavoitteena on löytää tavat, joilla eri näkökulmat ja resilienssin tasot linkittyvät toisiinsa.

Resilienssi-matriisi:

JL: Winlandin sisällä on huomattu, että resilienssillä on suuri määrä määritelmiä ja merkityksiä, minkä vuoksi käsitteeseen on haasteellista tarttua kiinni. Tässä diplomityössä testataan Linkovin ja kumppaneiden luomaa matriisia, sillä se tarjoaa konkreettisen tavan jäsentää, mistä kokonais- ja vesiturvallisuuden resilienssissä on kyse.

	Varautuminen	*Häiriön aikainen toiminta*	*Palautuminen*	*Sopeutuminen*
Fyysinen				
Informaatio				
Ajattelumallit / kognitiivinen				
Sosiaalinen				
Poliittinen				

4. **Tuntuuko vesiturvallisuuden resilienssin jaottelu esitettyihin neljään vaiheeseen ja viiteen ulottuvuuteen toimivalta?**

JL: Linkov ja kumppanit ovat omaksuneet käytetyt neljä vaihetta National Academy of Sciences:in resilienssin määrittelystä. Vastaavaa vaiheistusta on käytetty myös Suomessa huoltovarmuuskeskustelussa. Linkovin ja kumppaneiden valitsemat neljä ulottuvuutta ovat US Army:n Network-Centric Warfare –doktriinin mukaiset 4 yleistä hallinnan ulottuvuutta, joita on sanottu voitavan soveltaa mihin tahansa monitahoisen systeemiin (Fox-lent et al. 2015, p. 210). Haastatteluissa käsitellään lisäksi poliittista ulottuvuutta, jonka myötä pyritään hahmottamaan eri toimijoiden välisiä valta- ja vastuusuhteita sekä heidän välisiä synergioita ja ristiriitoja.

5. **Miten resilienssi-matriisi mielestänne soveltuu vesiturvallisuuden valtakunnalliseen tarkasteluun?**

JL: Liitteenä oleva syventävä esimerkki matriisin sovelluksesta käsitteli tarkasti rajattua aluetta (Fox-lent et al. 2015, s. 210-212).

6. **Miten arvioisitte resilienssi-matriisin täydentämisen etenemisjärjestystä? Onko se hyvä sellaisenaan? Mikä siinä on haasteellista?**

JL: Matriisin täydentämisen etenemisjärjestys: 1) Systeemin rajaus ja uhkien määrittely;
2) kriittisten toimintojen määrittely; 3) arviointikriteerien/-indikaattorien määrittely ja arvostelu; 4) matriisien yhdistäminen.

Huom! Arviointikriteerit/–indikaattorit voivat olla joko määrällisiä tai laadullisia.

7. **Kuka näkemyksenne mukaan määrittäisi vesiturvallisuuteen liittyvät kriittiset toiminnot ja niiden arviointikriteerit?**

JL: Linkov suosittelee, että kriittisiä toimintoja valitaan 3-5 analyysiä varten. Kriittiset toiminnot ja niiden arviointiin valitut kriteerit vaikuttavat merkittävästi tehdyn analyysin yleisarvosanaan. Kuinka taataan, että valinnat tehdään hyvin?

8. **Puuttuuko resilienssimatriisista jotain, tai onko siinä mielestänne ominaisuuksia, jotka ovat haasteellisia/harhaanjohtavia? Mitä tekisitte toisin?**

JL: Toukokuisessa Winlandin sisäisessä resilienssi-tapaamisessa resilienssi-matriisin päätettiin lisätä poliittinen ulottuvuus, sillä matriisi ei sellaisenaan huomioi toimijoiden välisiä valtasuhteita.

<u>Yhteenveto:</u>

9. **Millä tavoin vesiturvallisuuden uhkiin ja muutospaineisiin varautuminen on mielestänne yhteydessä energia-, ruoka-, tai kokonaisturvallisuuden varautumiseen Suomessa?**

JL: Winlandin julkaisuissa on nostettu esiin yhteyksiä Suomen energia-, vesi-, ruoka- ja kokonaisturvallisuuden välillä. Tulisiko nämä yhteydet huomioida valittaessa kriittisiä toimintoja ja arviointikriteereitä?

10. **Miten näette resilienssin käsitteen käydyn keskustelun perusteella?**

11. **Missä ovat vesi-/energia-/kokonaisturvallisuuden tämänhetkisen hallintajärjestelmän kipupisteet?**
    -Löytyykö eroavaisuuksia kuivuuden tai tulvien kohdalla?
    -Löytyykö eroavaisuuksia sähkön- tai lämmöntuotannon kohdalla?

12. **Muuttaisitteko jotain nykyisessä hallintajärjestelmässä?**

Appendix 4. Interview questions translated to English.

Background:

1. **Who do you consider to be the most relevant actors and stakeholders for Finland's water/energy/comprehensive security? Why?**

JL: -Water security is described in Winland's recent publication, as the main objective of water governance. In the same publication, it was stated that the "UN has defined water security as the adequate quantity and quality of water for livelihoods, health and wellbeing, and socio-economic development. It consists preventing the contamination of watersheds, preparing for water related catastrophes and threats, preserving the diversity of ecosystems, and a fair governance of water resources.". (Winland 2017b, p. 8.)

-Energy security has been defined in Winland's recent publication in the following way: It has traditionally been understood that energy security consists of energy availability (resources), accessibility (logistics), affordability (economy), and acceptability (society). (Winland 2017b, p. 6.)

-Winland (2016–2019) studies Finland's comprehensive security from the point of view of energy, food, water and resilience. Focus will be on the vital functions of Finnish society, the critical infrastructure and production. (Winland 2017b, p. 2.)

The aim here is to define the actors and stakeholders of water/energy/comprehensive security to define the system under analysis.

2. **How would you characterize the structure and dynamics of the governing system of water/energy/comprehensive security in Finland? Does the dynamics of the governing system change during an adverse event?**

JL: Here, governing system refers to the connections and power relations between actors. During the conversation, we aim to understand, how for example knowledge and responsibility is shifted inside the governing system.

First, we focus on planning and preparation, and the we proceed to discussing the absorbing phase, and possible changes in decision-making and responsibilities to act.

3. **Is resilience a previously familiar concept to you? How would you define it?**

JL: In this Master's thesis, resilience is analyzed especially on a systemic and governing level. The definition of resilience changes as we approach the practical level, and for example technical systems. One goal of the thesis, is to find the ways, in which the different viewpoints and levels of resilience are linked to each other.

Resilience matrix:

JL: It had been noticed inside Winland, that the many definitions of resilience made it difficult to take a firm old of the concept. In this Master's thesis, the resilience matrix, which has been created by Linkov et al., is tested, as it offers a concrete way of analyzing the resilience of comprehensive, energy, and water security.

	Plan/Prepare	*Absorb*	*Recover*	*Adapt*
Physical				
Information				
Cognitive				
Social				
Political				

4. **Does dividing the resilience of water security into the above four phases and five dimensions seem functional?**

JL: Linkov et al. have adopted the four phases from the definition of resilience by the National Academy of Sciences. A similar phasing has been used also in Finland within the national emergency supply conversation. The four dimensions derive from the US Army's Network-Centric Warfare doctrine, which states that these four dimensions can be used for any complex system (Fox-lent et al. 2015, p. 210). Political dimension is also considered in the interviews, with the aim of reviewing both the power and responsibility relations, and the synergies and conflicts between different relevant actors.

5. **In your opinion, how does the resilience matrix suit analyzing water/energy/comprehensive security on a national level?**

JL: The attached example of applying the resilience matrix focused on a clearly confined area (Fox-lent et al. 2015, p. 210-212).

6. **How would you evaluate the work order of the resilience matrix? Is it suitable as it is? What is challenging about it?**

JL: The work order of the resilience matrix: 1) Define system boundary and threats; 2) Identify critical functions; 3) Select indicators and generate scores; 4) Aggregate matrices.

NB! The indicators can be quantitative or qualitative in nature.

7. **According to your view, who would be the one(s), who would define the critical functions and indicators for water/energy/comprehensive security?**

JL: Linkov recommends, that 3-5 critical functions are selected for analysis. The critical functions and the selected indicators have a clear impact on the general score of the analysis. How can we make sure, that the choices are made well?

8. **Is there something missing from the resilience matrix, or does it contain properties, which are challenging/misleading? What would you do differently?**

JL: In a Winland's internal resilience meeting in May, it was decided that the political dimension should be added, as the matrix does not take into consideration the power relations between actors.

<u>Wrap-up:</u>

9. **To your opinion, in which ways is the preparation against threats and reformation pressures of water security connected to preparation of energy, food, and comprehensive security in Finland?**

JL: In Winland's publications, connections between Finland's energy, water, food, and comprehensive security have been highlighted. Should these connections be considered upon selecting the critical functions and indicators?

10. **How do you see the concept of resilience after the discussion?**

11. **Where are the problems of current governing system of water/energy/comprehensive security?**
    - **Are there differences between droughts and floods?**
    - **Are there differences between energy and heat production?**

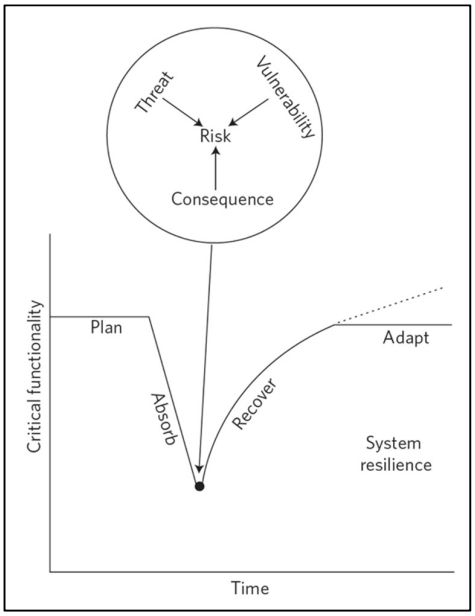
12. **Would you change something in the present governing system?**

Appendix 5. Finnish summary of the resilience matrix.

Resilienssi-matriisin soveltaminen Suomen vesiturvallisuuden arvioinnissa

Haastattelut keskittyvät Linkovin ja kumppaneiden resilienssi-matriisin toiminnallisuuteen vesi-, energia ja kokonaisturvallisuuden kontekstissa. Lisäksi pohditaan matriisin käytännön vahvuuksia ja puutteita.

Linkovin ja kumppaneiden matriisi käsittelee resilienssiä käsitteenä, joka on jaoteltu neljään vaiheeseen: varautuminen (*plan and prepare*), häiriön aikainen toiminta (*absorb*), palautuminen (*recover*) ja sopeutuminen (*adapt*) (ks. Kuva A5-1).



Kuva A5-1. Resilienssin 4 vaihetta (Linkov et al. 2014)

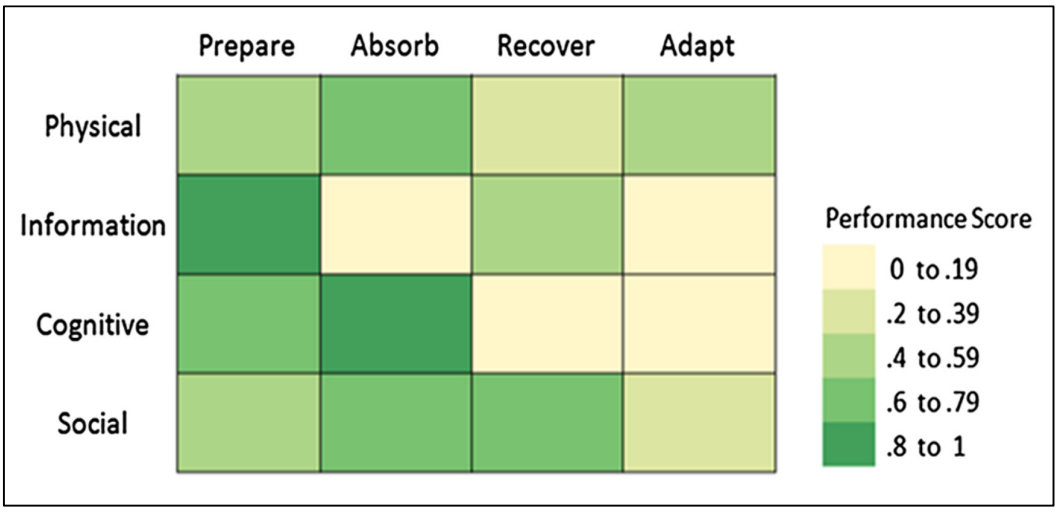
Resilienssin arviointimatriisissa näitä neljää vaihetta arvioidaan neljällä ulottuvuudella, jotka ovat: fyysinen (*physical*), informaatio (*information*), ajattelumallit/kognitiivinen (*cognitive*) ja sosiaalinen (*social*) (ks. Taulukko A5-1). Haastatteluissa käsitellään lisäksi poliittista ulottuvuutta, jonka myötä pyritään hahmottamaan eri toimijoiden välisiä valta- ja vastuusuhteita sekä heidän välisiä synergioita ja ristiriitoja.

Matriisin täydentäminen koostuu neljästä vaiheesta: (Fox-lent et al. 2015, s. 210-212)

1. *Systeemin rajaus ja uhkien määrittely;*
    a. *Systeemi tulisi rajata maantieteellisesti. Rajauksen laajuus määrittää arviointikriteerien tarkkuuden.*
    b. *Käsiteltävät uhkat tulisi myös määritellä. Esimerkkeinä: luonnon katastrofit, ihmisten aiheuttamat onnettomuudet (kyberiskut, kemikaalionnettomuudet) ja sosiaaliset katastrofit (lama).*
2. *Kriittisten funktioiden määrittely:*
    a. *Kriittiset funktiot ovat oleellisia systeemin häiriön aikaisen palvelutason kannalta ja ne tukevat systeemin palautumista. Esimerkkeinä: asuminen, puhdas vesi, vesihuolto ja teollisuuden toiminta.*
    b. *Jokainen kriittinen funktio arvioidaan omalla matriisillaan.*

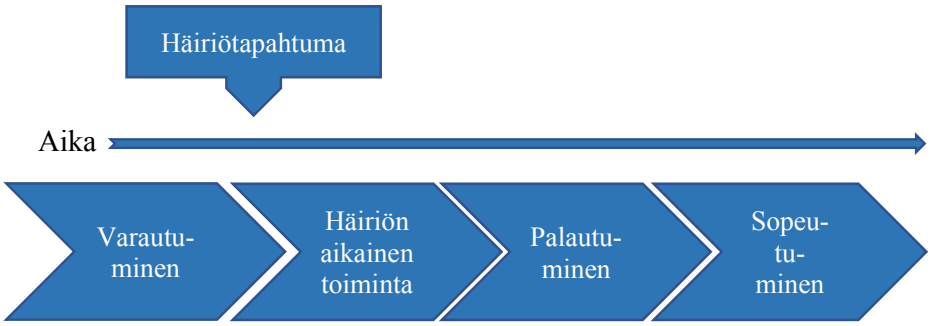
   c. *Kriittisten funktioiden määrä tulisi rajoittaa 3-5:een käytännön toiminnallisuuden vuoksi.*
3. *Arviointikriteerien/-indikaattorien määrittely ja arvostelu:*
   a. *Määrittelyssä tulisi huomioida paikallistason tietämys asiantuntijoiden arvioinnin lisäksi.*
   b. *Matriisin jokainen solu kertoo, kuinka hyvin systeemi toimii kriittisen funktion suhteen.*
   c. *Arviointikriteerit voivat olla joko määrällisiä tai laadullisia.*
   d. *Kriteerien valinnassa tulisi huomioida resilienttien systeemien ominaisuuksia, kuten: modulaarisuus, päällekkyys, robustisuus, sopeutumiskyky ja varautuminen.*
   e. *Solua kohden voidaan määritellä yksittäinen kriteeri tai kriteerien yhdistelmä.*
4. *Matriisien yhdistäminen:*
   a. *Kriittisten funktioiden matriisit voidaan yhdistää yleisen resilienssin tason määrittämiseksi.*
   b. *Kriittisten funktioiden arvottaminen tulee perustella hyvin.*

Noudattamalla edellä mainittuja askeleita, tavoitteena on luoda mahdollisimman edustava yleiskuva analysoitavan systeemin resilienssistä häiriötapahtumaa ennen, sen aikana ja sen jälkeen. Tulokset voidaan esittää visuaalisesti taulukon muodossa, jolloin nähdään, millä osa-alueilla systeemi toimii hyvin, ja millä osa-alueilla systeemin resilienssiä tulisi parantaa (ks. Kuva A5-2).



Kuva A5-2. Täydennetyn resilienssi-matriisin tulosten esittäminen (Fox-Lent et al. 2015).

Taulukko A5-1. Resilienssi-matriisi vapaasti suomennettuna. Eri aihepiireihin liittyvät asiat häiriötapahtuman hallintasyklin eri vaiheissa (Linkov et al. 2013b). Winlandin sisällä matriisiin on lisätty poliittinen ulottuvuus, jossa pyritään huomioimaan eri toimijoiden välisiä valta- ja vastuusuhteita sekä heidän välisiä synergioita ja ristiriitoja.



Fyysinen	Laitteiden ja henkilöstön tila ja valmiudet, verkoston rakenne	Tapahtuman toteaminen ja systeemin suorituskyky toimintojen ylläpitämiseksi	Systeemimuutokset aikaisemman toiminnallisuuden palauttamiseksi	Muutokset systeemin resilienssin parantamiseksi
Informaatio	Tiedon valmistelu, analyysi, esittäminen ja varastointi	Reaaliaikainen toiminnallisuuden arviointi, kasautuvien menetysten ennakointi ja tapahtuman sulkeminen	Tiedon hyödyntäminen toipumisen jäljittämiseksi ja palautumisskenaarioiden ennakoimiseksi	Tiedon varastoinnin ja hyödyntämisen protokollien luominen ja parantaminen
Ajattelumallit / kognitiivinen	Systeemin suunnittelu ja toimintaa koskevat päätökset haasteellisia tilanteita ajatellen	Ehdolliset protokollat ja ennakoiva tapahtuman hallinta	Palautumista koskeva päätöksenteko ja viestintä	Uusien systeemimäärittelyjen, tavoitteiden ja päätöskriteereiden suunnittelu
Sosiaalinen	Sosiaaliset verkostot ja pääoma, kulttuuriset normit ja harjoittelemi-nen/koulutus	Neuvokas ja saatavilla oleva henkilöstö sekä sosiaaliset instituutiot tapahtumaan vastaamiseen	Ryhmätyö ja tiedon jakaminen systeemin palautumisen vahvistamiseksi	Lisäykset ja muutokset instituutioissa, politiikoissa, harjoituksissa ja toiminta-kulttuurissa
Poliittinen	[-]	[-]	[-]	[-]