Identifications of renewable energy risks and risk management review

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Abstract

This report describes the basis of risk analyses of renewable energy and climate change risk to renewable energy. The report gives a background on risk analysis and management in connection with climate change and renewable energy. It identifies all aspects of renewable energy risks and risks due to climate change. Contributions give precise current types of risks of renewable energy. This report's novelty is the identification of renewable energy risks due to climate change. It is a background review report. This report concludes that even though the risks of renewable energy to the environment and/or risks of climate change to renewable energy are small compared to fossil fuels, they cannot be ignored. In addition, safeguarding renewable energy deployment is important. This can be achieved through analysing its risks, understanding energy laws and applying energy laws to renewable energy solutions throughout their lifetime. This report is a starting point and contribution to regional renewable energy development and future in-depth risk analyses of renewable energy by combining multidisciplinary fields.

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1 INTRODUCTION

According to Misra (2008), risk can be defined as "Risk is the possibility of a hazardous event occurring that will have an impact on the achievement of objectives. Qualitatively, the risk is considered proportional to the expected losses which can be caused by an event and to the probability of this event. Quantitatively, it is the product of the probability of a hazardous event and the consequences." If so, the impacts have consequences in the real world, economy or environment—usually, risk causes have negative impacts. Risk acceptability depends on decision-makers regarding the characteristics and severity of risk (Misra 2008). According to Misra (2008), three stages usually involve a quantitative risk assessment. These are risk identification, estimation, and evaluation. After the assessment, risk management will be built. This analysis is what I tried to do in this study.

According to Yaghlane et al. (2015), risk analysis has become much more important due to the increased number of accidents in industrial fields. This risk analysis is not about industrial processes but specific renewable energy resources and the user equipment for the use and production of these resources. In addition, this report is trying to analyse the risks of climate change's effects on renewable resources. However, to understand the historical starting point of risk and its analysis, it is noteworthy to look at the following paradigm: Newton's or celestial mechanics paradigm, Heisenberg's or the indetermination paradigm and Prigogine's or dissipation structures paradigm (Borgheshi and Gaudenzi 2013). They play a great role in understanding the starting point from the observer's perspective of the subject and object through system progress through living to new order establishment when there is minor, or major change took place through time. This change to new order can be the risk of not having some product in one process due to a change in system if, for example, we look at it concerning risk in industrial production systems.

Risk can be an environmental, economic, technological or social risk. It can be a change in process to the new order, which is undesirable. Thus, this change risks those sections of our world and people. Loss alone and the negative consequences that follow can make us assume one man suffers instead of risks in general (Borgheshi and Gaudenzi 2013). Loss and gain can appear in contrast to one another. One loss can be for other gains, but the loser is at risk in terms of many things and business risks. In terms of environmental risk, the loss can be losing the naturally kept perfect environment to more polluted and insufficient for the ecosystems to survive. In economic terms, risk can be the loss of money. In terms of technology risk, we could lose a sufficient way of gaining a product from the environment. Due to technology shortages, the energy that can be gathered will reduce dramatically. In terms of social risk can be the loss of the perfect living environment or social status. For example, climate change causes a risk to our only living planet, which can, in turn, be a risk to efficient social survival. An unfavourable event can be considered a risk to business and the economy in addition to a loss or a gain (Borgheshi and Gaudenzi 2013). For example, investing in the 2007-2008 economic crisis time can cause risk to the investor.

"The consequences of a risk may be either negative (hazard risks), or positive (opportunity risks), or could lead to uncertainty, and uncertainty is the lack (even if only partial) of information about a future situation (or state of a system)" (Borgheshi and Gaudenzi 2013). Climate change causes uncertainty in our world and people. In this report, want to show the risk of climate change in renewable energy and the risk of renewable energy use and production to the environment by focusing on the energy side of untouched renewable energy. Hazard is the condition/s that may create or increase the likelihood of an unfavourable event arising from a given peril (a cause or source of the unfavourable event (Borgheshi and Gaudenzi 2013). They also classify hazards as 'Physical', 'Moral' or 'Morale hazards'. In this risk analysis, we are mainly dealing with physical hazards.

The first risk classifications were based on: 1.'The effects resulting from the event occurrence' (economic and non-economic risks), 2. 'The criterion of the nature or origin of the potentially unfavourable event' (technical, physical, and economic risks), 3. 'Static risks and dynamic risks', 4. 'The type or nature of the economic result resulting from the event' (property risks, liability risks and personal risks), and 5.' Pure risks from speculative risks' (Borgheshi and Gaudenzi 2013). There are a lot of renewable energy benefits, such as less global warming, improved public health, inexhaustible energy, jobs and other economic benefits, stable energy prices, and reliability and resilience [Concerned Scientists (2013): subsection benefits of renewable energy]. However, this risk analysis deals with the negative environmental impacts of renewable energy use and production and/or climate change's impact on renewable energy resources.

The objective of this report is to identify the risks of renewable energy. There have been several risks identified from two points of view, which are 1) the risks of climate change on renewable energy and 2) the risks of renewable energy use and production to the environment. The identification results are studied with SWOT analysis, identifications and scope definitions and Analogy as shown in the results section. The scope in terms of types of renewable energy the report is addressing the identifications of risks for all types of renewable energy resources except wave energy. Renewable energy was classified into three general levels during the data collection stage. Those are 1) geothermal energy, 2) Bioenergy and biomass and 3) Solar-based energy. The whole analysis used a limited number of experts. However, our results were more or less similar to that of Holma et al. (2018), which validates our results.

The overall structure of this report is that after the introduction section (Chapter 1) the methods used (Chapter 2) in this identification process are presented. Then the identification process results are presented in Chapter 3. The SWOT analysis and identifications and scope definitions are presented first. Then, in the Analog section of the result chapter, the comparisons between the whole risk analysis results and those presented by Holma et al. (2018) are made as the validation of the study. Next, the discussions (Chapter 4) about related topics to the analysis of the risks of renewable energy and risk management are briefly presented. Finally, the conclusions of this report are presented in Chapter 5.

2 METHODS

2.1 Risks and risk analysis process

Risk analysis includes several stages: identification, estimate/analysis, evaluations, and calculating risk using the probability of risk. In this paper, there are two risks to analyse 1. Climate change risk to renewable energy resources, and 2. Risks of renewable energy use and production to environment. The organisers of this whole risk analysis were me and Professor Erkki Hiltunen who made the risk identification in this report's case study. In addition, comments were asked about the risk identification process from more than 20 people from Finland, mainly the Vaasa region's experts. These experts made risk analysis by evaluating the risks levels 0 – 6 from no risk to very high risk in the matrix of risk analysis table. Points were given by members of the participants: 6 = extremely high-level risk, 4 = high-level risk, 2 = medium-level risk, 1 = low-level risk and 0 = no risk; empty box computed as zero risk. All risks analysis in this whole study is negative risks or threats, not positive risks. After that, the risk analysis is made by the risk analysis organisers. The feedback gained by email from the experts was used in this risk analysis for the final results.

a) Risk identification

In the risk assessment process, risk identification is a distinct activity (Borghesi and Gaudenzi, 2013). The next Table 1 presents the detailed risk descriptions in this study. We are dealing mainly with risk analysis. Risk assessment consists of identification, analysis and evaluations. A full description of the risks identified gives the full value of the risk identification procedure (Piney 2003). Risk statements usually include effects, causes, impacts, risk areas, and events (Piney 2003). The risk identification lifecycle processes used in this study are 1. Template identification, 2. Basic identification, 3. Detailed identification, 4. External cross-check 5. Internal cross-check, and 6. Statement finalisation (Piney 2003). Here only the risk identification process introduction is given.

b) Risk estimation/analysis

Risk estimation and analysis were done by building two matrix tables. 1. Climate change risks on renewable energy resources, and 2. Risks of renewable energy use and production to environments. The evaluation was asked from more than 20 renewable energy experts, mainly in Finland and the Vaasa region. Only 14 – 16 experts were able to fulfil the risk analysis matrix for data collection. They have to estimate risks in number 0 = no risks up to 6 = extremely high-level risks; after collecting these expert estimations, the average values of all estimations were calculated.

Table 1. Detail risk descriptions (Borghesi and Gaudenzi 2013).

Risk name	**Unique identifier or risk index**
Risk scope	Risk scope and details of possible events, including a description of the events, their size, type and number
Risk nature	Risk classification, the timescale of potential impact and description as hazard, opportunity, or uncertainty Determine if their impact is strategic, operational, and/or financial?
Stakeholders	Stakeholders, both internal and external, and their expectations
Risk analysis	Probability and magnitude, which analysis method is involved (qualitative-quantitative?)
Loss experience	Previous incidents and prior loss experience of events related to the risk
Risk tolerance, appetite or attitude	Loss potential and anticipated financial impact of the risk The target for risk control and desired level of performance
Risk response, treatment and controls	Existing control mechanisms and activities Level of confidence in existing controls Procedures for monitoring and review of risk performance
Potential for risk improvement	Potential for cost-effective risk improvement or modification Recommendations and deadlines for implementation Responsibility for implementing and improvements
Strategy and policy developments	Responsibility for developing strategy related to the risk Responsibility for auditing compliance with controls

c) *Risk evaluation*

Many theories can be used for uncertain/imperfect data generated by risk evaluation, such as expert opinion. These theories include probability, possibility, and evidence (Yaghlane et al., 2015).

c1. *Elicitation of Expert Opinions (Yaghlane et al. 2015)*

The quantitative method by expert opinion used in this work: "in the quantitative approaches, the expert is asked to give his judgement using numbers. Depending on the problem, these numbers can be modelled according to the probability, possibility or evidence theory. It is very difficult for experts to express their opinions, especially when unfamiliar with the theory used in the elicitation problem. Then, the qualitative approach can be more suitable to elicit experts' opinions." (Yaghlane et al. 2015). It was used as a procedure for risk analyses done in this study. I appreciate the help of the experts who gave us their opinion and assigned the risk level in the risk matrix. This process was difficult and time-consuming, and I am grateful for their help.

c2. *Aggregation of Expert Opinions into average result*

The expert results were averaged in each renewable energy category and risk type. The whole renewable energy evaluated for risk of climate change in renewable energy and renewable energy use and production in the environment. 1. Geothermal energy, 2. Bioenergy and biomass, and 3. Solar-based energy. The detailed types of renewable energy resources in the three categories are given along with their types of renewable energy solutions. More than 20 experts were asked to identify their opinion on these three categories and fill in the risk analysis matrix. Then each box in the matrix average was calculated, and risk levels were identified for the total average for each renewable energy production technology type.

Environmental, economic, and social risks

"Even though the environmental impacts of most renewable energy sources appear small, they cannot be completely ignored" (Sokka 2016). Environmental risks and economic risks are widely addressed topics in various fields. However, the risks of renewable energy use and production to the environment are not that much addressed. This area is one of the contributions of the risk analysis study. In addition, the risks of climate change to renewable energy resources are addressed for another contribution. This study does not go in-depth into the economic and social risks.

Environmental risks

The potential or actual threats of various effects on the environment and living organisms by emissions, resource depletion, effluents, wastes, and other factors can be defined as environmental risks.

Economic risks

The likelihood that investment can be affected by microeconomic conditions can define economic risk. Microeconomic conditions can be political stability, exchange rate or government regulations.

Social risks

The commutes around the business or technology can be affected by different activities. These lead to social risks. Some of the main quantifying for social risks include political uncertainties, public health, human rights, and labour issues. Additionally, there is also a political risk, which is an unstable renewable energy policy (Wing and Jin 2015). Political risk can generate by changing technological policies. When there is a price decline in one technology, a shift can happen in other technologies toward the lowest-priced technology (Gatzert and Kosub 2016). This change led to a decline in some technologies, especially renewable energy technologies, continuously developing.

Technological risks

The ideas received during a discussion with Dr Pekka Peura were the following concerning this topic of technological risks. The lack of system integration of renewable energy is the main problem in spreading the use of renewable energy technology and resources. Similar ideas were raised by Green paper (2000). Building infrastructure that would support technology deployment was supported in policy proposals for an energy transition towards net-zero emission resources (IEA 2020). Uncertainty and carelessness for the environment is the main risk of renewable energy utilisation. It means using the environmental resources without care and responsibility and depleting it as much as possible. The risk in Finland would be the end of forestry. The young renewable energy market means the risks are not as high as other developed fossil fuel energy resources. The sale price in the market is guaranteed by policies for renewable energy resources and grid access (Wing and Jin, 2015).

Newer technology development leads to obsolete technology and implies lower efficacy than newer ones (Gatzert and Kosub 2016). Therefore, early planning of new technologies project in renewable energy is risky. Because the equipment efficiency might develop further, leading to diminished public acceptance of the project and might have less support from politics (Gatzert and Kosub 2016). In addition, early planning inaccuracies regarding resource assessment and the supply of renewable energy technology can also create risks (Gatzert and Kosub 2016).

2.2 Risk management process

For this study, the risk analysis process can be generalised as risk identification, scope definitions, risk estimation (collecting data from an expert view), quantitative risk analysis, and evaluating and presenting the results. In this paper, only the identification of the risks to renewable, afterwards risk management suggestions were made.

The risk management process described here briefly

According to Misra (2008), the steps in the risk management process are 1. Identification of risk in a selected domain of interest, 2. Planning the remainder of the process. 3. Mapping out the following; the social scope of risk management, the identity and objectives of stakeholders, and the basis upon which risks will be evaluated constraints. 4. Defining the framework used in the activity and an agenda as identification. 5. Developing an analysis of risks involved in the process. Moreover, 6. Mitigation of risks using available technological, human and organisational resources. Figure 1, originally presented in ISO 31000 (2015), shows the diagram presenting the proposed solutions in risk management.

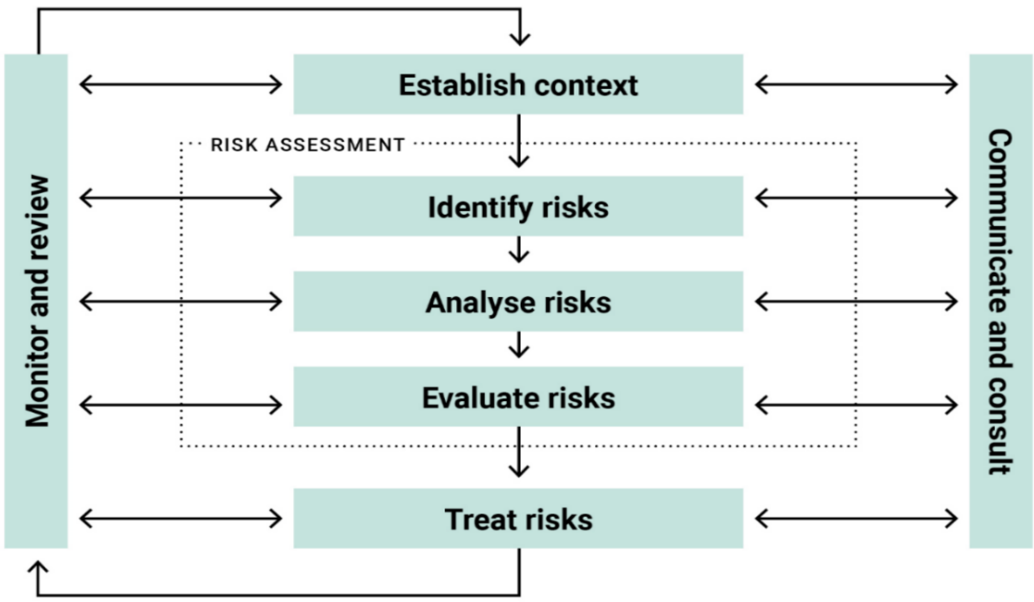

Figure 1. Diagram presenting the proposed solution risk management process (designed by Andrei Palomäki at Studio Andrei. The source of the picture was ISO 31000 2015).

Context: understanding the main causes of risk, establishing theoretical context about the subject, the background experience of others, and setting the background for the risk assessment process. Risk analysis should answer the following questions: What can happen and why? What are the consequences? What is the probability that they will occur? Is there a way to minimise the consequences and/or reduce the probability that it occurs? And is the risk level acceptable, or are further actions required? Based on Landell's (2016) and ISO 3100 (2015) descriptions.

Risk assessments:

- Identifying the risks: "implies a systematic identification of risks to understand what could happen, how, when and why" (Landell 2016).

- Analyse risks: "is about creating and understanding each risk, its consequences and the likelihood of those consequences" (Landell 2016).

- Evaluate risks: "is about making decisions about the level of risk and the priority for attention to the risks" (Landell 2016).

Treat risk: "comes after the assessment and involves evaluation of and selection from options on if/how to manage risk" (Landell 2016).

Monitoring and reviewing: this is a process of insuring the risk analysis established continues to be useful and adjusting changes in time to avoid future risks and negative consequences.

Communicate and consult: There must be continuous communication between researchers, risk analysers, government, environmental centres, communities and warning agencies to address proper risk measures for the environment.

2.3 Qualitative risk identification process and procedures

The six-risk identification process shown in next Figure 2 was used in the identification process of the risk analysis—various techniques used in the risk identification process based on Piney's (2003) paper. As shown below, the Holma et al. (2018) article was the basis for the risk identification and analysis procedure. There is not that much research done on the risk of renewable energy. Therefore, Holma et al.'s (2018) results were used in the first stage of the basic identification process in analogy tools as recommendations by Piney (2003). This process is important at least to find results to compare with one of the risk analysis topics: risks of renewable energy use and production to the environment.

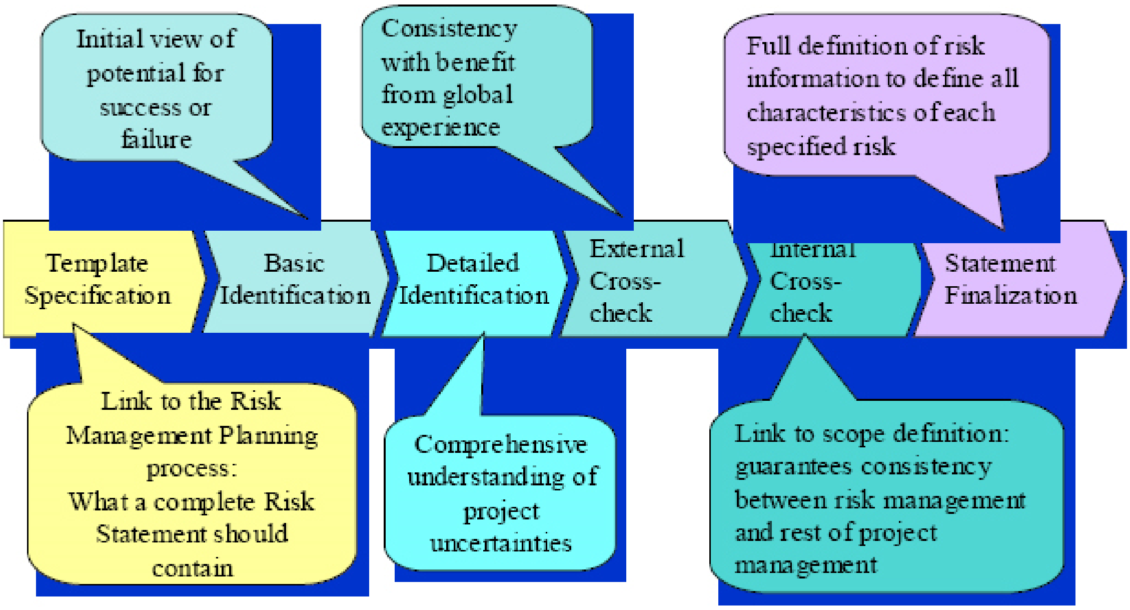

Figure 2. The six phases of the risk identification lifecycle (Piney 2003).

Holma et al. (2018), in an expert view, identified the possible risks of renewable energy to the environment and the 2020 renewable energy target, which probably was the first analysis of the risks of renewable energy in Finland. Therefore, it is important to identify and analyse renewable energy risks. In addition, in this research, we conducted additional risks caused by climate change to renewable energy, which was an interesting side of this study.

Building on the Holma et al. (2018) article use of expertise to identify risks of renewable energy to the environment in Finland, we conducted our research group and other outside expertise risk identification and analysis. The two types of risks analysed in our expertise meetings were: 1. risks of climate change on renewable energy resources and 2. Risks of renewable energy on the environment. Shortly what was done was: identifying the potential members for the specific type of renewable energy based on their expertise and grouping them into four groups. The four groups of renewable energy expertise were: 1. Geothermal energy group, 2. Bioenergy group, 3. Solar-based renewable energy group (solar, wind and hydropower), and 4. Forest and biomass-based energy group. The matrix tables were made based on the risk indication process, which is classified into two tables: 1. The climate change risks to renewable energy and 2. The risks of renewable energy use and production to the environment: First, it was planned to conduct a panel discussion, but due to the coronavirus situation during the years 2019-2020, risk analysis was done individually by experts after sending them by email. After collecting the result using these risk matrix evaluations method, the calculation was made to determine the risk levels of each risk type in both matrix tables.

The procedure planned and used based on Holma et al. (2018) modified by our experts

A similar evaluation was first planned for both risks: 1) Risks caused by climate change on renewable energy resources and 2) Risks caused by renewable energy production and use on the environment. However, the plan was to include:

a) Verbal discussion between the group members on both types of risks and impacts. This was done mainly in emails.

b) Critical stage: in determining the impacts and risks and overall impacts determined with verbal evaluation. The contributions of the experts are also included in the identification of risks.

c) The group member identified both types of risks in identification tables. Done only by email to some extent.

d) The new risks identified were added to both matrix tables for both risk identifications.

e) The panel discussion was not done because of COVID-19. All members gave their ranking in risk matrix tables by contacting them by email.

f) Then all collected table data were calculated by the organisers.

g) After the calculation, the experts will receive the risk analysis result table by email.

h) The organisers will ask for comments on the final risk table.

i) The modification will be done according to the comments. No comments were received as feedback everyone agreed with the average results calculated.

j) The final table of risks will be sent to all experts by email. The result will be used in the dissertation work of Nebiyu Girgibo for risk analysis as a result and further analysis.

The panel discussion was not conducted due to the Coronavirus situation in the whole world and the Vaasa region. Therefore, most face-to-face contacts were not used except for a few discussions by email. Afterwards, the experts were asked to evaluate the risk analysis matrix and to send us by email to avoid face-to-face contact. This approach was chosen because of the COVID-19 disease situation worldwide, including in the Vaasa region.

3 RESULTS OF THE RISKS IDENTIFICATION PROCESS

Risks Identification phase

The risk analysis was generalised into two sections of analysis, which are the basic identification process those are SWOT and Analogy. SWOT (Strength, Weakness, Opportunities and Treats) is based on own expertise view, and analogy descriptions are mainly based on Holma et al. (2018) results because of the shortage of similar analyses for renewable energy risk. The main risks focused on SWOT analysis were threats or negative risks to renewable energy from climate change and risks to the environment from renewable energy use and production.

3.1 SWOT Analysis

The next Table 2 shows the SWOT analysis for climate change risks on renewable energy.

Table 2. SWOT analysis for climate change risks to renewable energy.

S – Strengths	**W – Weaknesses**
- Creates national and international collaborations - Few advantages are generated from it for energy production and plant growth	- Affects threats to the biodiversity - Creates threats to earth and her people - Disadvantages are much higher than their advantages - Causes more problems in already settled systems (e.g. wastewater management)
O – Opportunities	**T – Threats**
- Increased wind speed - Global warming - No ice on the sea - Water temperature increase - Sufficiency of Bioenergy - Cost of bioenergy - Effect of Land rising - New plants to the fields (invasive species) - New trees in the forest: growing areas to the north - Decrease in rainfall	- Extreme weather phenomena - Wind speed - Storms (wind speed and lightening) - Local or temporal air temperature increase - Global warming - Ice melting: 1. melting ice in Greenland and polar areas, and 2. Melting of permafrost in Siberia - Increase in Greenhouse gasses - Precipitation (rain) increase - Severe Drought (no rain) - Sea level rise - Water temperature increase - High waves - The thickness of ice on seas and lakes - No Ice on the sea - Sufficiency of Bioenergy - Cost of bioenergy - Effect of Land rising - New plants to the fields (invasive species) - New insects to the fields (invasive species) - New trees in the forest: growing areas to the north - Insects in the forest: two generations in summer

Two SWOT analyses were done for both risk types: 1. Climate change risks to renewable energy and 2. Risks of renewable energy use and production to environment. Mainly it was done only in the threats section of the SWOT analysis for both types of risks because the idea of this risk analysis was to identify the negative risks only. This idea is important because it will focus the research on one result that helps us to develop other parts, such as positive risks in future analysis. However, this study's negative risks or threats were analysed and evaluated based on expert knowledge. The above Table 2 and the next Table 3 presents the SWOT analyses.

Table 3. SWOT analysis for risks of renewable energy use and production to the environment.

S – Strengths	**W – Weaknesses**
- Safe energy source - The sustainable energy source for some resources - Local economy benefits - Geopolitical conflicts decline to some level those created by oil competitions - Lower maintenance requirements - It has numerous environmental benefits - Benefits of clearing water and air - New job opportunities - Can cut down on waste	- Limited production of some types of energy - Location limited - Sometimes might not be a sufficient amount of energy resources for local need - High upfront costs - Intermittency (is not available 24/7) - Storage capabilities (high need for storage technologies) - Renewables are not always 100 % carbon-free
O – Opportunities	**T – Threats**
- Fossil-free energy source - Creates new job opportunities - Creates economy to stay in local areas - Supplements of grid electricity	- Climate change - Ozone depletion - Acidification - Tropospheric ozone formation - Particulate matter formation o Public health effect - Eutrophication - Toxicity - Impacts of biodiversity - Soil depletion and soil quality - Water use / Water footprint - Land use (Land area as a resource) - Abiotic resources depletion (metals, minerals, fossil fuels) - Radiation - Plants pests and disease - It affects birds and other animals

3.1.1 Identifications and scope definitions of risk types of climate change on renewable energy resources

This section delivers the different possible risks of climate change on renewable energy resources definitions. These risks of climate change have been used in risk analysis data collection from expertise. The overall risks and effects of climate change can be referred to in depth from literature review reports.

Extreme weather phenomena

Extreme climate events can be defined as "events that occur with extraordinarily low frequency during a certain period (a rarity), events with high magnitude (intensity) or duration, and events causing sizeable impacts such as losses (severity)" (Pawlak & Leppänen 2007). Extreme weather can affect almost all types of renewable energy equipment and their installation infrastructures.

Wind speed

A wind speed can be risky if the speed is very high. For example, when the wind speed is very high in wind energy production, the wind turbine has to be shut down to avoid damage to the blades. Wind turbine noise can probably be higher during high wind conditions causing environmental noise disturbance.

Storms (wind speed and lightening)

Storms can cause very high wind speed, bad weather and lightning conditions. These conditions might cause disturbances in energy production and damage renewable energy solutions and their infrastructure. Some nations have stormy weather more often.

Local or temporal air temperature increase

Currently, the air temperature has been increasing all over the world. This fact could influence, for example, water temperature increase creating more potential for heat energy production from water bodies. On the other hand, the air temperature increase can influence plant growth and CO_2 uptake.

Global warming

The increase in solar irradiance can create global warming. During the higher global warming periods, solar energy production might increase. There are various factors of global warming in energy production, species growth, and living conditions. Bioenergy production can be influenced by global warming.

Ice melting:

Ice melting can be facilitated by global warming. This melting can cause different problems, such as flooding. Thus, affecting renewable energy solutions infrastructures.

- *Melting of ice in Greenland and polar areas*

Melting of Greenland and polar areas can contribute to flooding. In addition, it might help the process of change in the Gulf Stream. The change in Gulf Stream might cause more warming in nearby lands.

- *Melting of permafrost in Siberia*

Melting permafrost in Siberia can release methane from marsh areas. Causing pollution to the environment cycling back and facilitating other effects and risks of climate change.

Increase of Greenhouse gasses (GHGs)

The increase of Greenhouse gasses in the atmosphere is the main cause of climate change. Therefore, most of the other risks of climate change described here can be facilitated by an increase in GHGs. These climate change risks can affect all types of renewable energy and, thus, the overall risk of climate change in renewable energy solutions and resources.

Precipitation (rain) increase

Rainfall increases can be facilitated by climate change. Some parts of the world face this rainfall increment, but others face a shortage in rainfall, even severe droughts. Rainfall increase can influence renewable energy resources, such as hydropower production potential.

Severe Drought (no rain)

Severe drought can cause a shutdown of hydropower plants in some parts because the river, which is used for hydropower production, becomes dry. Drought can also cause conflicts between nations with the same water resource. For example, the Nile river shared by Ethiopia, Egypt and Sudan caused conflicts when Ethiopia built a dam to produce electricity. Because of the other nations, Sudan and Egypt can get less Nile River water flow. Drought contributes, to some extent, to this situation.

Sea level rise

Sea level rise can cause flooding, which mainly influences all types of infrastructure in harbour cities. These harbour cities' energy infrastructures are also influenced by flooding.

Therefore, sea level rise will negatively influence the installation of renewable energy resources.

Water temperature increase

The water temperature increase positively influences the water heat exchanger to collect heat from the water. From a nature perspective, the water temperature increase negatively influences the species living in the water and nearby areas. The water temperature increase is expected to be higher due to global warming.

High waves

High waves might damage wave energy technologies to some extent. As well, they are causing flooding in harbour cities. This situation might facilitate the initiation of the storm and can mainly damage renewable energy infrastructure in harbour areas.

The thickness of ice on sea and lakes (No Ice on sea and No ice in sea)

The decline and disappearance of thickness or ice on the sea can create an opportunity to use more wave energy. This opportunity can also create easy access for offshore wind turbine installations. The disappearance of the sea ice can create an opportunity to use deep wave energy technologies. There are more possible effects in the transportation of appropriate materials to the seaside and islands if there is less or no ice on and in the sea.

Sufficiency of Bioenergy

Bioenergy sufficiency can influence the food crops when used for fuel production, competing with food access and resources. Balancing between using food crops for energy and innovating new uneatable plants for energy can ensure the sufficiency of bioenergy.

Cost of bioenergy

The cost of bioenergy can be declined by identifying and finding better nonfood plants for bioenergy production. The cost of bioenergy can be declined by innovating new technologies to make biofuels or other bioenergy resources. The cost of bioenergy can be risky for renewable energy resources such as bioenergy because the expensive cost of production and transportation can become unusable.

Effect of Land uplift

Land uplift can cause a problem in using wave energy in coastal areas. During the land uplift, former installed wave energy equipment might not receive any more massive waves, or there can be a water shortage because the land is growing through coastal areas. A similar risk can be noticed if, for example, a water heat exchanger was not installed in a very deep area of the water body. If a water heat exchanger is installed in nearby coastal areas, it might face a water shortage for heat exchange.

New plants to the fields (tulokas lajit or invasive species)

Invasive species could be both plants and animals. The practice of transporting animals from their native regions to new areas can become invasive species. Alien species are considered invasive when they begin to have negative consequences in the new habitat. These so-called invasive species may cause environmental harm, economic harm, or impact human health. For example: at a time when invasive species cause environmental harm, mainly to bioenergy production plants, new plants in the fields (invasive species) can be considered as risks in renewable energy not only by killing other plants by their toxicity but as well by competing for nutrients, growing area and water resources and then caused decline in the type of plants required for bioenergy productions. Some plants also alter the environment, making them more favourable for them but less favourable for native plants. This process is called ecological facilitation.

New insects to the fields (invasive species)

New insects in the fields can cause harm to bioenergy plants then this invasive species can be considered a risk for renewable energy production. The harm can be damaged by eating the bioenergy production plants. The effect of invasive species can be reduced by avoiding transporting different species to new locations because their consequences can harm the environment, the economy, and people's health.

New trees in the forest: growing areas to the north

New trees in the forest can damage local trees by disturbing their growth. Thus, causing a decline in biomass production from local tree types. The other outcome can be that trees can grow far from local areas where they were needed for use, causing a decline in the area. The positive side is that trees can cover more area to increase biofuel and biomass production in northern nations. The biomass production in these nations can increase currently compared to the past.

Insects in the forest: two generations in summer

Insects in the forest can damage the forest before they can be used for bioenergy production. This damage can happen from local insects or invasive species. It is most common to see such effects from invasive species. The season of the year can facilitate or decline the growth and production of insects. Therefore, the risks of insects in the forest can be seasonal by its amount of effects.

3.1.2 Identifications and scope definitions of risk types of renewable energy use and production to the environment

This section discusses the possible risks of renewable energy use and production definitions. These risks of renewable energy use and production have been used in risk analysis data collection from experts. The intensity of environmental impacts from renewable energy depends on the specific technology used, the geographic location, and several other factors (Concerned scientists 2013). A life cycle assessment must be done to understand the future risks of renewable energy to the environment (Pehnt 2015).

Climate change

One example of climate change can be in extremely cold conditions. Ice can build up on wind turbine blades. Then it can fall when melting, causing damage to humans, the environment or the infrastructure at the bottom of the wind turbine. This point could be considered a risk for using wind turbines to produce renewable energy. It is important to notice that the production of renewable energy equipment might not be sustainable, might not be fossil fuel free and can be resource intensive. They can cause the emission of greenhouse gases, thus, facilitating the effect of climate change. There are emissions associated with lifecycle renewable energy, including: "material production, material transportation, on-site construction and assembly, operation and maintenance, and decommissioning and dismantlement" (Concerned scientists 2013).

Ozone depletion

Ozone depletion facilitates the effect of climate change, mainly solar energy irradiance reaching the earth's surface. Hence, the production of renewable energy equipment most probably is not sustainable, and fossil fuels free from releasing gasses can facilitate this effect.

Acidification

Based on IPCC (2014) info, the pH of the ocean surface decreased by 0.1 (high confidence), which corresponds with a 26 % increase in acidity (measured as hydrogen ion concentration); acidity in oceans was because of CO_2 uptake by the oceans since the beginning of the industrial era. Any energy resource that contributes to some level of CO_2 emission caused or added effect to this acidity result.

Tropospheric ozone formation

The emission of hydrocarbons and nitrogen oxide facilitates tropospheric ozone formation. The emissions from the production of renewable energy equipment can include hydrocarbons and nitrogen oxide. Thus, renewable energy equipment production can cause the risk of tropospheric ozone formation to some level.

Particulate matter formation

The release of smoke from industries contributes to particulate matter formations in the atmosphere. The industries can be working on producing equipment for the use of renewable energy production. Thus, equipment production for renewable energy became a risk to the environment and public health. Combustion of biomass creates smoke in the atmosphere contributing to the formation of particulate matter and air emissions. Some types of geothermal power plants can produce air emissions (carbon dioxide, methane and potent global warming gases) (Concerned scientists 2013).

- *Public health effect*

Public health has been affected by polluted air. Some nations face very high health and death rates because of air pollution. One of the sources of polluted air content is particulate matter. This situation might be related to renewable energy equipment production on some level. The public health and community concerns about wind turbines are sound and visual impacts associated with operating wind turbines (Concerned scientists 2013).

Eutrophication

Eutrophication can be defined as the intensive and higher amounts of growth of phytoplankton, mainly algae, in water systems during a particular period facilitated by human nutrient pollution. Bioenergy plant farming can cause pollution to nearby water because of the leaching of phosphorus and nitrogen from the use of fertilisers. This circumstance happens a lot on agricultural food plantations because of the amount and intensity of agriculture. However, the increased use of agriculture products and other plants growing for bioenergy has been affecting the water quality and causing eutrophication.

Toxicity

Toxicity can be defined as the quality of being poisonous. Toxicity can happen to different species because of pollution and/or the consequences of pollution. Such toxicity can contribute to the production of equipment with renewable energy. The equipment used in renewable energy production is not sustainable. Thus, it can cause some toxicity to species present in our environment.

Impacts of biodiversity

Impacts on biodiversity can differ in different environments: land, water or atmosphere. For example, the release of some pollutants in water can cause a decline in oxygen levels and can cause the death of fish. Such effects now can be noticed more often because the effect of climate change facilitated them. The source of such impact on biodiversity can be contributed by using and producing renewable energy and its equipment. Wind production has been impacting wildlife (National research council 2010).

Soil depletion and soil quality

The use of bioenergy production plants growing in massive amounts might affect the quality of the soil for producing food plants. An example could be used up (soil depletions) of the nutrients from the soil or influence its properties. The connection between land (soil), water and atmosphere can show how the effect of one of them can influence the other parts of the environment. Therefore, renewable energy use and production can risk soil pollution, depletions and/or indirect quality paths.

Water use / Water footprint

The construction of sediment heat and hydropower plants can affect water quality. Heikkilä (1986) stated that construction nearby or at the water bodies affects them by polluting to some extent. This kind of environmental risk by renewable energy construction to water bodies consequently to water use. The amount of clean water used for drinking or household use declines such construction in water bodies. Biomass production and hydropower production causes an effect on water use. Hence, both affect the use of water level, quantity and quality as well. Depending on the plant design, plant location and the type of cooling systems, water use can be affected by concentrated solar thermal plants (Concerned scientists 2013), but not photovoltaic (PV) cells. Water quality (water contamination) and use can impact the use of geothermal power plants (Concerned scientists 2013). Aquatic ecosystems, including fish, algae production and more, can be significantly affected by hydropower plants (Concerned scientists 2013).

Land use (Land area as a resource)

Land use can be influenced by infrastructures built for renewable energy production. For example, bioenergy plantation land might be used for producing food products but for growing plants for energy production. Solar energy plants can use large lands if it is large production plants. One way to minimise such solar energy production panels can be by using the already existing infrastructures (roofs of houses) to install solar panels. Wind turbine and hydropower plants located in flat areas take more land than those turbines located in hilly areas (Concerned scientists 2013). Offshore wind turbines compete with fishing, sand and gravel extraction, recreational activities, navigation, oil and gas extraction, and aquaculture (Concerned scientists 2013). Due to the removal of water from geothermal reservoirs, land surface sinks, and this phenomenon is called land subsidence (Concerned scientists 2013). This removal can be avoided by pumping back water into geothermal reservoirs. In addition, due to their locations of geological "hot sport", geothermal plants can lead to higher earthquake frequencies (Concerned scientists 2013). "The use of previously developed sites can reduce land-use impacts, co-occupation with other land uses, using military and government sites, and encouraging distributed generation technologies to minimise the need for more transmission lines" (National research council 2010).

Abiotic resources depletion (metals, minerals, fossil fuels)

The production of the equipment used in renewable energy can be very materials intensive, causing abiotic resource depletions. In addition, the equipment's production usually uses fossil fuels, causing pollution and depleting the number of fossil fuels such as oil. Thus, the overall life cycle of renewable energy equipment of production and the uses of renewable energy is not sustainable. The circular economy can probably do much more in future to decline these risks of renewable energy use and production.

Radiation

Radiation can happen in some renewable energy equipment productions. On the other hand, by affecting climate change, they can increase solar radiation levels by releasing greenhouse gases and depleting the ozone level. The increase in solar radiation affects all components of the environment, including weather patterns. Thus, leading to global warming and the destruction of the whole earth.

Plants pests and disease

The use of plant pests and disease avoidance can affect the environment. Such application can be maximised in the production of bioenergy-specific plants, perhaps not as much as agricultural plantations because most plants can be used as bioenergy resources even if they are not the specific species. Therefore, bioenergy plantations can contribute to the pollution of the environment, not to mention resource depletion.

The effect on birds and other animals

The use of wind turbines can cause killing to birds and bats from collisions when they fly through the blades of the wind turbine when spinning. Other renewable energy types, such as wave energy, can affect species such as fish in the ecosystem. The building of hydropower dams can cause a shift and affects the species in the water body's living conditions, growth and production (Wetzel 2001).

3.2 Analogy

Holma et al. (2018) risk analysis result comparison with Girgibo et al. (forthcoming)

The paper of Girgibo et al. (forthcoming) is an article based on this report's risk identifications. The results of Holma et al. (2018) were compared with Girgibo et al, (forthcoming). The validation of these identified risks was noticed in the analysis and development of the Girgibo et al. (forthcoming) article.

4 DISCUSSION

4.1 Future climate change caused risks and impacts

According to IPCC (2014), climate change will amplify existing risks and create new risks for natural and human systems. The next figure shows the representative risks for each region, including potential risk reduction through adaption and mitigation and limits to adaption. This picture shows that some risks are more relevant for individual and global regions. IPCC (2014) reported that disadvantaged people and communities at all levels of development could receive greater risks, and risks are unevenly distributed.

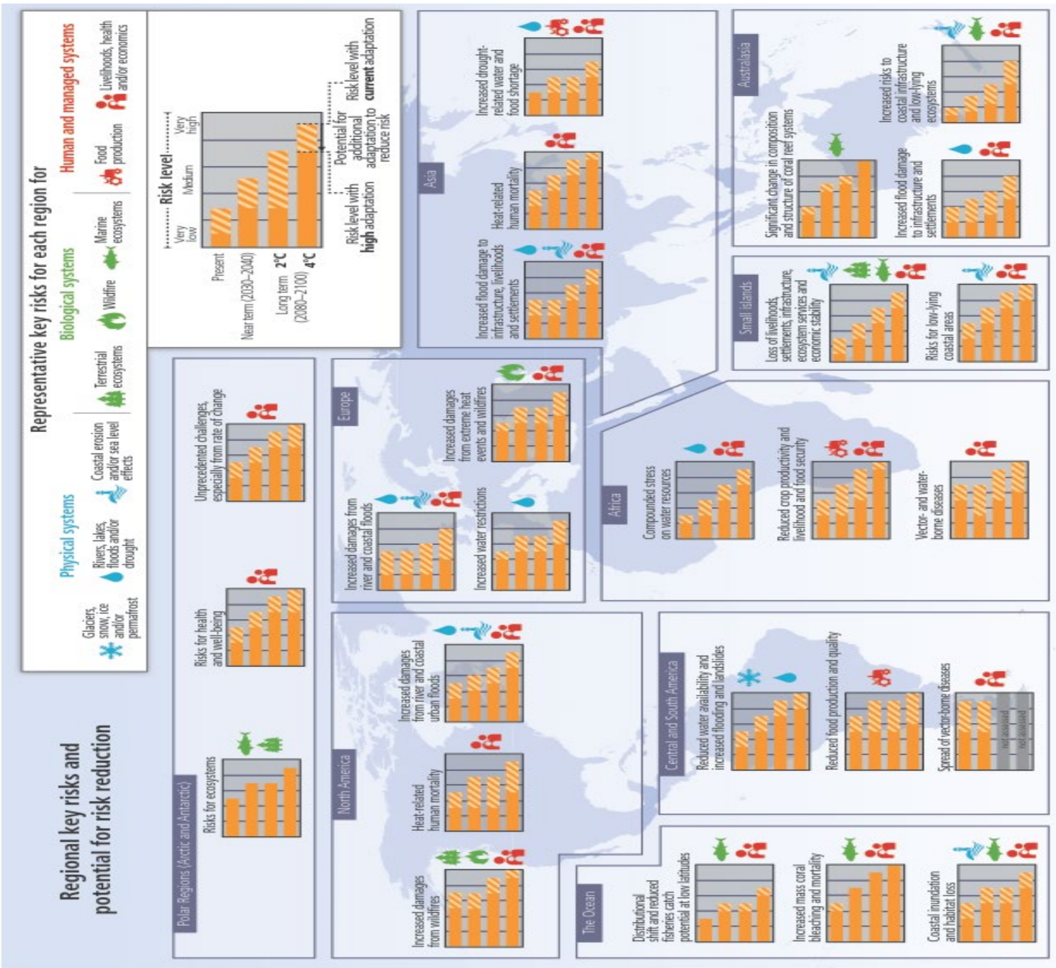

Figure 3. From IPCC (2014), titled representative risks for each region, including the potential risk reduction through adaption and mitigation and limits to adaption.

Climate change can cause a risk of resource scarcity (and a threat to security), especially water and food availability leading to forced migration (Arcanjo 2019). This scarcity causes additional conflicts between nations in addition to shared water stress due to climate change conflicts, on other extreme risks, climate change is identified as the gravest risk by the likelihood of extreme events happening (Arcanjo 2019). The same article mentioned that climate change and environmental factors are the five of the main ten risks. Those are "extreme weather events, failure or climate-change mitigation and adaption strategies, manmade environmental damage and disasters, biodiversity loss and ecosystem collapse, and water crises" (Arcanjo 2019).

The scarcity of resources also causes instability, as seen in the Sahel region of Africa, facilitating the rise of terrorist groups and their attacks (Arcanjo 2019). The same paper states that climate change does not create terrorists but alters the context in which they operate and act as a driver of conflicts. Avoiding false pretences, military intervention suggested not causing much more unmanageable conflict in the area. "The overall risks of climate change impacts can be reduced by limiting the rate and magnitude of climate change, including ocean acidifications" (IPCC 2014). We must work on solving climate change and its causes. The temperature rise contributes highly to crossing these risks threshold, but the precise threshold level for combating these risks is uncertain (IPCC 2014).

4.2 Risks from the use of renewable energy and its equipment production to the environment

Renewable energy use has a huge good effect on combating climate change compared to its environmental impacts. However, renewable energy equipment's production might not be sustainable—one solution to making its equipment production sustainable can be recycling materials and implementing a circular economy. The circular economy is a field by itself and is not dealt with in-depth in this report. Circular economy uses in renewable energy equipment's production can be an ideal way of minimising the risk of resource depletion and impacts on environmental pollution due to the production of renewable energy equipment. This approach could be one way to mitigate risks generated by renewable energy use and production. Policymakers must understand the pollution generated by fossil fuels compared to renewable energy pollution and how to improve renewables by making them more energy efficient to make good policies (National research council 2010).

1. Using renewables for energy production risks

The use of renewable energy production has an impact on the environment and generates risks to the environment to some level. Greening and Azapagic (2012) concluded that replacing the gas boiler with the air source heat pump is not sustainable because they found out that it has a 2.5 % higher impact on direct greenhouse gases (GHG) emissions, and a 2.4 % saving can be achieved by the ground source heat pump and water source heat pump compared to gas boiler in the UK. This example of risk is one using different types of options that air source heat pump has more pollution compared to the others. Thus, identifying the efficiency and pollution source levels of equipment and their components during using renewable energy is very important to avoid environmental impacts.

National research council (2010) stated that all environmental concerns could not be eliminated by using renewable energy sources. In addition, they stated that renewable energy installations could cause land use and wildlife habitat disruption, and some technologies can consume significant quantities of water. Even though renewable energy resources generate lower emissions of CO_2 and GHG other gasses compared to fossil-fuel based in producing electricity (National research council 2010). Therefore, renewable technologies and resources have advantages over fossil fuels. The life cycle assessments of renewable energy resources and other energy resources for electric production studies show how much the CO_2 equivalents as presented in the next figure (Figure 4).

The next figure shows that geothermal has the lowest average amount of grams of CO_2 e/kWh after biomass and wind energy. However, a lower amount of geothermal emissions depends on the composition of the reservoir gas. If these gasses are vented to the atmosphere, as can occur in flash technologies, the emission amount of CO_2 e GHG can be relatively high (National research council 2010). Compared to others/non-renewable renewable technologies has lower emission level. This result shows that the positive advantages of renewable energy are much greater than their negative emissions in terms of use for energy production. It is important to notice here that the production of energy from renewable energy has emissions and impacts on the environment, this is important to know and should not be ignored.

Air pollution is also the other type of environmental impact of electric energy production, for example, in China and the United States (National research council 2010). A similar pattern is noticed here: renewable energy technologies have lower life cycle emissions of conventional air pollution such as coal and natural gas plants (National research council 2010). The same book states that solar power tower has low air pollution, biomass combustion produces much more toxic air pollutants, and geothermal has a low air pollution level except produces hydrogen sulfide (H_2S). However, other renewable technologies' life cycle has much lower air pollution and has been generated mainly from the manufacturing or construction stage of life cycle assessments (National research council 2010). The other areas of impact on the environment are land and water use. Renewable biomass production (in the first level), hydropower (in the second level depending on dam size), and wind energy (in the third level are the highest land-consuming technologies compared to other renewable and even non-renewables (National research council 2010).

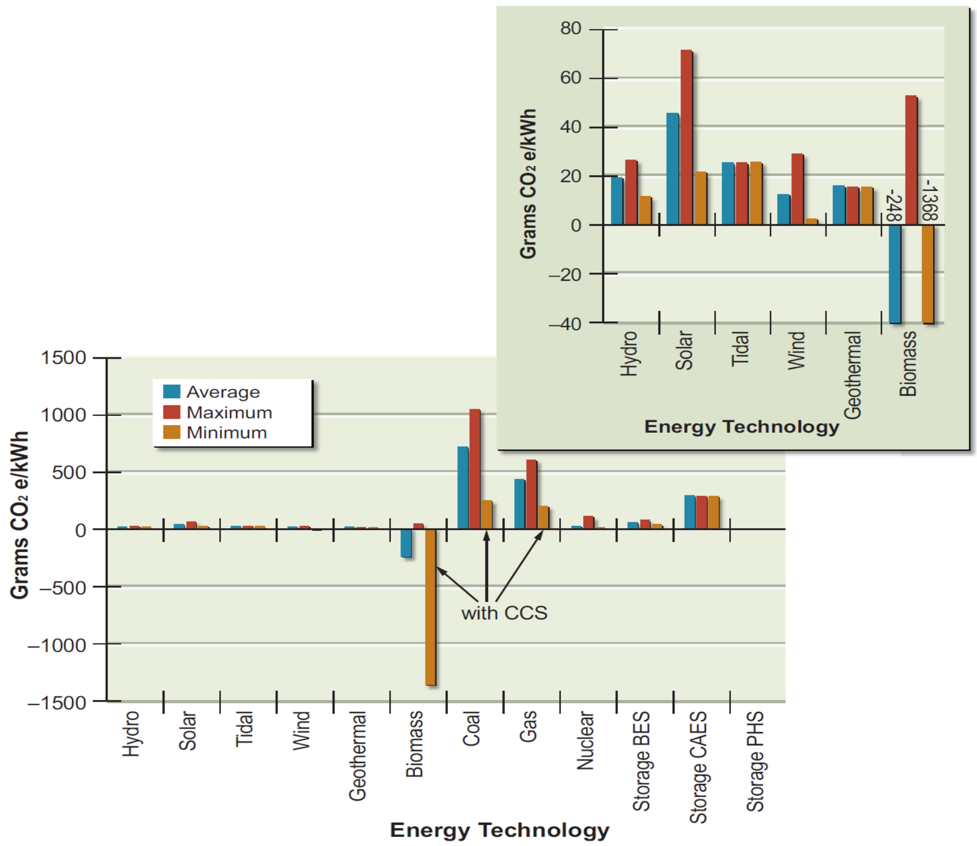

Figure 4. Life cycle emissions of greenhouse gases (CO_2 equivalents) for various sources of electricity. CCS = carbon capture sequestration/storage, BES = Battery energy storage, CAES = compressed air energy storage and PHS = pumped hydroelectric storage (National research council 2010).

Thermoelectric production for its cooling systems, hydropower by evaporation loss and geothermal resources use water much higher than others (National research council 2010). Wind and solar Photovoltaics (PV) use less water, but solar thermal technology uses water to some extent. The electric production from renewable energy might have these impacts: soil erosion or degradation, forest clearing, disturbance or loss of wildlife, air and/or water pollution, noise pollution, and impairment of scenic vistas depending on technology, location and scale of the facility (National research council 2010). Additional impacts can be cultural, wildlife and aesthetic (National research council 2010). According to Chebotareva et al. (2020), renewable energy projects show two general patterns: 1. Subsidised and non-state support projects tend to have a higher risk in the pre-investment stage and a decline in risk in the post-investment stage. 2. Loaned projects show lower risk in the pre-investment stage and higher risk in the post-investment stage. Projects were implemented and analysed in Russia. The risks analysed were: the risk of access to the grid, administrative risk, political risk, financial risk, technical and managerial risk, and risk of public acceptance (Chebotareva et al., 2020).

2. Productions of renewable energy equipment risks

Manufacturing and production of renewable energy equipment produce risks and environmental impacts. Manufacturing raw materials for heat pump contribute 10 % and operation contributes 84 % to the total environmental impacts (Greening and Azapagic 2012). Manufacturing and transporting renewable energy sources produce some emissions and pollutants even though they produce relatively low levels of GHG emissions and conventional air pollution (National research council 2010). The production of some renewable equipment can cause more impact on the environment. For example, generations of toxic substances can contaminate water resources in the production of some photovoltaic (PV) cells (National research council 2010). Manufacturing of PV panels is very energy intensive, and it has emissions of CO_2, NO_x, and other air pollutants at a significant level (National research council 2010). The production of PV panels also uses or produces by-products. Those can be hazardous materials that must be monitored, handled and disposed of. These process steps are required to minimise risks to workers, the public, and the environment (National research council 2010). In addition, a large amount of acidic and alkaline wastewater is produced. Fluoride in wastewater causes a special problem for the public during PV production if it is not treated appropriately (National research council 2010).

4.3 Risks to the environment from seaside energy solutions

These are good examples of seaside renewable energy risks. The focus was mainly here on geothermal energy because the main equipment planned to be installed was ''a water heat exchanger'' and the other part of this whole study was sediment heat energy production both are a seaside heat source geo-energy, which is one type of geothermal renewable energy resource.

Geothermal energy: Environmental impacts, regulation and geo-hazards

This section was mainly referenced by Banks (2012) as an example of renewable energy risks.

a) The regulation framework

Ground source heat can be used for space heating and cooling, and it can be utilised with low carbon emissions and minimum visual impact, as argued by Banks (2012) book. Ground source heating and cooling (GSHC) is ideal. Even though the heat source installation has to overcome certain bureaucratic regulations in most nations, banks (2012) stated that the planning, construction and operation of GSHC could fall under one or several classes of legislation, including; water resource legislation; pollution prevention legislation; energy efficiency legislation; mining legislation; specific geothermal energy legislation; planning legislation; and codes of good practice, which may not be legally binding.

Banks (2012) also mentioned it is important to EU nations a few key pieces of EU legislation; Directive 2000/61/EC – the Water Framework Directive – its Groundwater Daughter Directive 2006/118/EC; Directive 2009/28/EC – the Renewable Energy Directive; and Directive 2002/91/EC – on the Energy Performance of Buildings. The definition of pollution and pollutant in the Framework Directive Banks (2012) identified as one of the important notes, ''release of heat to the ground can cause pollution". However, he states that heat extraction does not cause pollution according to the Directive, even though this could potentially damage ecosystems and cause other impacts. In addition to the heat release of refrigerants or antifreeze to groundwater/ or boreholes that can contaminate water bodies due to improperly sealing, there is potential pollution (Banks 2012).

Banks (2012) describes that the regulations are strict for open-loop groundwater-based GSHC schemes because they involve the physical abstraction and influence of groundwater and more often discharge to the natural environment. Open-loop systems are much riskier to the environment from this side of view. The license of open-loop systems involves physical checkups in the water systems, such as a survey of potential environmental impacts (e.g. pumping test and hydrogeological risk assessment) (Banks 2012). It might be difficult to meet the regulations if there is a risk of environmental exposure. Based on Banks (2012), the open loop, which recharges thermally 'spent' water back to aquifers, is much more acceptable because it keeps the aquifer from depletion and minimises the local hydrological impacts.

This concept of an open loop system connects energy and water, which is interesting to this report and doctoral study work. Because of water quality changes, checkups are a requirement to get discharge consent to return water to natural recipients or water bodies (Banks 2012). In addition to water quality changes, the regulation will consider the resulting flooding, any additional contamination risk, or a thermal risk to ecosystems or water (Banks 2012). The regulations in open loop GSHC systems seek to prevent wastage of groundwater, prevent changes in temperature and chemical quality of surface water recipients, prevent or limit widespread change in aquifer water level and prevent large-scale changes in aquifer groundwater temperature (Banks 2012).

In the case of closed-loop systems, there may not exist legal tools for environmental regulations. However, there is ongoing development to protect the groundwater, at least in England and Wales (Banks 2012). Banks also stated that closed-loop systems require an environmental permit in Denmark and Germany.

b) Thermal risks

As with the over-abstract of groundwater, we can over-abstract heat or cloth, if extraction or rejection of heat exceeds the ability ground surface or aquifer to replenish or disperse that heat (Banks 2012). This very risky condition for the environment, microbiology and ecosystems. It is not clear yet how much magnitude of ground temperature change can consider deemed 'unacceptable' (Banks 2012). Before looking for whom to blame for local ground temperature change, it is good to understand the ground temperature profile in the local area. Global and local temperature is not static, meaning the ground temperature changes along with these (Banks 2012). Global warming affects the ground temperature to some level, especially the ground surface temperature because the ground earth temperature is constant after some depth. UHI - ''Urban heat-island'' effect is the temperature in cities may exceed rural areas temperature is also a concern in recent days (Mäkiranta et al. 2018 and Banks 2012). In addition, a downward heat leakage from the warm urban environment; is also considered 'thermal pollution' (Banks 2012).

If two close-loop adjacent ground sources are apart >20 m, their impact on each other is minor if they are both used only for heating (Banks 2012). Keeping them at this distance is important to get the most efficient resources. Banks (2012) showed that the regulation of minimum distance between two close-loop systems differs from nation to nation. If soil temperature exceeds 60^{O}C, soil sterilisation may begin to occur, affecting the microflorae and microbiological communities in the soil (Banks 2012). In the case of a 'water heat exchanger', which extracts heat from the sea, it is important to consider aquatic ecology based on Banks' recommendations. Future studies on the aquatic environment in the water heat exchanger' in seaside locations is an interesting point to investigate after several years of operation.

c) Hydraulic risks

Based on Banks (2012), water abstraction from one well and dumping in another took place in open-loop GSHC operations. This common practice in such systems is also related to Groundwater energy utilisation (GEU). However, such systems will cause problems. For example, worst case, it might dry up the well or spring and/or result in a rise in well-pumping cost because the water level is lowered (Banks 2020). In addition, he stated that it could cause a problem of reducing flow to spring/spring-fed rivers, groundwater-fed ponds, or wetlands level reduction. These problems might happen if GEU or open-loop GSHC is established. On the other hand, the injected wells or ground level might rise, and land heave can occur very occasionally (Banks 2012). Further described by him that cellars or basements may become flooded.

If the groundwater is close to the surface, it may overflow into the land, and injection might not be possible (Banks 2012). One solution proposed was to seal the well and reinject it under pressure. However, he stated that if the aquifer is unconfined or, in some cases, if, it is confined might cause groundwater flooding. See the difference between confined and unconfined aquifers in Girgibo (forthcoming/ groundwater report). Another type of aquifer, typically confined but unconfined, is called an artesian aquifer (Banks 2012). This type of aquifer has various problems when establishing either open-loop or close-loop GSHC systems. One thing it might cause artesian overflow. This type of overflow has various consequences such as prosecution, flooding, pollution and acute embarrassment for cities (Banks 2012).

d) Geotechnical risks

Ground movement around operations systems can be caused by other mechanisms such as sand pumping, frost heave, vapour migration, thermal expansion and evaporation (Banks 2012). The next few sentences mention each of these causes. Sand pumping can cause problems by abrading impellers and heat exchangers by clogging the good screen or aquifers around the re-injection well (Banks 2012). Pumping of sand causes undesirable situations. For example, if sand is pumped so much, some houses may disappear into the hollowed-out ground if they are adjacent to sand-pumping wells (Banks 2012). Frost heave may be created when a closed loop ground source heat pump runs below zero for a long time, resulting in ice forming in the pores spaces of the rock or sediment (Banks 2012). This book further explains that loose sediment might create the ground surface frost heave.

Vapour migration and progressive drying (even shrinking) of soils can occur in the case of closed-loop systems operating in cooling mode, especially in shallow horizontal systems (Banks 2012). This vapour migration might affect structured standing on soils nearby this system. For example, borehole thermal energy storage (BTES) can cause thermal expansions with significant concern in large cooling-dominated schemes (Banks 2012). Some natural matter, such as rock, expands when heated. In an arid environment, soluble minerals deposited in the geological past evaporate (Banks 2012). Their type includes an example, halite (NaCl), sylvite (KCl), gypsum ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$) (Banks 2012). These minerals may cause various problems. They might cause the risk of dissolving the evaporated minerals with our drilling fluid and result in subsidence (Banks 2012). Banks described other risks minerals might hydrate to form gypsum and expand. This expansion may happen in cases when groundwater migrates along improperly sealed closed-loop boreholes and if it comes in contact with a mineral such as anhydrite.

e) Contamination risks

Banks (2012) states that drilling in contaminated land is another risk. In other words, they are drilling deep closed-loop boreholes in connection with the redevelopment of 'brownfield' (formerly industrial) sites (Banks 2012). In addition, there is a concern about contaminating the groundwater while drilling boreholes if it is too deep and close enough to groundwater or aquifers (Girgibo, forthcoming/ groundwater report). It is important to keep the groundwater in natural conditions as possible. Because most direct circulation heat pump systems use refrigerant through the subsurface, environmental regulators tend not to favour them (Banks 2012). The reason for that is that they risk contaminating the environment if those refrigerant liquids containing halogenated hydrocarbons leak. In addition to refrigerant contamination, there is also a possibility of leakage contamination from carrier fluids (Banks 2012). According to his descriptions, the most commonly used carrier fluids are based on ethylene glycol (a more toxic one), propylene glycol or ethanol.

f) Geochemical risks

Based on Banks' (2012) explanations, groundwater might react with minerals and is temperature dependent. In addition, he explained that geochemical risks are present in these groundwater surroundings. In GSHC, more detailed geochemistry is recommended, especially in schemes operating at more extreme temperatures such as BTES systems.

g) Microbiological risks

The general agreement among microbiologists is that the increase in temperature is intended to increase microbiological activity (Banks 2012). In his explanations, Banks stated that microbiological effects are unlikely to represent serious environmental risks. However, potentially macro-biotas dwelling in aquifers can be impacted by temperature changes.

h) Excavation and drilling risks

Checking the environment/ground before drilling is necessary. Contacting environmental authorities before excavation and drilling is important (Banka 2012) because the authorities know the land geology and the underground infrastructure. In addition, boreholes or wells provide a way through which gases can escape from the ground (Banks 2012). Sometimes these gases can be crucial. The gases can be methane, carbon dioxide, vapours and gases from contaminated land or landfills and Radon, a radioactive gas (Banks 2012).

4.4 Balance between profits /positive/ and risks /negatives/ in renewable energy

According to Chebotareva et al. (2020), renewable energy sources might help reduce the impacts of global warming and prevent the depletion of the world's energy resources. The positive effects of renewable energy are higher if we consider it in combating climate change. As seen in the above figure (Figure 4), the emission of grams of $CO2$ e/kWh for renewable resources is much lower than that of non-renewables. Thus, as stated in the above section, this shows that the profits of renewable energy are much higher than their risks. However, it is essential to estimate the risk level and minimise the risks by any means, such as increasing the efficiency of renewable energy production. If we compare renewable energy to fossil fuels, renewable electricity resources can offer substantial environmental benefits, especially regarding GHG emissions such as electricity production by solar, wind and geothermal (National research council 2010).

Renewable energy has much more uses than its impact. The idea of analysing the risks of renewables does not mean that I am saying that renewable energy is bad. However, we are trying to make them much closer to perfection, which can be done by identifying the risks caused by the current climate change effect and how they impact the environment—leading to balancing between the negative/risks and the positive/benefits of renewables then making them much better for future. I argue and acknowledge that the use of renewables in terms of energy production and combating climate change is much higher compared to their risks and the use of fossil fuels.

4.5 Risk management briefly

Risk management was presented briefly. Because the diverse type of risks presented here focused only on general solutions for renewable energy, land uplift and climate change, these risk management topics can hopefully be dealt with in-depth in future research.

a) Risk management and mitigation for renewable energy

According to Misra (2008), "Risk management is an activity, which integrates recognition of risk, risk assessment, developing strategies to manage it, and mitigation of risk using managerial resources". Let us first see risk management history based on Borghesi and Gaudenzi's (2013) risk management in a business book since the 1950s have been the theorisations and applications of risk management systematically (Borghesi and Gaudenzi 2013). This show is a mature section of the risk analysis and management field, at least in business risks. Risk management in renewable energy production was conducted for solar and wind in Germany based on different analysis methods by Hain et al. (2018). At the most basic level, risk management is about common sense (Knight 2010). Based on Watts (2011), the following measures can be utilised to mitigate renewable energy risks.

1. Risk reduction: (Concerned scientists 2013), for example, stated that best management practice helps reduce some environmental risks caused by renewable energy such as wind turbines. Wind turbine risks cause birds and bats death by collisions with spinning blades that can be declined by operating the wind turbine mainly in high wind periods

because it was found that birds and bats do not fly so much in high wind periods. Such that high-speed wind periods have very less risk to birds and bats.

2. Insurance during transport and operations periods: in flooding areas, houses with insurance have less loss.

3. Intensify communication with policymakers: to avoid policy changes by the policymakers. For example, insurance for the risk of damage due to natural hazards (Gatzert and Kosub 2016).

4. The diversification of different technologies helps reduce weather-related volume risks (Watts 2011).

5. Using proven technologies and fostering industry expertise and product development.

6. The steps shown in the next figure (Figure 5) fisheries management cycle can also be implemented to manage the risks of renewable energy. This proposal is my suggestion for adapting such steps in energy risk management can help the process management to be easier.

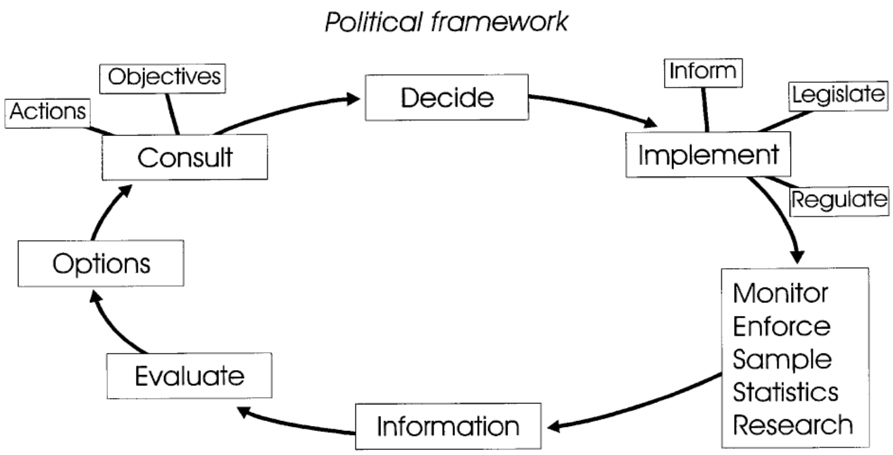

Figure 5. The fisheries management cycle is recommended to be used in managing climate change risks [picture taken from Caddy (1999) and originally described at FAO (1995)].

We must see the whole management problems in a generalised world instead of separating them into specific fields (Caddy 1999). In doing so, it becomes easier to learn from other fields of study, such as fishery management, to solve our renewable energy risk management.

Three interpretive models in the governance of risk management: Borghesi and Gaudenzi (2013) described in their book that the three interpretive models in governance and risk management are i. Structure-conduct-performance focused mainly on the ability to harmonise the "forecast, planning, organisation, control, coordination and monitoring". The other two are business oriented, which are: ii. Systematic approach and transversal/process view risk management, and iii. Value-based management. Governance and value creation: This is consistent with the systematic view of business and value-based management (Borghesi and Gaudenzi 2013). Moreover, they stated that the task of setting up and guiding development actions is allocated to the body charged with governance, which has additional tasks. The long-term perspective of value creation and governance is that the risk must be managed through long-term strategies Borghesi and Gaudenzi (2013). From a business perspective, this has to be because of competitive edge and value consolidation in the long-term, the same book stated.

b) Energy law briefly

Based on Heffron and Talus (2016, a and b) stated that "energy law concerns the management of energy resources". Energy law governs energy use and taxation of energy from renewable or non-renewable. According to Heffron (2016), the definition of energy law can be:" the area of law concerning the management of energy resources and the rights and duties over all energy activities over each stage of energy lifecycle and at the local, national and international level." The lifecycle of energy includes Extraction → Production → Operation and supply → Consumption→ Waste management → recycling back to the Extraction section based on Heffron’s (2016) descriptions. Future energy law is changing. Even though the greatest global challenge for future energy law is incentivising new low-carbon energy infrastructure, there is a top-eight key development in the global energy sector by 2040 (Heffron 2016). 1. Coal and gas prices stay low. 2. Wind and solar costs drop. 3. Asia-pacific leads in investment. 4. Electric car boom. 5. Cheap batteries everywhere. 6. A limited "transition fuel" role for gas outside the US. 7. Coal is diverging trajectories. And 8. The 2 °C scenario. More descriptions of these aspects are presented in Heffron (2016).

Changing energy resources from conventional to renewables is a must and requires devotion (Blakeway 2008). He also reviewed Scheer, Hermann's book comment saying "the breakthrough to a renewable energy future cannot happen until enough people break out of the 'prison' of 'one-dimensional' thinking about conventional energy". This point is true in terms of energy law or the need for new ways of environmentally friendly energy sources such as renewable energy resources. The sustainable energy law in the past and future was described in the past 30 years and the future 30 years in his article by Bradbrook, A. J. (2012). The summary of these events and future forecasts for 30 years were presented in next Table 4. The table shows what happened, including energy laws, protocols and conventions suggested at national and international levels.

Table 4. The past 30 years highlight and the next 30 years suggest legislation, protocols and conventions adopt at national and international levels (Direct summary from Brandbrook 2012).

The past 30-year major highlight in the energy sector	**In the next 30 years, the suggestion of legislative control to be adopted by national governments and new conventions or protocols to adapt on the international level**	
	By national governments	**In international level**
Recognition of peak oil has either been reached or is rapidly approaching	Wind planning guidelines should be included in local planning controls to ensure that development does not unduly disrupt the life of nearby residents.	Establishing domestic programmes for energy efficiency and conservation
Climate change has become centre stage	Geothermal legislation regulating resource exploitation should be adopted in all jurisdictions where the resource exists in exploitable quantities.	Creating binding, differentiated targets for nations to increase their electricity supply from renewable energy resources
The conflict between development and environmental protection led in public internal law to the concept of sustainable development	Small-scale runs of the hydro river schemes (less than 10 MW) should be favoured over large-scale hydro schemes.	In the case of developed countries, creating binding, differentiated targets for nations to reduce energy intensities and, by so doing, improve energy efficiency;
The crucial role of energy in alleviating poverty in developing nations has been belatedly recognised		Integrating energy considerations, including energy efficiency, affordability and accessibility, into socio-economic programmes
Nuclear energy got support from some nations		Developing and utilising indigenous energy sources and infrastructures for various local uses
Energy law has become increasingly important internationally		Promoting increased research and development in the fields of renewable energy, energy efficiency and advanced and cleaner fossil fuel technologies
Widespread privatisation of the electricity and gas industries in many nations		Adopting the principle of externalities costings when examining competing energy sources so that the prices of each source reflect its environmental impacts
The rapid development of technology has produced a host of new legal issues and concerns		Providing for the transfer on concessional terms to developing nations of advanced, cleaner, more efficient, affordable and cost-effective energy technologies
		Requiring nations to develop policies promoting sustainable energy by reducing market distortions and phasing out subsidies to fossil-fuel industries

According to Heffron and Talus (2016 a), "Energy law and policy is in the centre of the energy law, and policy triangle (Energy Trilemma) and on the three points of the triangle are economics (finance), politics (energy security) and environment (climate change mitigation). These three issues are each trying to pull energy law and policy in their direction". This explanation is very important for understanding, applying and promoting energy law. The change in energy law is influenced by international, national and local level changes. These three can influence one another, but it is possible not to influence one another. Based on Heffron and Talus (2016 a), 1. International treaties, international agencies, international politics (relations), and international business and trade influence change in international energy law. 2. Change in national energy law related to the aim of the government, availability of finance, advances in technology, and social preferences. And 3. Change in local energy law is complex and can be specific to local issues and individual perspectives.

Heffron and Talus (2016 b) also presented the evolution of energy law, and to date, there have been five stages in the evolution of energy law. Those are 1. Safety (1820 onwards). 2. Security (1910 onward). 3. Economics (1960 onward). 4. Infrastructure (2000 onwards). And 5. Justice (emerging); as presented in their article. Heffron et al. (2017) state the challenges of energy law in Asia and Africa. International energy law has different characteristics in different places worldwide (Wawryk (2014). There is no one holistic international energy law. It is different from place to place. However, EU international energy law is a key component (crucial part) of international energy law, universally acknowledged (Wawryk 2014). She also stated that there are no universal treaties regarding renewable energy law, although the EU has a directive for renewable energy, binding on the EU's member states. According to Wawrky (2014), "Energy law at an international level is best understood to concerning the sources of law that regulate the allocation of rights and duties concerning the exploitation of all energy resources between individuals, between individuals and the government, between governments, and between states."

c) Another flavour of risks: Land uplift risk assessment and management

The ISO 31000 (2015) publication presents the principles and practices of the risk management process in depth: the key elements at its core are shown in Figure 1. Business organisations usually apply risk management principles but can be useful in other spheres too. Applying these risk management principles to the issue of land uplift and sea-level rise produces the following strategic guidance.

<u>Establishing context</u>: Examining and evaluating the theories that connect the two can be used to forecast future local outcomes. The first premise is that climate change causes sea-level rise due to the temperature rise that is the consequence of global warming. Moreover, global warming is caused by the greenhouse effect. Equations 1 and 2 presented in (Girgibo

et al. 2022 b) demonstrate the effect of temperature on sea-level rise. The second premise is the theoretical model describing the relationship between sea-level rise and land uplift (Okko, 1967). Then, three tools have been applied to the study: cause and effect theory, the theory of demand and shift in supply, and the risk management process. All help establish a context for the effect of sea-level rise and land uplift and the relationship between them. Forewarning of the local effects is a huge benefit to the community. Data from a literature review has also been used to establish the forecasting context.

Identify the risks: After establishing the context, the next step is the identification of the risks. The first risk is the sea-level rise that threatens flooding, storm and surge, species migration, land swamping etc. Second, land uplift poses a risk at shorelines or harbour areas. That may necessitate harbour infrastructure expenditure and adds complexity to investment in renewable energy resources such as wave energy at the shoreline. It can also affect the phosphorus cycle, causing eutrophication (Bryhn & Hkanson, 2011), and continue in future, changing the old harbour sites and shifting vegetation levels.

Analyse risks: Introducing cause and effect theory to sea-level rise and land uplift is useful in risk analysis for local effects (Girgibo et al. 2022b). If any worst outcomes materialise, such as the Antarctica or Greenland ice sheets melting completely, we can expect a sea-level rise of 7–70 meters (Dasgupta and Meisner, 2009). Such an overwhelming rise would make the effect of land uplift meaningless. However, if future sea-level rise can be kept below 1 m (IPCC, 2007; Dasgupta and Meisner, 2009), land uplift may partially or fully compensate in some areas. In the case of the Vaasa region of Finland, current data suggest that it is likely that there will be higher land uplift than sea-level rise (Figure 9, at Girgibo et al. 2022 b).

Evaluate risks: Flooding on a significant global scale would be catastrophic. More than 56 million people in the developing world could be displaced due to sea-level rise (Dasgupta and Meisner, 2009). This point underlines the criticality of evaluating flood risk. That calls for continuous measurements in areas where flooding is likely and even where it is unexpected. Planting programmes on islands and in new land uplift areas also can help circulate air and water by evapotranspiration. In most areas of the world, significant land uplift is unlikely, so it poses a far lower risk. Nevertheless, the long-term risk and repercussions for harbour facilities should be evaluated in the locations where land uplift is occurring.

Treat risk: What must we do to handle a massive sea-level rise? One thing is to plan and prepare cities for those people who are forced to relocate, not only preparing new cities but also expanding facilities and support in cities that are not threatened by sea-level rise so that they can help accommodate displaced people. Another solution is undertaking financial planning so cities and governments can invest in appropriate infrastructures, such as Florida's sea relief underground pipes. Protection against storms and frequent surges must be constructed for the general population worldwide. These risk measures, including forecasting upcoming storms and surges, not only save a life but can also reduce or prevent property damage. Support centres must be built in areas with greater storm risks, surges, high rainfall, flooding and other similar threats. They provide relief when all other measures fail or prove inadequate.

Monitoring and reviewing: Forecasting is essential in those areas where risk is high. This procedure should include reviewing and communicating information about potential relocation sites. The twin processes of continuous monitoring and reviewing must also apply to areas of land uplift to ensure harbour facilities and other infrastructure remain safe and secure. There must be more research into the consequences and effects of sea-level rise and land uplift, raising awareness and making an important contribution to addressing the risks in local areas and on a global scale.

Communicate and consult: Island communities must have continuous information about current land conditions and sea-level rise. There must be the availability of advice and consultation about personal safety in stormy conditions, how to relocate, how to adapt and how to obtain help or support. There is a need for reliable and continuous communication between researchers, government, environmental centres, communities and warning agencies. Local centres must be established to provide communication and advice to surrounding communities.

5 CONCLUSIONS

This report shows a risk identification process and reviews the research of risk analysis on renewable energy. There are two flavours of risks analysed those are 1) Climate change risks on renewable energy and 2) Renewable energy use and production to the environment. The results of the whole risk analysis will be presented in Girgibo et al. (forthcoming). As stated in this report the comparison between the results of the forthcoming publication that is built based on the current study with Holma et al. (2018); it was found that more or less the study Girgibo et al. (forthcoming) was similar to that of Holma et al. (2018). This validated the research results and the identified risks in this report. Building on Holma et al. (2018) we extended the new section on the risk of climate change on renewable energy. This is the novelty of the study, which addresses climate change effects on renewable energy. We call it the untouched ground of climate change and renewable energy studies.

This study concluded that even though the risks of renewable energy on it or from it can be a little, it is important to analyse these risks to safeguard the use of renewable energy as safe for the environment and a sustainable energy resource. The whole process of identifying and analysing risks related to renewable energy was a big step for future extensive risk analysis on renewable energy with a significant number of expert opinions. It is important to build and safeguard renewable energy development and implementation at regional levels. Energy law and risk management play a great role in the whole process. Renewable energy is a means of gaining sustainable energy. It helps in combating and mitigating climate change. Further, it can help in building a safe and better world for future generations.

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Nebiyu Wolde, Girgibo

2022, Vaasa, Finland

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