The effect of climate change on water and environmental resources in the Kvarken Archipelago area

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Abstract
The reduction of carbon dioxide emissions is a choice that all should follow to combat climate change. Climate change causes problems such as global warming and meetings on these problems conclude that nations must integrate the Kyoto protocol commitments along with a reduction in greenhouse gases. The purpose of this study is to investigate the effect of climate change on water and environmental resources for the Kvarken Archipelago area. In the region, the sea level rise and river water runoff increase cause flooding and erosion. Measures such as dams and wetlands have to be installed for controlling these effects. Moreover, the use of renewable energy to replace non-renewable energy sources is one-step forward to combatting climate change. 'Demonstrative energy' is an important way of showing the usage of renewable energy. The Merten Talo or Havets Hus which is a part of the archipelago and Nature 2000 area will be a research site for the University of Vaasa. Paradoxically, climate change effects could even be used to our advantage, where for example, warm water could be used as a heat source, offering benefit to all sides by combatting and adapting to climate change. A microclimate is a set of meteorological parameters that characterize a localized area. The microclimates found in the Merten Talo area could be used as a tool to study climate change effects. The other area addressed was the land uplift. Land uplift is faster than the sea level inclination in the site, and in the Vaasa region, land uplift is on average 8.77±0.30 mm/yr. All in all, promoting sustainability and adapting to the effects of climate change is important, not only generally, but for the area in particular.

Keywords
Natura 2000, renewable energy, microclimate, sea ice, land uplift, plankton

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Abbreviations

AIDS	Acquired immune deficiency syndrome
ATES	Aquifer thermal energy storage
B. C.	Before Christ
BTES	Borehole thermal energy storage
BP	Before present
CH_4	Methane
CO_2	Carbon dioxide
°C	Degree centigrade
E	East
EA	Environment Agency (UK)
ENSO	El Niño/ Southern Oscillation
eq	Equivalent
EU	European Union
EV	Electric Vehicle

GEU	Groundwater energy utilization
GHGs	Greenhouse gases
HAWT	Horizontal axis wind turbines
IIASA	International institute of applied system analysis
IPAT	Impact population affluence technology
IPCC	Intergovernmental Panel on Climate Change
N	North
NAO	North Atlantic Oscillation
NE	North east
ppm	Parts per million
SACs	Special Area of Conservation
SD	Standard deviation
SLE	Potential sea level rise
SPAs	Special Protected Area
SPCS	Solar Powered Charging Stations
SST	Sea surface temperature
SW	South waste
$	Dollar
UNFCCC	United Nations Framework Convention on Climate Change
UTES	Underground thermal energy storage
UV	Ultraviolet
VACCIA	Vulnerability Assessment of ecosystem services for Climate Change Impacts and Adaptation
VAWT	Vertical axis wind turbines
WEC	World Energy Council
yr = a	Year, (anno)

1 INTRODUCTION

Climate change is the major global challenge affecting the world, and the future of our globe and our children is in danger. The current forecasts of climate change are not good. Some changes are evident, such as rises in water temperature that are causing cyanobacterial blooms in the waters of Finland and later parasitic influent. Events that are happening even now are global warming, changes in weather patterns, sea level changes, acidification, flooding, draughts, increases in storms and clouds, and other changes in the environment. The current study focuses on the possible effects of climate change in the 'House of The Sea' (Merten Talo or Havets Hus) area, which is found on the shore of the Kvarken archipelago in Western Finland near the city of Vaasa. The mentioned events due to climate change are studied in relation to water bodies and future energy possibilities, the environment and microclimate are described, and the land rise/uplift is explained. The problem is that climate change effects are affecting us in a negative way. Consequently, knowing how we can adapt to climate change effects makes it easier to combat climate change.

For example, the temperature of the seawater will increase in the coming years. This warming has already started. In order to combat this effect, emissions of carbon should be decreased all over the world. This means that we have to change our fossil fuel energy sources towards carbon-natural energy sources to reduces greenhouse gas emissions from energy production. This is important in combating climate change (IEA 2020).

The water resources are changing globally, mainly in two ways. Firstly, in those areas where there is a shortage of water, the number of droughts will increase. Moreover, there will be more floods, and the sea level will rise in the coming years (Scavia et al. 2002). In the case of floods, the fresh water quality will decline dramatically. It will be polluted by different substances such as wastewater, dust, and nutrients from the soil, as well as by salt from seawater intrusion especially to fresh water, ground water, and aquifers. There will be a significant change in the ways that we clean and supply pure water to the community. There is also likely to be a significant pressure placed on wastewater treatment plants due to the higher volume of water and precipitation. The flow from rivers will be higher to the sea and lakes. However, in some of the earth's rivers, the water volume and speed are expected to decline (Shrestha et al. 2014). The effects of climate change are interrelated. For example, the temperature change will affect plankton abundance and distribution. Thus, the phytoplankton level will limit the zooplankton abundance, and influence the fish and fish larva, which feed on the zooplankton and phytoplankton. On the other hand, there is a higher chance that the temperature changes will directly affect the fish in sea and river water in terms of physiology and ecology level. The enzyme reaction in fish will be modified due to the water temperature difference and metabolism, which will increase and decrease as the water temperatures rise and decline (Brander 2015).

The Merten Talo exhibition building is in an area that is quite near the shore of Western Finland in the Kvarken Archipelago. An exhibition of the 'Towards Renewable Energy' study shows the issues of combating climate change, with an installation and for the use of local restaurants and community. The literature review contributions of this study are briefly as follows:

- The study encourages companies and people to get involved in combating climate change.
- Using climate change effects to our advantage is the main idea of the paper. Such as temperature increase in water bodies for heat exchange or ground soil temperature increase for installing boreholes.
- The study aims to start a research site in the Merten Talo area for the University of Vaasa.
- Producing a renewable energy source in the first phase of the project. The first goal is to use it for heating, producing electricity, and storing. The second goal is to demonstrate the use of renewable energy for possible visitors and children in an exhibition. Sediment energy, biogas (created due to the implemented cleaning system), and hydropower (not currently visible because of the small capacity of the rivers) are briefly described in the paper.
- The river study shows that the incoming rivers are not high enough for hydropower usage, but the effects of climate change in their waters would lead to a higher volume, velocity, and turbulence in current site rivers.
- The sea level rise is one effect of climate change (Climate Institute 2010). Heat exchangers can be installed for use in heating and cooling.
- Algal blooming has been examined by www.jarviwiki.fi, and non-algal bloom was found in the Merten Talo area.
- The fish stock is analyzed briefly from the literature. Fish are affected by the salinity of fresh water after contamination by seawater, oxygen depletion, and the temperature inclination in all waters.
- Environmental effects are also studied briefly by literature review. Something affected by climate change is the wind speed and patterns. According to Pryor et al.

(2010), the Baltic Sea ice cover decline can be measured in periods of hundreds of days, thus an increase in wind speed was predicted in our area. However, it is not predicted to be too high, and it increases the efficiency of wind turbines. Moreover, in the studied area, the sediment is hotter than before, but due to the stones present on the sea bottom, it is not possible to use sediment energy. Solar panel use will also be advantageous for the area.

- The possible types of efficient renewable energy resources for adaptation are described and analyzed here, having the main connection to the study of the dissertation carried out by Girgibo, Nebiyu started in 1.1.2017.

- Microclimate is a set of meteorological parameters that characterize a localized area (Hogan 2010). The relation of climate change to microclimate is briefly discussed.

- Theories about facts on land uplift are presented. The current land uplift is faster than the sea level rise, at least in Finland (Löfman 1999).

- Adaptions and the sustainability of the area related to climate change is particularly important. Sustainable adaptations to climate change must be developed for the current site, and also other areas of the world. Sustainability in water resources must be developed for making better use of the existing natural water resources, controlling demand, and reducing losses, and achieving much efficient water management.

2 THE PROBLEM

One of the major global problems we face is climate change, and its effects are still progressing. The current site is also affected by these problems. This can be seen in phenomena such as the sea level rise in the Baltic Sea, the speed and volume increase of river water, the temperature increase in the water and soil, rainfall, flood and erosion increase, and cyanobacteria blooming (that might not be currently evident, but is predicted in the future). The report lists/reviews perspectives on climate change and its related issues at first hand. To minimize our energy usage, we can take simple and seemingly evident measures such as turning off lights in empty rooms, but steps are needed to convert our energy use to sources of renewable energy such as solar or wind turbines for electricity and borehole heating systems for our houses. Recycling our waste and toilet effluent offers a simple and minimum-maintenance biogas plant (Girgibo 2009). Using green products such as the fruits and vegetables we consume reduces emissions in production and transport, and buying and driving cars using renewable energy sources such as electricity, biogas, natural gas, and possibly alcohol contributes to replacing benzene. Some measures are not going to be 100% efficient, but even though the energy sources of these types of cars cause pollution, it is less so or harmless when compared to benzene usage. In these cases, the usage of renewable energy is one-step forward for the community.

The problems in river water in the current site would be the inclination of runoff and volume. This not only affects us physically by increases of flooding and erosion, but the present species in the area have to adapt to a new and changing environment. In some parts of the world, the opposite is true, and drought is spreading. Increases in the temperature of sea and river water is another problem and will affect many species, where especially the seas and rivers, fish are in danger. The temperature increases also cause sea ice to melt, with glacial melt causing a runoff all over the world and continues the decline in global freshwater resources. The effect of global warming is especially visible in water resources (Archer 2007). The acidification of sea water decreases its pH value and can be observed in seas, oceans, and even in river waters. pH increase causes the water to diminish in quality, and the more alkaline the water the better it is (Armitage et al. 2010). As sea ice is melting faster than before, this also has implications for other types of wildlife, including a few types of bears that inhabit the northern climates (IPCC 2007).

Sea levels rise, and this causes subsequent pollution to fresh water resources and soil in the environment. A related problem is flooding and erosion, and nowadays there are floods and erosion in areas where it has not happened before, and it is predicted in this paper that it will also occur in the current site. Erosion and flooding are already noticed in Mustasaari Kvarken archipelago area in the past (Berghäll and Pesu 2008). Changes in weather patterns will have global effects. There was an expectation in history that a ‘black Christmas’ will come in the future, according to discussions with a doctor in limnology, but it is already happening in Finland. The precipitation is going to increase leading to increased incidences of storms and hurricanes (Scavia et al. 2002). More clouds are expected, and wind power is increasing in the current site, but generally, wind power is expected to decline in most parts of the world (Pryor et al. 2010; Barton 2014). Sever draught also affecting some parts of Finland because of climate change (Veijalainen et al. 2020).

Costal living populations will be moved to other areas, and possibly to cities leading to further crowding of already crowded cities. The waste handling systems of many nations must also be developed. Otherwise, climate change will increase pollution due to the warm surrounding air. Landfills (areas where we bury waste) will leach much more due to higher precipitations and runoffs. Therefore, sustainable and adaptable methods must be implemented to address these issues, as their impact can be seen on both local and global scales.

2.1 Aims

- To describe climate change and related issues as described in published literature.
- To describe how companies and individuals can combat climate change.
- To investigate the current condition of the area and the coming changes due to climate change.
- To outline new possible energy advantages due to climate change. Especially, the possible renewable energy sources that can be used in Merten Talo, and to provide an analysis of future energy options.
- To describe the possibility of microclimate change, and plankton conditions.
- To investigate literature concerning the ice thickness of the seashore and its possible change in the future.
- To explain and explore the land rise effect.
- To investigate the energy availability to inheritance area from the literature review.

2.2 Questions addressed in the study

1. What are the effects of climate change in the current area, and what are the possible major changes?
2. What are the possible future energy solutions that can use climate change effects as an advantage? Moreover, which can adapt, combat, and mitigate climate change?
3. How can the possible way energy uses be described and how they are connected to climate change?
4. What are the microclimate changes, plankton effect, and fishery changes related to climate change?
5. What is the depth of the ice on the sea?
6. What is the land uplift effect in Finland and why does it happen?

3 HYPOTHESES

The following hypotheses were put forward for this study:

Null hypothesis H_0: There will not be any change in one or some of the next hypotheses.

H_1: The incoming river potential will increase due to climate change, and the outcomes of hydropower will increase in the area.

H_2: The sea level will rise, the winds will increase, and these changes will affect the islands of the archipelago.

H_3: Precipitation, erosion, floods, and ground water will dramatically increase due to climate change.

H_4: Phytoplankton will increase and the fish community will decline due to the increases in temperature.

H_5: The land uplift will continue to increase whether there is climate change or not, and the sea ice will shrink due to the melting effect.

H_6: The potential of energy will decrease, and the surrounding temperatures will increase due to global warming.

4 WHAT IS CLIMATE CHANGE?

It has been argued in the literature (Hannah 2011) that the current state of climate change is due to the effect of the natural cycle of our world. But even though there have been eras where a natural cycle (heating or cooling) has been seen to take effect, the current climate change situation has been proved to be due to anthropogenic (human) effects (IPCC 2007, 2008, 2014). The following are the two most common definitions of climate change (Hannah 2011; IPCC 2007, 2008, 2014):

1. Climate change in IPCC (Intergovernmental Panel on Climate Change) usage means: A change in the state of the climate that can be distinguished using statistical tests; typically for decades or longer periods in changes of the mean and/or the variability of properties. The changes in climate through time can be due to human activity or natural variability.

2. Definition of United Nations Framework Convention on Climate Change (UNFCCC): Climate change means a change in the climate that is related directly or indirectly to human activity, that disturbs the composition of the global atmosphere and in addition to the natural climate variability, it is noticed to last over longer periods.

To understand climate change fully, one must know the related issues of climate change. Those may include the following. <u>Climate change biology</u> (Hannah 2011): this discipline dealt with changes in climate and its interaction with biological ecosystems. Here, the induced impact of climate change on natural systems was studied. It emphasizes that the future impact due to climate change is a big area of study that touches all aspects of biology. <u>Chemistry of change</u>: the effects of greenhouse gases (GHG) impact on the ecosystems of both the land and the water. The dissolving of CO_2 into the seawater causes both an increase in the earlier acidification of the sea and reduces the amount of calcium carbonate in the water (saturation state). This leads to an impossibility for creatures to produce calcium carbonate shells or skeletons, as they usually get the calcium carbonate from the sea water. The expectation is a 60% drop in the availability of calcium carbonate as the sea pH decreases by 0.5 (Climate Institute 2010). The secretions of calcium carbonate by Bivalvia such as mussels was studied and have been known for a quite long time (mussels were one of the creatures that Darwin was interested in). As water becomes more acidic, it leads to extinction, a reduced abundance, or a range shift for species as diverse squid, shelled sea creatures such as mussels, and corals because of the fact that there is less calcium carbonate. The direct effect of acidification would be an altering of the pH state in the sea water. In the past century, the ocean water became more acidic (decrease in pH 8.1 to 8.0) because of 30% more H^+ due to dissolved CO_2 pollutions, and this means that the environmental quality of oceans declines (Armitage et al. 2010). It is known that phytoplankton will capture CO_2 and to sink to the bottom of the sea water. The growth of plants is stimulated by inland CO_2 because of the input of photosynthesis pathways. Thus, the warming effect and dissolved CO_2 can affect global vegetation. However, the complex effect of CO_2 is not well known in the ground or water.

A greenhouse planet (Hannah 2011): combustion produces CO_2 in higher quantity, but CO_2 and water vapor also exist in the natural state. The product of these CO_2 effects would be to cause a disruption in global temperature. The data of the past century shows that increases in CO_2 in the atmosphere are mainly (around 30%) caused by releases of CO_2 from the burning of coal, oil, and natural gas, with an associated reaction. First releases indicated that it was from the use of coal, but later it was seen to include the burning of oil and natural gas. In some books such as the work of Princiotta (2011), it is stated that there is an agreement to stop using coal in 2015 in Europe, and this offers one step forward in minimizing emissions of CO_2. The effect of CO_2 rise would be one of global warming, but the direct effects also alter the growth of plants and sea water chemistry. "Greenhouse effect" (Hannah 2011): some of the atmospheric gasses' 'trap' heat. The sun's radiation warms the earth's surface. Some of this radiation is absorbed and then re-emitted by atmospheric gases such as CO_2, and by water vapor. Consequently, part of the re-emitted radiation is directed back towards the earth, resulting in a net redirection of long wave radiation from the atmosphere back to earth. This warms the lower surface of the atmosphere and is likened to the glass in a greenhouse trapping the heat from the sun.

The knowledge of the climate system is as important as understanding climate change. Definition of Climate system (Hannah 2011; Shrestha et al. 2014): climate system = the atmosphere + the oceans + the earth's land surface (see Figure 1). Due to CO_2 or natural effect, the energy that would be directed to space is captured and re-radiated by the atmosphere. Because of the greenhouse effect, the atmosphere absorbs the heat and releases it back in the form of long wave light radiation to the land surface and oceans. The main components of the air are nitrogen (78%), oxygen (21%), water vapor, and CO_2. The oceans are the other component of the climate system. Its importance is that it contains water and dissolves gases. CO_2 is also absorbed by oceans and this reduces its concentration in the atmosphere. However, warmer oceans can cause more storms like hurricanes and they release much more water vapor.

The land surface consists of different structures like lakes, rivers, forest vegetation, exposed rock, soil, snow, and ice. The reflective properties of land surface structures cause differences in how ground warms. Darker surfaces (such as asphalt) absorb more solar energy and re-radiate it. Darker surfaces have heat that may be trapped by GHG in the atmosphere. Light surfaces would normally reflect radiation back to space in wavelengths not trapped by GHG and so they affect cooling. Glaciers, snow accumulations, and ice cool the ground not only because they are cold, but also because they are white. This means that they reflect the sun's light back to the atmosphere. An increase in global warming reduces the amount of ice and snow by melting. Then the Earth warms much more because less reflecting components retain more heat.

Hydrology studies the movements of water within and between the components of the climate system. Water vapor has powerful heating and cooling effects. Water moves through the hydrology cycle evaporating from oceans; condensing as clouds and raining out over land as fresh water that flows back to the sea. An increase in global temperature can accelerate the hydrologic cycle by speeding up evaporation from oceans (Hannah 2011). This is the main concern, as the incoming river's velocity and volume will increase in our study site. The next picture is taken from the book '*Climate change and water resources*', illustrating the components of climate systems, their process, and interactions.

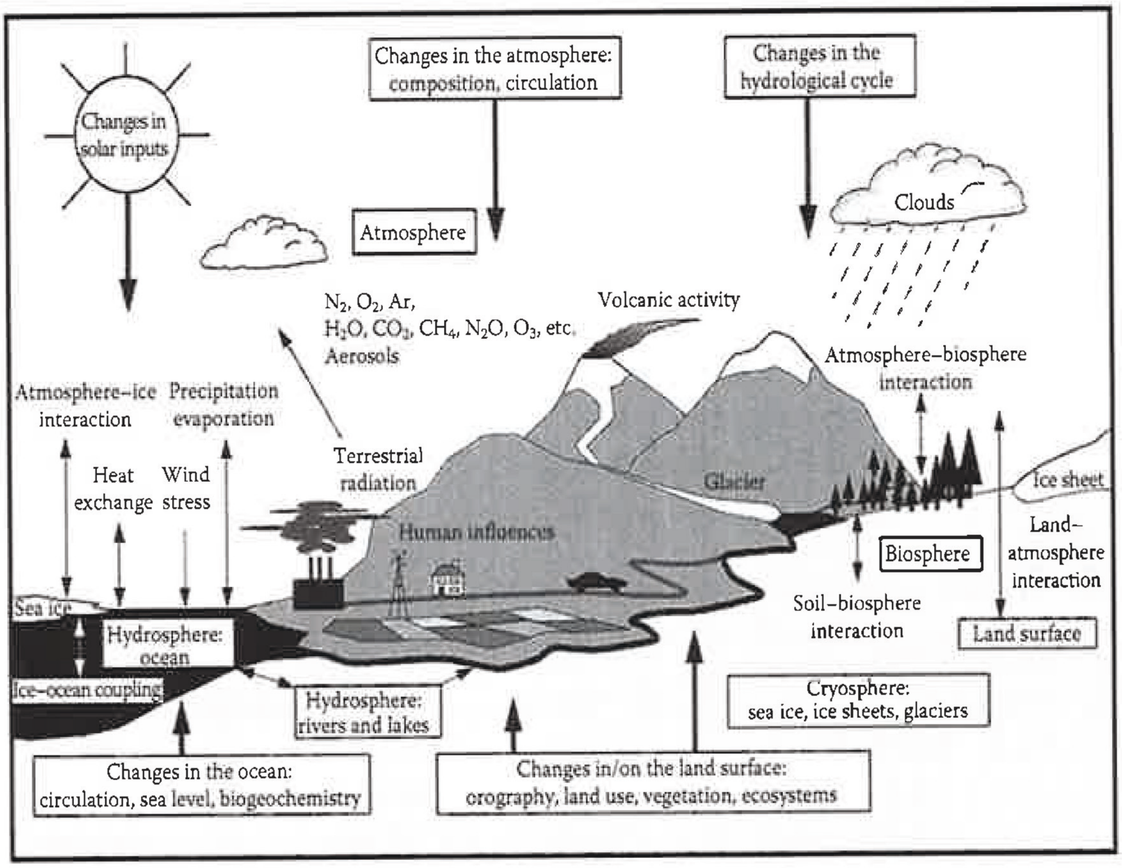


Figure 1. A view of the global climatic system components, their process and interactions (thin arrows), and some aspects that may change through time (bold arrows) (Shrestha et al 2014).

Global challenges are interrelated (Pirilä 2000): global warming is not the first global issue that has caused collaboration between nations. Other issues have been ones such as resource decline and AIDS. A global reaction was also observed related to ozone depletion, and before that, 'acid rain' was curbed through limiting emissions of sulfur dioxide and nitrous oxide. In China, 258 cities suffered due to the ‘acid rain’ caused by excessive emissions of sulfur dioxide. Hence, we do not know the real consequences of global warming as a unique challenge. However, the economic consequences such as its effects on water resources will be far-reaching. Consequently, the GHG effect is much larger than it was expected to be and has been projected an average temperature rise of 1°C with a respective reduction of 0.05°C by 2050.

What is climate change’s impact on the environment? To understand the impact of climate change on the environment, it is good to refer to the IPAT model which determines the impact situation (Pirilä 2000); this is influenced by factors caused by human actions. Impact = population X affluence X technology. Population size is one of the components, with affluence that determines the economic activity per person, and technology which determines the number of resources extracted or waste produced per unit of economic activity. According to the IPAT model (2000 data), the global population was over 6 billion and growing at a rate of 1.33% per day (annual net addition is 78 million people). Most probably, the population will be at 8.9 billion in 2050. Thus, the challenge will be seen in the need to increase the levels of food production when the population increases. Affluence determines environmental degradation. Rapid progressions of economic activities are associated with rapid rates of resource use and waste production. Generally, it is thought that an increase in affluence tends to exacerbate environmental impacts. An example is shown using the deviation system derived from differences in types of energy that are used (profit from waste), the types of goods and services that are consumed, and produces the general level of technological development.

The social and cultural forces are unique to each nation. Technology creating new problems and saving or reducing environmental problems are two ways of observing the technology effect. As an example: the carbon dioxide emissions caused by using a car are bad, but it is still good to use cars. Waste and recycling technology can create improved and new sources of product resources but are also a source of pollution. Meat production is good in terms of industries, but their energy and material use (e.g. water) is intensive. Moreover, fertilizers and fossil fuel combustion are good in increasing production output, yet lead to pollution. Yet with only 4% of available land being utilized or controlled by humans, this means that with fertilizers, a little percent of the land can still be enough for food production and living.

The environmental factors likely to be affected by climate change in relation to water resources are temperature, rainfall evaporation, water level, ice cover, nutrient availability, stratification/mixing (e.g. Graham et al. 2009; Winder et al. 2004), circulation, acidification, cloud cover, irradiance, and UV (ultraviolet) exposure. Figure 2 shows the possible interrelation of these environmental factors in an aquatic system.

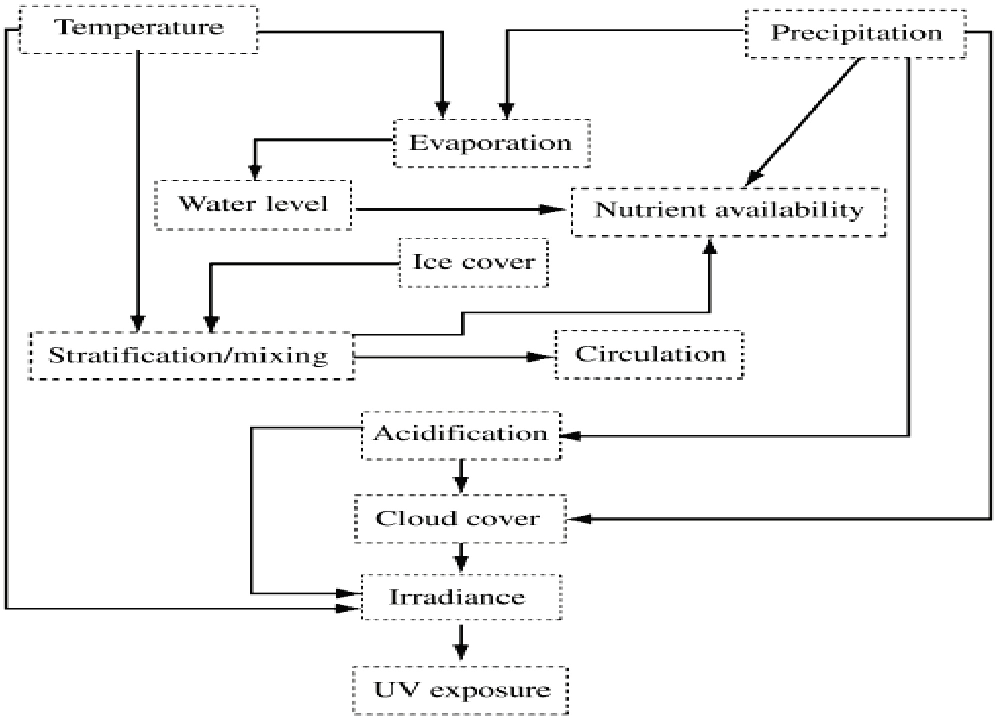


Figure 2. The possible environmental factors likely to affect aquatic systems predicted from climate change scenarios (Graham et al. 2009).

Evolution of the earth's climate (Hannah 2011): Earth has formed 4.5 billion years ago and single-cell life appeared approximately 1 billion years ago. The major atmosphere was formed about 100 million years ago because these microbes produced oxygen. The formation of the ozone layer in the upper atmosphere was supported by the buildup of oxygen around 600 million years ago. Life in the oceans became possible because the ultraviolet (UV) light would not reach the oceans once the ozone layer had developed. Planet Earth, became a life supporter after the ozone layer had developed. During the past 500 million years, there have been four major cold periods and four major warm periods. During cold periods, polar ice and snow exist on the ground and the global mean temperature is low. In warm periods, there is little or no polar ice or ice and snow on the ground. The warm period is associated with higher levels of CO_2 and the cool period is mainly associated with low CO_2. Mostly from 100 million to 1 billion years ago, warm greenhouse conditions have dominated, but been interrupted by several cool episodes. The current warming period started approximately 20 years ago. Consequently, during these periods, it is unusually warm, the climate is not stable, and manmade greenhouse gas emissions are currently causing the climate to warm.

Climate is changing (IPCC 2007, 2008 and 2014): this forecast is related to the reality that scientists estimate a 0.6^{o}C increase in the planet's temperature over the last century. The IPCC (Intergovernmental Panel on Climate Change) reported in 1995 that scientific evidence exists to explain the global climate change caused (inter-alia) by CO_2 emissions. The warming of the atmosphere is a starting point to analyze other consequences. The scientists agreed that strengthening of the greenhouse effect has a strong correlation to the concentration of greenhouse gases. However, the concentration of CO_2 in the atmosphere has increased in the last hundred years and the global average temperature has risen.

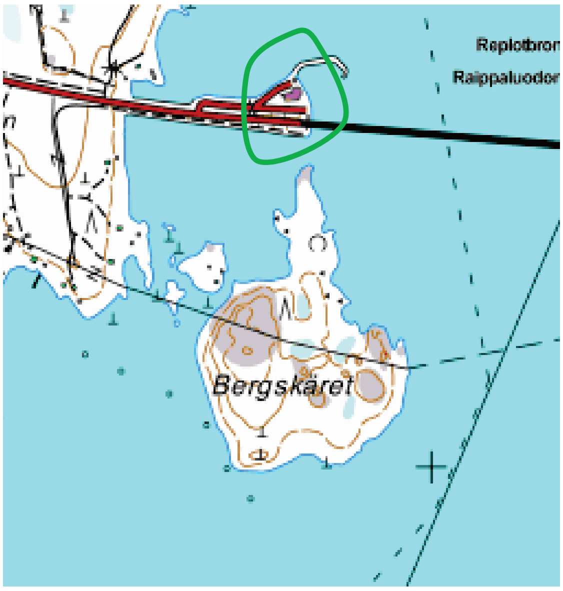
A choice before us (Hannah 2011; Pirilä 2000): there are three difficult choices the global population has to face. Business as usual – 'to hell with atmosphere'– has been the strategy of most nations after the Kyoto climate conference. In regard to the adoption of nuclear energy, as it is said that the impact of nuclear energy is less/lower, and decreases the impact of fossil fuels. With regard to accepting and reducing the standard of living, the existence of poverty will limit us, but providing people with the best alternative is relatively easy. The author agrees that accepting and reducing the standard of living is the way the world should follow.

The Kyoto Protocol: The Kyoto framework report (1998) is based on the facts that a) global warming exists, and b) manmade CO_2 emissions have caused it. It commits state parties to reduce GHG emissions by way of an international treaty. This extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC). In Kyoto, there were 192 parties in December 1997. The protocol came into action on 16th February 2005 and was adopted in Japan in 2005. Canada withdrew from it in December 2012, and the USA has not ratified the protocol at all.

5 STUDY AREA

Merten Talo / Raippaluoto island (Replot in Swedish): the study area is on the shore of Raippaluoto island, located in the archipelago of Vaasa in western Finland. The area is near to the Raippaluoto Bridge and the Kvarken World Heritage Gate. Here, the seawater can be used for cooling in the summer and for heating in winter. This coastal area is generally under threat from rising sea levels, but on the other hand, the land itself is rising. It is a part of Natura 2000 protected area in the archipelago. Figure 3a is taken from the National Park Finland web page in 2016, and Figure 3b is a coordinate map from the Retkikartta web site showing an exact view of the area (marked in pink within the green circle). The coordinates of the area are latitude 63° 12.4383' and longitude 21° 27.7626'.

(a)



(b)

Figure 3. (a) Map of 'House of The Sea' area (Merten Talo/Raippaluoto). (b) The pink colored area within the green circle on the right of the bridge is Berny's restaurant. (Taken from National Park Finland 2016 and Retkikartta web pages 2015, respectively)

Natura 2000: more than 100 000 conservation areas in 54 different countries are included in the Natura 2000 project. Europe has the largest number of Natura protected regions out of the whole world. To ensure the long-term sustainability of regions of valuable biodiversity, the European Union (EU) created the Natura 2000 system as an addition to the already protected areas in individual countries (e.g. national parks, natural parks, nature reserves, protected landscapes, etc.). Two groups of areas are included in the Natura 2000 network: the 1st are Special Protected Areas (SPAs) which are classified under the Birds Directive in order to help conserve important and special areas for rare and vulnerable birds. The 2nd Special Areas of Conservation (SACs) are classified under the Habitat Directive in order to conserve rare and vulnerable non-bird animals, plants, and habitats (Arau'jo et al. 2011). Natura 2000 areas constitute 17% of the land area of the EU, and out of 27 EU countries, it contains 27,661 sites covering 117 million hectares. Even though the protected areas are established in understanding and implementing the impacts of climate change, it is also important to implement their sustainable management. The current site is a part of the Natura 2000 area. Therefore, the species sustainability findings that follow (see Figure 4) for the Natura 2000 area are also applicable to the current site.

6 CLIMATE CHANGE FORECAST AND POTENTIAL

As circled in green in Figure 3a the 'House of The Sea' is located on the island of Raippaluoto on the shore of Vaasa in the western Finland archipelago, just next to a long bridge. The seawater and floods in the close rivers will affect the shores. There is currently a restaurant in the protected area. For possible energy generation, the use of wind turbines offers good potential because of the open sea. The first possibility considered in the past in the protected area was to install renewable energy sources of a wind turbine and solar panels/cells for both electricity and heating, and to store the energy in boreholes and batteries. In the nearby exhibition hall, the second demand is for so-called demonstrative energy. This means energy mechanisms that demonstrate how energy is produced, even they do not actually function as an energy source. The possible climate change effects for the area are similar to those faced by the rest of the world. Due to global warming, the water temperature and surrounding air temperature are expected to rise. Here, the effects are classified as water resource changes and environmental changes. The water resources include both the seawater and water from the incoming rivers.

It is expected that the area is much more influenced by climate change, compared to other areas that are not on the shore. On the shore of the island, there will be higher expectations of erosion, flooding, or island rise because of the land uplift effect (see section 11). Strong winds exist on the shore of the sea because it is an open space. The weather conditions are changing due to climate change, and therefore it would be an advantage to install a wind turbine to get energy for heating and electricity for the exhibition hall, but not at a level that generates enough power to serve the whole of the nearby community. On the other hand, the river water level is rising, so the velocity and perhaps the water volume is expected to increase. Therefore, it might be an advantage to install hydroelectric power for Merten Talo.

Figure 4 is represented from the work of Arau´jo et al. (2011) entitled "*Climate changes threaten European conservation areas*". The study analyzes four emission scenarios which are listed in the figure. The forecast also includes the outcomes of the protected areas and Natura 2000 areas expectations for the 2080s. The green color in the figure indicates winners and the blue losers, where they face different scenarios. As can be seen in the figure, most of the species such as plants, mammals, birds, and amphibians have a higher prediction of losing (58 ± 2.6 %; Median ± SD, in protected areas) and (63 ± 2.1 % for Natura 2000 areas) in relation to the current climate and forecast. An exception is seen in most of the scenarios where reptiles are winners (67 ± 3.7% winning), and in two cases of protected areas, amphibians are also winners in relation to current climate change. This means that reptiles will in fact benefit from the hotter climate. The CO_2 emissions vary between 530-786 ppm (parts per million) in 2080. The Natura 2000 areas are more vulnerable to climate change. Moreover, country-by-country analysis shows that two countries (Sweden and Finland) have more loser than winner species in Natura 2000 areas. In the protected areas, however, more countries become winners, and these tend to be situated in the colder corner of Europe.

Increases in flooding and the increment number of floods is another outcome of climate change, and even though the land is rising there will still be flooding now and then. Floods currently take place at intervals of 10 to 20 years in contrast to a historical frequency of 100 years interval (WWF Global 2016). Some flood protection coverage might be needed for building. The other possible effect is increased erosion due to sea level increase, which will clear the soil from shores. Possible means of protection must be planned to avoid this erosion, and will further enable species to flourish and to have a home for their next generations. Flood protection might be effective all along the coast to prevent flooding. As well as minimizing erosion from the sea, it may also be possible to implement along the shores of rivers. However, dam and flood protections near the water body may change the water ecosystem environment. It may disturb natural ecosystems and have an influence on the ecosystem services such as fish production, on which the human economy depends. The biodiversity decline in river ecosystems often range <10% of a dam's pre-regulation conditions. This means that if one dam is implemented, the decline in ecosystem is <10% the dam area's regulation capacity (Wetzel 2001). Hydrological alteration might also induce habitat fragmentation, deterioration of irrigated terrestrial environments and associated surface waters, and dewatering of the rivers from diversions. The other point is that the tourist attraction levels might also decline, which means that people travel to see a natural archipelago that is not surrounded by flood protection measures and dams. Therefore, its attractiveness can decrease, but this might depend on the size of the dam and flood protections, as well as their visibility.

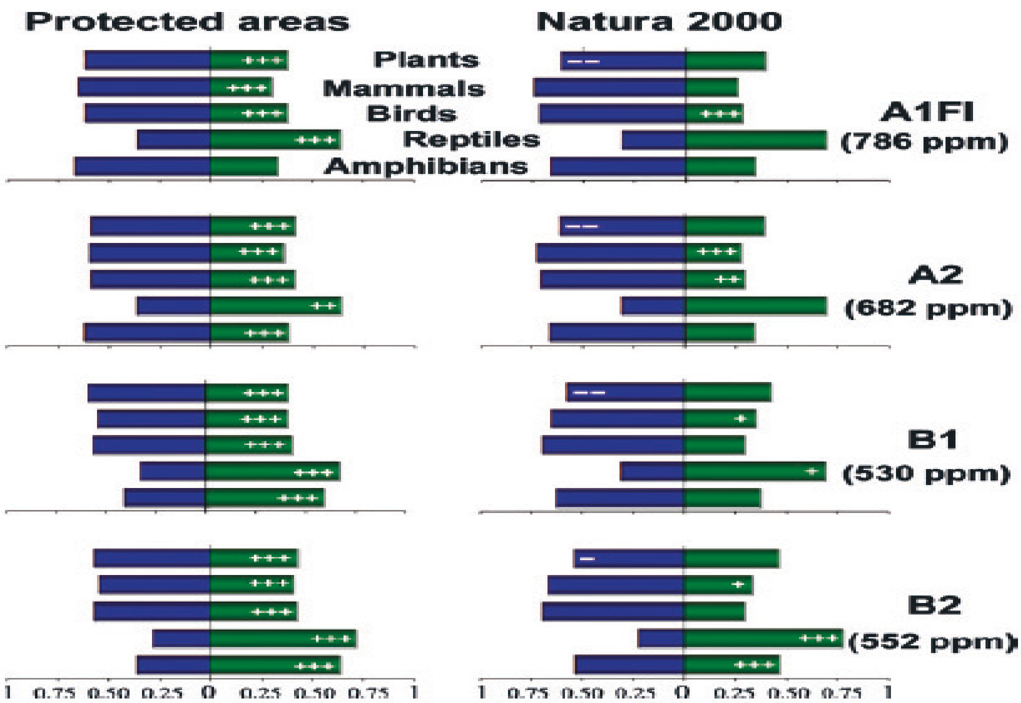


Figure 4. Scenarios of the development of the European conservation areas for four emission cases up to 2080 (ppm is 'parts per million' concentrations of CO_2eq), proportion of species projected to gain (winners: green) or lose (losers: blue) sustainability gained by climate change. For the Natura 2000 area, for EU Bird and Habitat Directive species occurring, projections are provided for all analyzed species in protected area. Conservation areas having more climate sustainability for species than expected in randomly selected unprotected areas are marked with +++ (p<0.001), ++ (p<0.01) and +(p<0.05), whereas conservation areas preserving less climate sustainability for species than expected in randomly selected unprotected areas are marked with - - (p<0.01) and - (0.05) (Arau´jo et al. 2011).

The migration of birds and fish due to climate change causes an issue that has a far greater impact than its effect on the archipelago's natural attractiveness. Climate change alters the phenology of migratory species (Hannah 2011). The effect is that due to the long summer, the birds have to arrive quite earlier and then they depart quite late to their next possible warmer area. Some populations or individuals became resident entirely in cooler parts of their range as the climate warms (Hannah 2011). Maybe there will be a wider diversity of birds seen here in Finland, mainly in wetlands, but they might not be attractive in terms of being be unique birds to Finland, as they are not natural residents and they can also be seen in other parts of the world.

Anthropogenic climate change creates many stressors in animal survival and living environment, which was noticed in Europe too falling to adapt to novel conditions. According to Ylönen et al. (2019), vole cycles around Europe are changing in many ways including prey-predator conditions. They told that one of the strong factors is climate change, for example, change in North Atlantic Oscillation and its effect on winter property. Heavy snow winter used to hide the nesting places for voles, but now they can not hide that much in winter so that they caught easily by a weasel. Winter snow-depth decline was noticed in Konnevesi, Jyväskylä, which affects the hiding of voles' nests (Ylönen et al. 2019).

6.1 Changes in water resources in the 'House of The Sea'/Merten Talo area

Here, water resources mean fresh water (incoming rivers) and seawater. The study of seawater and fresh water are quite related, but they are two different disciplines. Predicted climate change effects in temperature can have subsequent impacts on e.g. water temperature, precipitation (e.g. increasing in precipitation in Finland), wind circulation patterns (where the sea ice melting increases the wind speed and gales), marine climate, sea level, and wave height (Graham et al. 2009). Both marine and river water is expected to warm, and the ambient temperature is envisaged to increase. In the case of precipitation, more rainwater or snow is coming in winter, and dry summers mean less rain. Higher wind movements are being observed in the coastal areas of Finland, and this has also been seen in the coastal regions of other nations like the UK (Graham et al. 2009). Marine climate change may cause a blooming of algae in coastal areas, and generally, the phytoplankton community is expected to decline in seawater due to climate change. The phytoplankton absorbs CO_2 causing it to sink to the bottom of the sea (IPCC 2007). The sea level is predicted to rise 23–36cm by the 2080s (Graham et al. 2009). The blooming of cyanobacteria is predicted to increase all over Finland, although this has not yet been found in the current area. The fish stock is affected by both plankton bloom and water temperature, and both can alter its ecology in regard to how they get food and physical effects on their metabolism. A global increase in wave height and storms is also predicted (Dasgupta et al. 2009).

6.1.1 Incoming rivers

A river's ecosystem includes both the channel and the flood plain. Associated with lateral migration, they are both dependent on erosion. When this happens, the area of the stream expands letting it become a bigger river and waterway. In this case, streams decrease in size and become lower. Rivers can be classified by numbering the main stream with a small number and joining streams with a higher number. The smaller the number is labeled with, the greater the chance that it might be one of the origins of the bigger river water (Wetzel 2001). Most of the ecosystems are more motile as the river moves through them, and some are able to resist currency and turbulence (water flow disturbance). The ecosystems of a river are quite different compared to the ecosystems of lakes or seawater. For example, river mussels will allow the water to pass through their body so that they can collect the microbes and planktons in water, without being affected by the water current and turbulence. Also, they might participate in creating water disturbance because one mussel filters around 40 liters of water per day. Lake mussels pump water through their body and filter food from the lake water. Consequently, the fish species living in a river are dissimilar to species found in the sea. Climate change is expected to have a greater influence on river waters than lake waters because there will be a stronger water flow, and those species that can resist only mild flows will be washed away (Wetzel 2001). There will not be any stable nutrient supply because of the water movement, and the nutrient content will vary meaning it will be difficult for the community to establish a stable living in the water (Winder et al. 2004). The increase in water temperature will also affect the community. In some rivers, the water levels will decline due to drought and due to farming practices (e.g. as has been discussed related to the Nile river by 2040-2069 and 2070-2099: Shrestha et al. 2014). This means that conflicts between nations will increase in areas where they share the use of the same river water. The Raippaluoto area can expect to have more water. River water is expected to increase in volume and velocity and might flood. The hydrologic cycle will control the strength of the flow, which means the speed or velocity of the water. The timing of the cycle is related to the seasons, and volumes of delivery of freshwater and its chemical and sediment load to coastal ecosystems will be influenced due to the capacity of the cycle (Scavia et al. 2002). There is annually 470 km^3 of fresh water input into the Baltic Sea. This corresponds to a layer of approximately 1.3 m of the shore fresh water (Vermeer et al. 1988).

The alkalinity of river water can affect its water conditions and environmental quality. In Dorset (UK), rivers with low alkalinity are found to be poor in their environmental quality, whereas rivers with higher alkalinity are found out to be of good or very good quality (Armitage et al. 2010). The water alkalinity is decreasing all over the world due to the dissolving of CO_2. In the past century, ocean water has become more acidic (pH 8.1 to 8.0). This is partly due to the river water, because of 30% more H^+ and also the dissolved CO_2 pollution (Hannah 2011). According to a UK science report on fish, temperature increase did not affect the growth in size per age of the fish population in river water (Environment Agency (UK) 2005). The annual fresh water flow is between 91–98 Km^3 in the current site, according to Ojaveer et al. (2005) (see Figure 5 for a map of the Baltic Sea). The annual fresh water flow in the Merten Talo area is significantly high compared to the rest of the Baltic Sea. The total flow in this area is high, and because of the higher movement of fresh water, the salinity of the seawater in this area is quite low. The ecosystems of the fresh water might in fact travel to the seawater because of the higher fresh water input, so their ability to survive in seawater is perhaps not limited.

Floods of both the aquatic and terrestrial parts of a river ecosystem add mineral nutrients, which contain both dissolved and particulate organic matter. There might be an increase of 1–3°C in the present century, with higher warming in the center of continents, increased evapotranspiration (but not significantly decreasing the flow), and down-stream flows are anticipated to fluctuate more often relative to base flow on an annual basis. Snowmelt has considerable effects on the river ecosystem. The spring maxima snowmelt will be reduced, the winter flow increased, and the precipitation couples with annual runoff, resulting in increased volume. In general, climate change models predict less rain (in some areas) and a decrease in frequency, but with more intense precipitation events (Wetzel 2001). The reductions in the river flows might be favorable for urban and agricultural flood control, but these would need to be considered in relation to other ecosystem use objectives such as water supply, hydropower, recreation, and more importantly biodiversity. Possibly, earlier flooding is a threat, and the increased differences between flooding and drying events increase will cause a major decline in the habitat quality of semi-permanent wetlands. There is less water, the concentration of nutrients is higher, and there will be a general decline in cleanness. There will be an elimination of fish and bird populations due to the above-described situations, and the water ratio will shift to closed basins with no open-water areas. All-in-all, climate change will add additional stress on the ecosystems of river waters.

<u>Wetlands:</u> In addition, to providing a habitat for fish and wildlife, wetlands enhance ground water recharge, reduce flooding, trap sediment and nutrients, and provide recreational areas (Schwab et al. 1996). The effects of climate change on these wetlands are salinity intrusion, dry up, a decline in peat production, a shift of the ecosystem from dry conditions to wetland areas, and an upslope growth of plants in wetlands that sometimes benefit from the salinity due to freshwater accumulation caused by hurricanes and storms. This will happen in some areas of the world where the accumulation of fresh water is observed due to storms and hurricanes. When the sea level rises, it might flood into the wetlands causing salinity intrusion and CO_2 accumulation. Both of these issues can affect the wetland and shift its ecosystems towards supporting different species or even causing death to others. It has been noticed in some parts of the world, that the dry-up of wetlands not only causes habitat loss, but also economic loss related to declining peat accumulation. Freshwater is essential for wetland peat because of the different plants needed to grow on peat soil. But because of less sediment accumulation, these plants start to grow on higher areas of organic matter, or in upslope areas causing an upslope of the plant habitat (Scavia et al. 2002; Vartiainen 1980).

The Raippaluoto area wetland is not lost, but it is protected. For further protection and the successful transplantation and re-establishment of wetlands and wetland vegetation, the following criteria must be met. Selection of suitable areas, the creation of required ecological conditions (e.g. soil, water supply, and river flow), the control of water the levels and nutrient content, protection from access by people, grazing animals and eutrophication, and a natural turf or soil selection complete with their vegetation cover (Schiechtl et al. 1994).

6.1.2 Seawater

Seawater has a higher salinity level, and its ecosystems differ from lake and river water. The Baltic Sea surface area is approximately 400 000 square kilometers, and its average depth is 56 m. The Baltic Sea water source is from its incoming rivers. The ocean salinity is 3–5 $^{0}/_{00}$. The salinity of the Baltic Sea at surface level is 3–6 $^{0}/_{00}$, and at the bottom 1–4 $^{0}/_{00}$ higher than the surface (Leppäranta et al. 1988). The effect of climate change on seawater would be a decline in the total population of planktons, temperature rise, acidification, wave height increases, sea level rise, erosion, and flooding (European Agency 2005). Salinity, sea level rise, temperature, and oxygen deficiency are the factors that affect ecosystems of the sea. This report is focused on the western aspect of the Baltic Sea, which lies between the Bothnian Sea and the Gulf of Bothnia. Figure 5 shows the relations of the Baltic Sea, as well as information on the size of the area, volume, and annual flow for each part. The red brackets in this figure show the current study area. The current area is surrounded by seawater so any changes in seawater and sea ice conditions will directly affect the site.

The seawater increase may cause flooding and erosion. The sea level is predicted to rise 15–20 cm in all seas (Climate Institute 2010), and is expected to rise 23–36 cm by 2080 (Graham et al. 2009). The global sea level will rise 9–88 cm by 2100 (Scavia et al. 2002). The concentration of CO_2 is likely to increase from 380 ppm in 2000 to a maximum level of 800 ppm in 2080 (Arau'jo et al. 2011). The IPCC forecast that thermal expansion would lead to a 15–28 cm sea level rise (+/- about 50%) and a 10–20 cm rise due to glacial and ice cap melt.

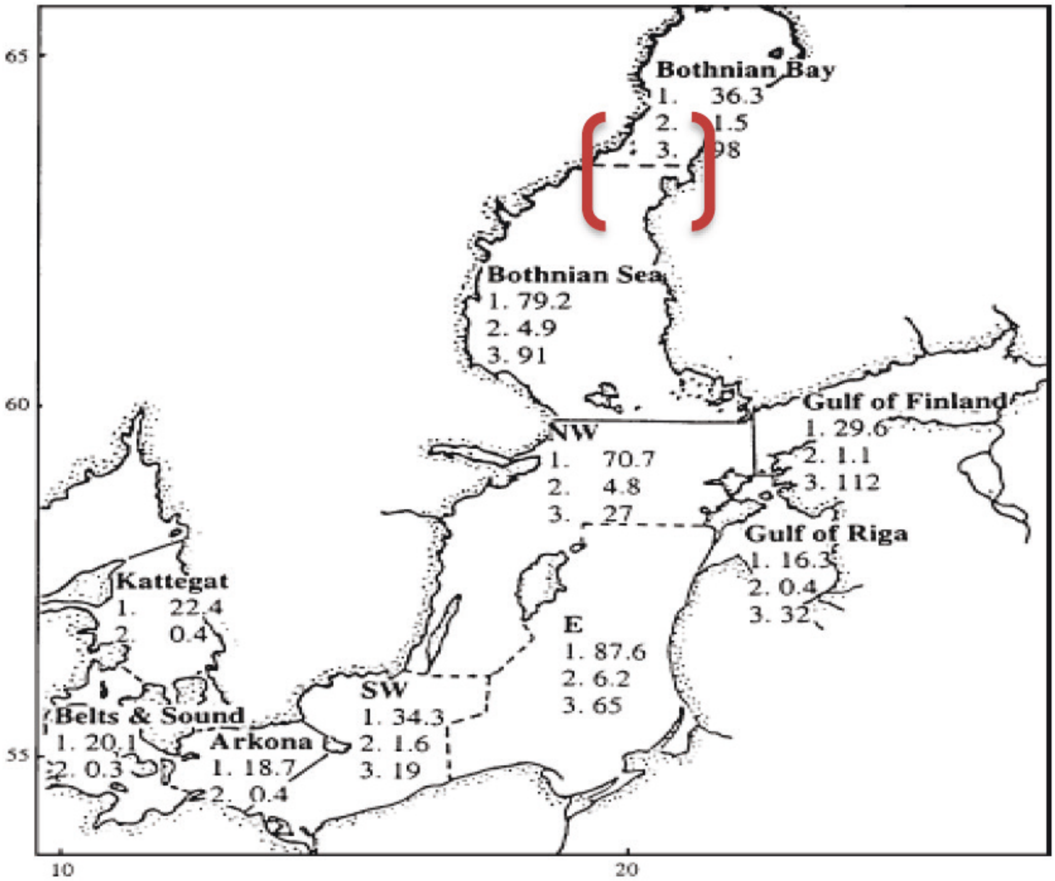


Figure 5. Regions of the Baltic Sea. 1 – Area (km^2) X 1000; 2 – Volume (km^3) X 1000; 3 – Annual freshwater in flow, (km^3) (Ojaveer et al. 2005).

The sea level rise is due to the water expansion caused by warming water (thermal expansion), glacial and ice cap melt, and the loss of ice mass from Greenland and Antarctica (Climate Institute 2010). Figure 6 shows reasons for sea level rise, including the water flow parameters and average sea level rise. The variation of sea level in the world is caused by regional differences in groundwater. This might cause the sea level to rise or fall according to the movement of seawater to the ground water, or groundwater to the seawater. When oil is taken out of the ground, it creates a space where seawater will seep into, causing a decline in sea level. The compaction of muddy soil will push ground water towards the sea, and further disturbances will be caused by subsidence, isostatic rebound, and tectonic uplift (Scavia et al. 2002). The consequences of this movement and disturbance would be floods, erosion, wetland changes, salinization of aquifers and soil, and a loss of habitat for birds, fish, other wildlife, and plants (Scavia et al. 2002). The sea level rise will also cause displacement in the population. There are around 600 million people living in coastal areas, which are at most 10 m above sea level. According to the Climate Institute (2010), 33% of the coastal land will be lost in the coming hundred years to seawater. Scavia et al. (2002) envisage that the potential of a sea level increase/rise by

50 cm will cause an economic loss between $20 and $200 billion by the year 2100. Rises of up to 100 cm will double that loss. As the sea level increases, there will also be more frequent floods and an expansion in erosion.

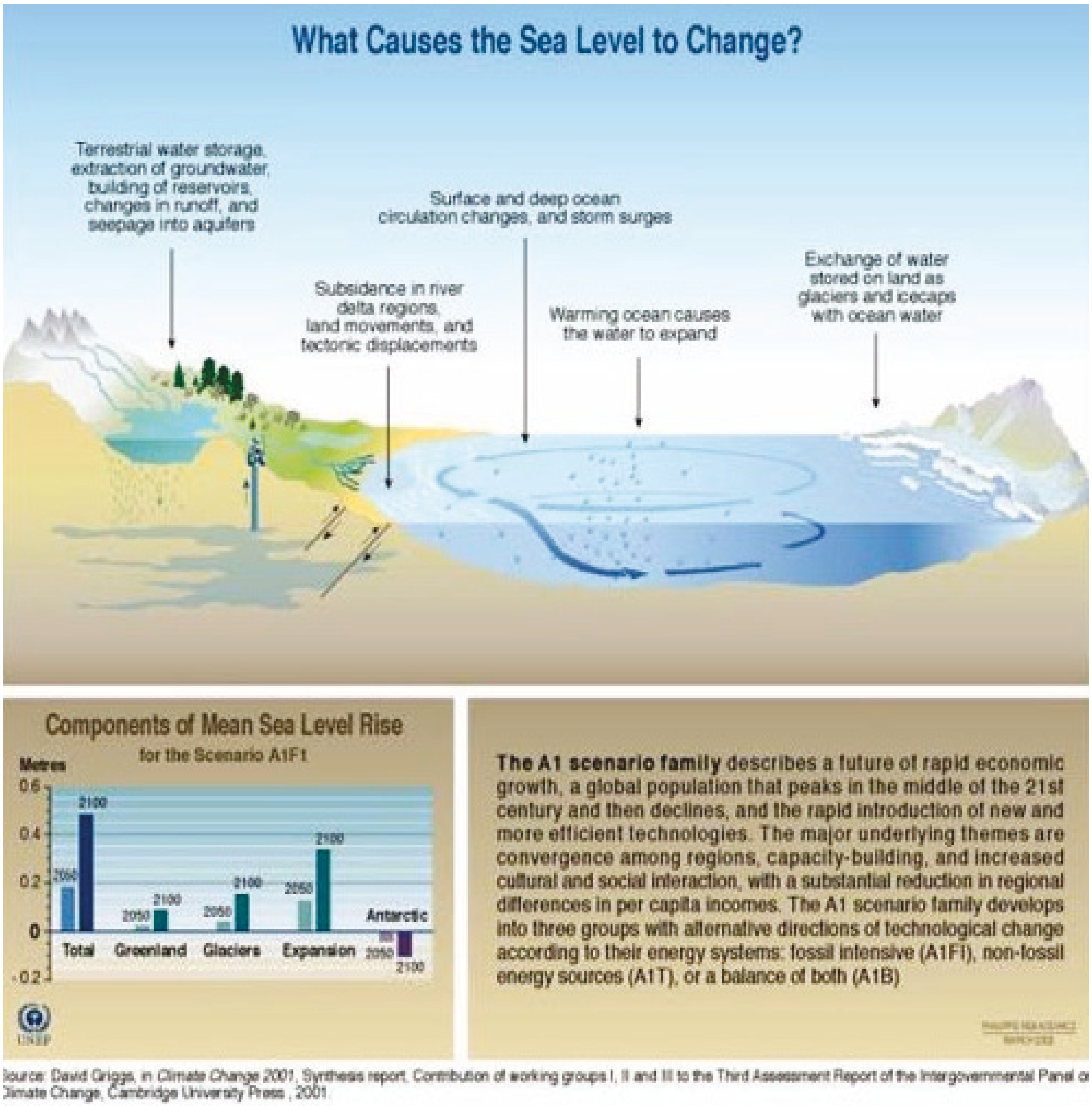


Figure 6. Reasons for sea level rise due to climate change (Climate Institute 2010).

<u>Coral reef</u>: coral reef ecosystems can be affected by climate change, and it is said that the most dangerous impact of climate change is coral bleaching leading to coral demise. The corals provide a home for microscopic algae (protozoa) - zooxanthellae that inhabit the coral cells in a symbiotic relationship. The microalgae give the coral nutrients and photosynthesis, and the coral gives a physical structure for photosynthesis. The loss of zooxanthellae will cause coral to become white or 'bleached' due to sea surface temperature increases of 1–2°C for 3–5 weeks. El-Nino events with temperature increase cause the most

bleaching in corals. Once bleached, the corals die. The bleaching is also facilitated by the pollution of the sedimentation, earlier temperature increases causing severe effects, and those disturbed by tourism are less likely to recover (Hannah 2011). Consequently, the increase of CO_2 in the water can affect the coral reef's existence (Hannah 2011).

The effective way of preventing seawater flooding to land is by building dikes, seawalls, bulkheads, and revetments. This generally sacrifices beach, wetland, and other inter-tidal zones, but they leave dry land relatively unaffected (Scavia et al. 2002). Once sea flooding has taken place and the seawater covers a shore's former area, it is hard to restore the shore to its original state. The current site is considerably affected by both the rise in sea level rise and the uplift of the ground.

6.1.3 Precipitation, erosion, floods and ground water

<u>Precipitation</u>: Precipitation is predicted to increase from current levels by 10–40 % by the end of this century (Climateguide.fi 2016), and its severity will increase. The number of hurricanes is forecast to increase by a factor of three or more in the future, and their strength may increase by 5–10 %. In addition, the sea surface may warm by 2.2°C (Scavia et al. 2002). The current site is going to be affected by storms because storms will increase in coastal areas. In their article '*Growing season precipitation in Finland under recent and projected climate*', Ylhäisi et al. (2010) conducted a study on precipitation using 13 different models for each simulation; producing a global model and a regional model centered on the south-west and north-east regions of Finland. The models used for simulation are C41-H16, DMI-ARPEGE, DMI-ECMAMS, ETHZ-HC0, ICTP-ECHAM5, KNMI-ECHAM5, METO-HC0, METO-HC3, METO-HC16, MPI-ECHAM5, SMHI-BCM, SMHI-ECHAM5 and SMHI-HC3. The global models are HadCM3Q0, ARPEGE, ECHAM5-r3, HadCM3Q0, ECHAM5-r3, ECHAM5-r3, HadCM3Q0, HadCM3Q3, HadCM3Q16, ECHAM5-r3, BCM, ECHAM5-r3 and HadCM3Q3, and the regional models are RCA3, HIRHAM, DMI-HIRHAMS, CLM, RegCM, RACMO, HadRM3Q0, HadRM3Q3, HadRM3Q16, REMO, RCA, RCA and RCA. They found that the average precipitation is increasing over time. The north-east region will have higher precipitation, and higher precipitation is also expected in the Raippaluoto area. Precipitation has inter-decadal variability, and therefore it is hard to predict its behavior and future situation. Past precipitation rates have favored crop production, but in the future, this is uncertain. The precipitation rates may increase the water flow to rivers and the sea. Household heating requirements might be decreased due to the fact that there will be less snow or long cold winters. Therefore, heating needs will decline in the future, but possible ways to generate heat and electricity are still useful.

The current rainfall level in Finland is investigated on the web pages of 'Climateguide.fi', and shows the current monthly rainfall forecasts in all coming years to range between 125–

200 mm all over Finland. Figure 7 shows the average prediction of 10, 20, 50, 100, and 500 years since 2016 of variation in the specified month. As can be noticed, there seem to be no significant changes between areas. The overall precipitation is predicted to increase in the future. Other data from the same website shows that out of eight yearly rainfall conditions of Finland, six of them show an increase in rainfall level in the northern parts of the country, which is much more than has been seen in the south of Finland.

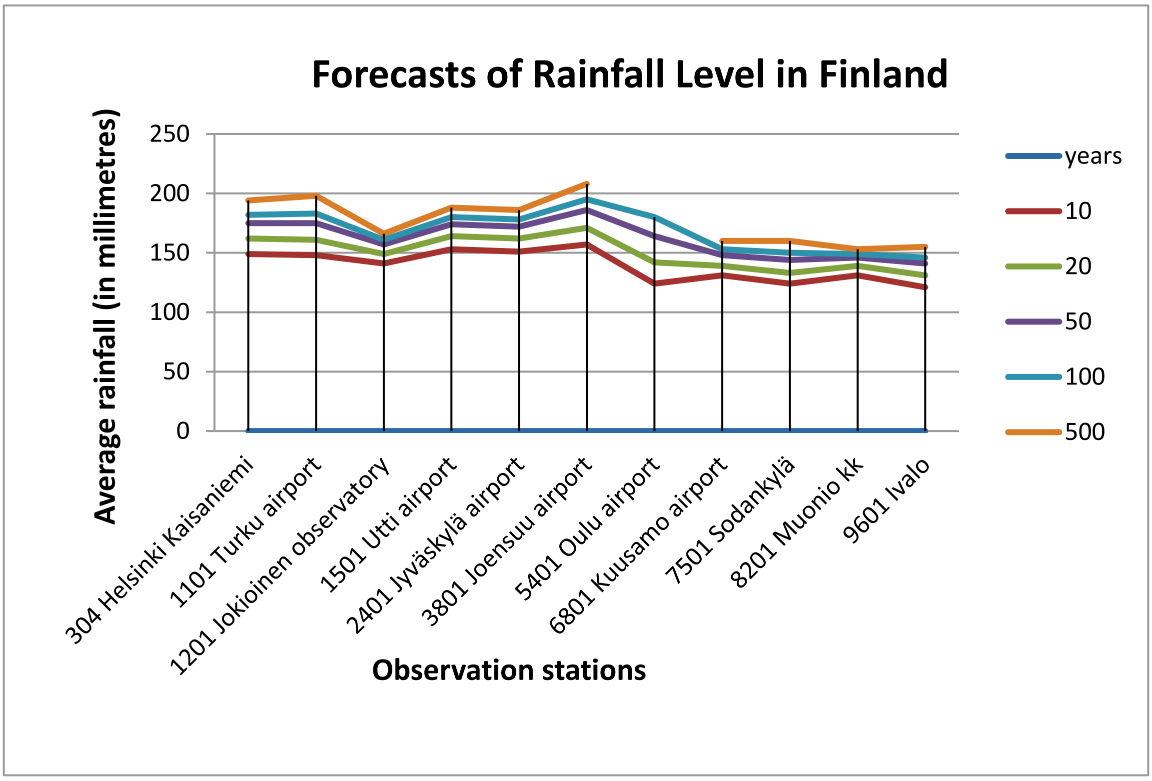


Figure 7. Future monthly forecasts of rainfall in Finland.

<u>Erosion</u>: The coastal environment, shoreline, beach, and coves will all be affected by continuing change due to natural processes. Factors affecting erosion by water are climate, soil, vegetation, and topography. Climatic factors are beyond human control. Wind and rivers bring new sediments to the shore, as well as to riverbeds and delta areas. Wind creates waves that break at the shoreline. The angle between the shoreline and the wave creates longshore currents that continuously bring new sediments to the shore. Different changes can be noticed which may be either natural or human-induced. These include: (1) changes to depth and width; (2) the speed and volume of river flows; (3) inshore and offshore currents and storm tracks (following previous conditions); (4) intensity (of a storm's effect) and duration (how long the storm stays), and these are likely to produce significant changes in sediment deposition and erosions (Scavia et al. 2002). Erosion takes place to some extent due to the flow of water from the rivers and the waves of the sea. Increases in volume, turbulence, and velocity of these two factors will increase the erosion.

Dams and flood protection can help to prevent/stop erosion. Eroded sediment can contain nutrients and particulate phosphates which can contribute to the eutrophication of the lakes and streams. Pesticide input might reduce the quality of freshwater. Two general types of erosion are geological erosion and activated erosion which is due to human and animal activities. Geological erosion may establish both soil creation and soil erosion, and maintain a balance in soil and water contact systems which is useful for plant growth. These systems can be canyons, stream channels, valleys, and deltas. Human or animal-induced erosion is caused by tillage and the removal of nutrients which facilitate breaking down soil aggregates and accelerates the removal of organic and mineral particles (Schwab et al. 1996).

According to Schwab et al. (1996), the types of geological erosion are raindrop erosion, sheet or inter-rill erosion, rill erosion, and gully erosion. Raindrop or splash erosion appears when rainwater contacts directly with a soil particle, which is then detached from the sediment. The rainwater part of the impact infiltrates the inner soil causing runoff and sediment transport from the field. Sheet or inter-rill erosion taken place during a storm. Riling takes place almost simultaneously, with first the detachment and then the movement of soil particles. Rill erosion is the detachment and transport of soil by a flow of water. The gully erosion produces channels larger than the rill (Schwab et al. 1996). There are two erosion control practices: tillage practices and cropping or vegetation management. In the current area, geological erosion is dominant, but the mixture of geological erosion types will contribute to the soil movement from the coastal areas and the island.

<u>Floods</u>: Floods cause dramatic weather challenges. The main causes of floods are sea level rise and hurricanes. Another is the ice jam, which is a blockage formed in rivers by the accumulation of broken ice. These ice jams can block the river water and cause severe flooding (IPCC 2007). Rises in sea level rise do not just cause flooding, but also contaminate the local freshwater with its salinity and microbes. Short term flooding (lasting from a few hours to several weeks) might happen several times a year. However, sudden flooding is less well tolerated than a gradual rise of the water level. Together with the Finnish rescue services, the Finnish environmental administrations are responsible for flood prevention and protection in Finland. Most of the after-flood management is looked after by a 'Regional Environment Center' (REC) and in the case of hazardous floods, regional rescue services take charge (Dubrovin et al. 2006). The flood research produced by the Finnish Environmental Institute (SYKE) supports regional authorities and supplies tools for flood prevention and protection. SYKE is also responsible for national hydrological monitoring and flood forecasting. Land use planning, which is important for the municipality at a regional level (Dubrovin et al. 2006) handles matters of flood damage prevention.

Drought: according to Veijalainen et al. (2020) result a significant impact on water resources and damage to the water supply in Finland can be caused by a severe drought. It is unexpected to hear about drought in Finland hence the nation holds a massive amount of water resources. Drought not only a risk for water security but also for energy security and food security (Veijalainen et al. 2020). Because it has a negative impact on hydropower production and agriculture based on their descriptions. Even though climate change is projected to increase precipitation in Finland, Veijalainen et al. (2020) found out that the minimum water discharge still decreased in these projections, especially in Southern and Central Finland. The Western side of Finland including the Vaasa area seems not affected by drought severely based on the above sentence.

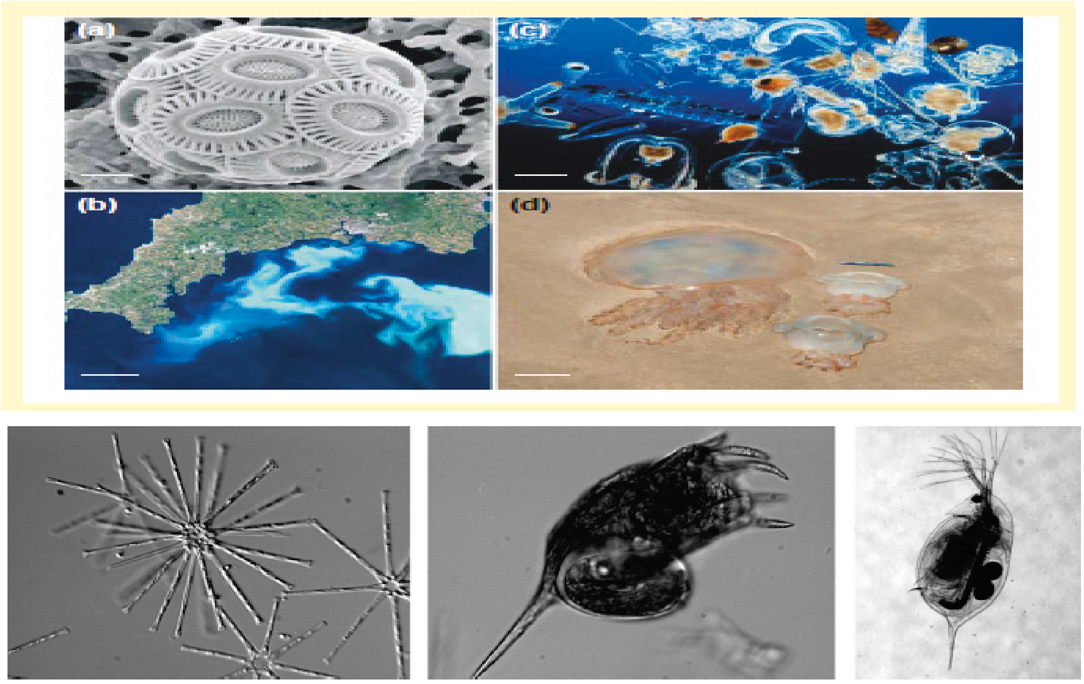
Groundwater: In the years 2014–2015, the groundwater of the region of Vaasa was studied by the author of this report [*Report on Groundwater and Aquifers in the Vaasa region*] (Girgibo 2020b). It has been determined that the Vaasa region's groundwater is confined and confirmed that it is good for public use. The expectation is that the current site has the same quality of groundwater.

The effect of groundwater in boreholes was examined in the groundwater report, and groundwater might cool the borehole in the summer time and heat it in winter in the Vaasa region. Therefore, an understanding of the ground water and its location must be achieved, in order to know the exact purpose of borehole energy storage systems, as well as to prepare for the case of a shortage of fresh water. Nearby the Merten Talo site, it is possible to pump water for household use in the case of a shortage of water. However, the aquifers near the sea might be affected by seepage, and seawater might contaminate the groundwater of the site. A suggestion in the groundwater report was that the area must be studied beforehand to find out the effect of drilling in this area. Due to the fact that the ground water is so near the surface, deep drilling might not be possible, and care must also be taken not to contaminate the ground water while drilling (Girgibo 2020b). The considered usage of proper instruments with appropriate multi-party discussion was suggested in relation to where water in the ground affects the drilling. The usage of a shorter borehole above the ground water is suggested in some literature. The protection of ground water resources from human pollution such as in times of drilling is essential because of their ecological, economic, and hydrological usages and value (Girgibo 2020b). Any contamination and depletion of ground water while drilling or by other means is irreversible, and it should be considered that some aquifers do not recharge quickly once they are depleted (Valuing Ground Water 1997).

6.1.4 Plankton community

Plankton can be either small single-cell plants or small animals. The plants are called phytoplankton and the animals as zooplankton. Plankton float in the water body, and are very sensitive to climate change. Plankton has the ability to change their depth by active swimming or due to the effect of buoyancy, but they are unable to resist the movements of ocean currents (Hays et al. 2005). The Raippaluoto area is near the shore, so the effect of currents might be one of the challenges faced because it will affect the ecosystem. Phytoplankton such as *coccolithophore* can produce calcium carbonate (calcification) which causes a higher CO_2 level in seawater (Hays et al. 2005). A clear idea emerges of the effects that the abundance, community structure, timing of seasonal abundance, and geographical spread of plankton have on fish stocks, and is widely seen (Hays et al. 2005). It is yet to see how the biota in the sea influence climate change, suggesting that the effect of biological components on climate change would be an area to investigate. The conditions monitoring biota (time-series) is one way to know more about the plankton effects (plankton caused effects on the climate change) in climate change and vice versa. It is possible to implement such time-series studies in the coastal line and Natura-2000 sites as a new research platform.

Figure 8 (taken from Hays et al. 2005; Winder et al. 2004) shows examples of marine plankton. The phytoplankton in Fig. 8 (a) is the *coccolithophore Emiliana huxleyi*, which is known for the production of calcium carbonate. In Fig. 8 (b), the satellite picture shows blooming on the cost of the UK, and Fig. 8 (c) and (d) show the meso and micro zooplankton respectively in marine water. Fig. 8 (e) shows diatom and zooplanktons that may possibly be found in temperate lake water. There is strong evidence that plankton has a big positive effect on fishery and another marine species abundance (Beaugrand et al. 2003).



(e)

Figure 8. A marine plankton community. a) *coccolithophore Emiliana huxleyi*. b) Land satellite image of a *coccolithophore* bloom off SW England in July 1999. c) Meso zooplankton, d) micro zooplankton, (G. C. Hays et al. 2005), and e) possible zooplankton and diatom to be found in temperate lakes (in order) the diatom *Asterionella Formosa*, the rotifer *Keratella cochleari* scaring parthenogenic egg, and the cladoceran *Daphnia pulicaria* with three parthenogenic eggs (Winder et al. 2004).

The number of algae blooms is assumed to increase in the future due to the increases in temperature. The blooming of cyanobacterial algae in the lakes of southwestern Finland and the Gulf of Finland will appear more often (Kanoshina et al. 2003). As shown in Figure 9 (left), the number of algal blooms has increased all over Finland. However, on the site of Merten Talo there are no algal blooms. Showing the algal concentration in our area, the blue dotes in the next map (right) can be linked to data from another page shown in the Figure 10 chart. As the chart shows, there is no algal blooming in the current site. A current task is to identify the effect of climate change on plankton. In some temperate lakes of the USA, temperatures can be seen to increase in 21 days. A long-term study in *Daphnia* population decline (Winder et al. 2004) showed that if there is enough food such as phytoplankton, then *Daphnia* populations show no response to climate change. Another way of seeing it is that these phytoplankton have less predation pressure, and can be less seen as a food source for *Daphnia* (Winder et al. 2004). However, the decrease in *Daphnia* population might still be due to a planktivorous fish abundance. The history of the USA's lakes is a good example of how the ecosystems interlink with each other, and how one may affect others in an unknown way. That is why the effects of climate change are unpredictable. In other words, an interlink between *Daphnia* and phytoplankton was expected with the expectation that the *Daphnia* would be increasing in population due to the availability of food, but this was not found, thus making predictions of climate change more difficult.

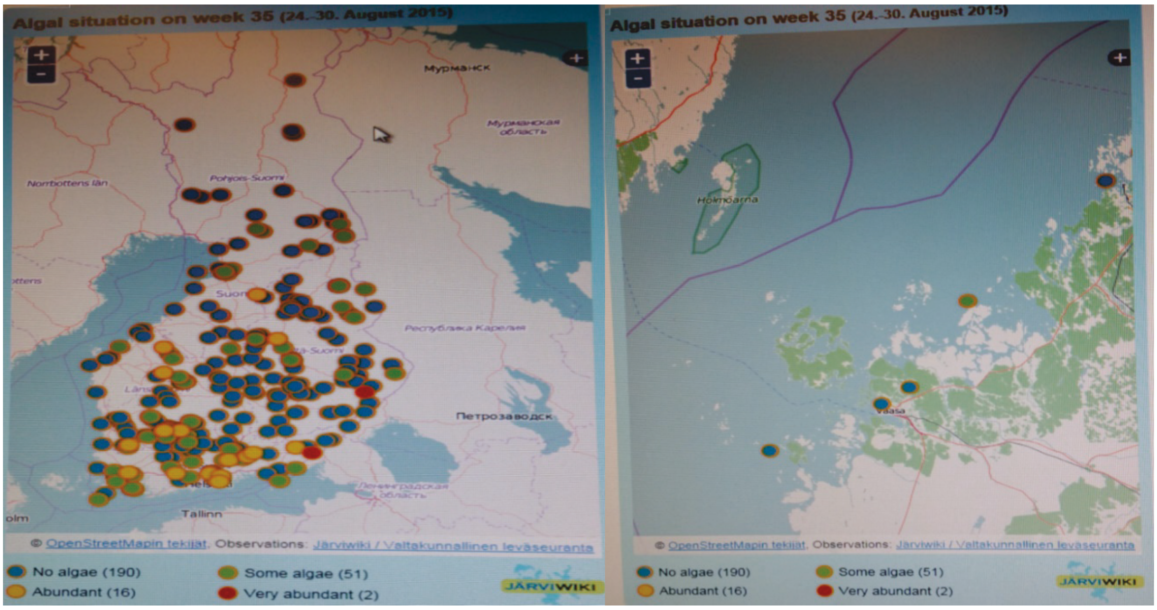


Figure 9. Algal blooms in Finland. The left side shows the overall blooming map of Finland waters. On the right side: it can be seen that in the Vaasa area there is only a very low blooming level (Lake and sea wiki (1 and 2) 2015).

Eutrophication is the enrichment of water with plants because of nutrient abundance. Eutrophication is one way that causes an increase in parasite influent (Lafferty et al. 1999). The abundance of parasites might be higher in other waters of Finland, based on a study conducted in Jyväskylä University that found that at a higher temperature there is a higher abundance of parasites. The reason for this is not only that there is more phytoplankton, but also because the water temperature increase causes a higher influence of parasites. From mussels, the outlet parasite was found to affect fish dramatically. On the other hand, no exceptional phytoplankton blooms were observed in 1994 in the Baltic Sea (Rantajärvi et al. 1995). Around 6000 known species of phytoplankton can be found in the Baltic Sea (Haecky 2000). However, approximately 250 species represent 15 classes of phytoplankton. The Arctic Ocean is the main area of distribution for some of the phytoplankton commonly found in the Baltic Sea. These phytoplankton are regarded as relics from former connections to the Arctic Ocean. Examples include *Melosira arctica, Thalassiosira baltica, Nitzschia frigida,* and *Achnanthes taeniata*, and because of their tolerance against cold and more saline waters, they grow in the brackish waters of the Baltic even during the wintertime when salinity is high and variable (Haecky 2000).

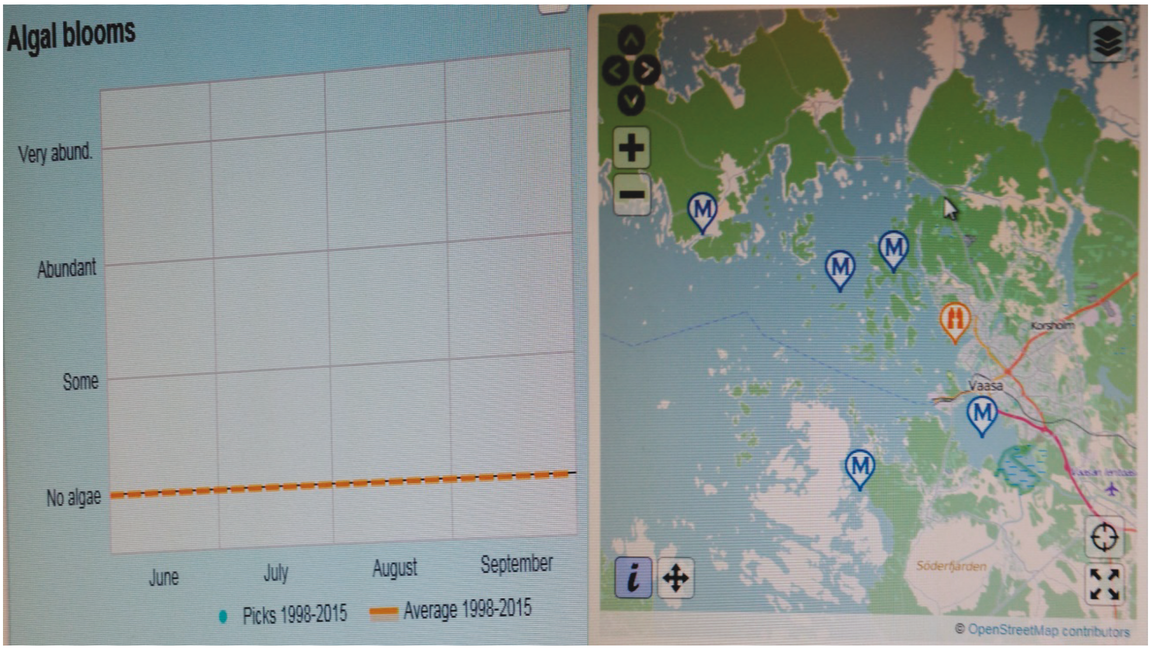


Figure 10. Algal blooms in the Vaasa archipelago. The left side shows the number of algal blooms from 1998 to 2015. The right side displays the Vaasa area with sampling sites (Lake and sea wiki (3 and 4) 2015).

The bacteria growth under sea ice is insignificant compared to open seawater growth, as the ice cover influences the temperature, salinity, and solar radiation of the upper part of the water column. Solar radiation is absorbed by the sea ice, and this reduces the availability of solar radiation for phytoplankton. In addition, it further reduces mixing in the column and affects the upper water salinity level while melting. Nutrient concentration and composition play a significant role in phytoplankton growth in the Baltic Sea (Haecky 2000 - paper III). Two species dominate the under-sea ice - the pennate diatom *Achnanthes taeniata* and the dinoflagellate *Peridiniella catenata*. *A. taeniata* had a relatively low sinking rate and *P. catenata* could counteract sinking by swimming. The sea ice is largely dominated by three diatoms: *Melosira arctica* (higher in carbon biomass under sea ice), *Chaetoceros whigamii* (not significant in carbon biomass but when the ice melts it accounts for 21% of total pelagic carbon), and *Nitzschina frigida* (Haecky 2000 - paper III). The study conducted in the Baltic Sea shows that micro-, pico- and nano-planktons would have the highest potential to photosensitize in temperatures of 10 – 20°C. The photosensitivity will decline after 25°C and these planktons show higher photosensitization in higher light radiation. Respiration also shows continuous growth as the temperature and daily light increases (Haecky 2000 - paper I). In the marine system, nitrogen is the limiting nutrient (which means that if there is slightly less nitrogen there will be no photosynthesis or other reaction). In fresh water systems, phosphorus is the limiting nutrient, which is explained by the fact that denitrification is more rapid in marine than in freshwater. In addition, nitrogen fixations (the integration of nitrogen in the synthesis) are lower in cold oceans than in warm lakes. As well, another reason may be the slower biochemical turnover in dissolved organic nitrogen than in organic phosphorous (Haecky 2000 - paper II). The 20–70% of total biomass accounted for in sea ice is dominated by sea alga. Silicate is the limiting nutrient in sea ice, which was noticed in both the Antarctic and Arctic (Haecky 2000 - paper III).

6.1.5 Fish stock

Plankton might affect the overall commercial fishery industry. The more plankton, the better the fish feed and the less the fish starve (Graham et al. 2009). Most fish, at least in their larva stages, consume zooplankton. In addition, some adult fish (e.g. mackerel *Scomber Scombrus*) continue to be planktivorous (consume plankton). In the Peruvian coast (an area impacted by ENSO (El Niño Southern Oscillation)), the recovery of the fish population can only partly be explained by the comeback of meso-zooplankton abundance. These kinds of effects are also possible in our study area if there is phytoplankton or zooplankton abundance. If blooming occurs, it will increase the fish stock for farm and trade use. If no blooming occurs, the negative effect is likely to be due to temperature inclination, oxygen change, and salinity. Long-term changes in plankton populations can have stable effects on the fish stock in this area. This means a constant growth if the plankton blooms for long periods, or a loss in stock size and type as the plankton declines. Major changes in fish communities can be expected during the next 50 years, and this will increase the need to adapt fishery and water management strategies accordingly (Graham et al. 2009). Temperature decrease will slow the metabolism of fish, and higher temperatures will increase metabolism. The effect of temperature varies in fish populations, manifesting in changes in its physiological and biochemical rates, for example, enzyme activity. In physiology, gonad damage occurs in higher temperatures, and death rates increase in fish at 14 ^{o}C most probably happens too in temperate fish. Temperature also influences behavior like breading activity and food uptake rate. Temperature variations influence almost all aspects of physiology and ecology, for example, the hatching and development of eggs and larvae), activity, oxygen demand, swimming performance, distribution, growth, maturation, immune function, the phenology of migration, foraging rate, production, reproductive success, the availability of prey, predation risk, and mortality (Graham et al. 2009). The inspected data along with historical analysis of spring samples show that for an elevated temperature, any prolonged or long-term exposure could cause very serious gonad damage, inhibiting successful spawning, and the sensitivity to cool water exposure depends on the pattern of ovarian development (Lukšienė et al. 2000).

The environmental factors affecting the fish community are cloud cover, ultra-violet (UV) radiation, sea and lake levels, storm surges, hydrographic regimes in estuaries, precipitation, runoff, wind intensity and pattern, evaporation, and river and stream discharges (see also Figure 2 for aquatic system environmental factors) (Graham et al. 2009). The response of the fish and other taxa (species) to climate change is further influenced by changes in temperature and other biotic factors likely in result changes in inter-species interactions (e.g. predation, competition, and parasitism) (Environmental agency (UK) 2005). Fish body temperature is quite dependent on the surrounding water temperature, and therefore the climate change effect on water temperature can highly influence the fish body temperature and other factors. The influence on growth and maturation is much more difficult to predict (Environmental agency (UK) 2005), and it is not known why fish gametogenesis can be damaged by exposure to higher than normal temperatures (Lukšienė et al. 2000). According to the (Environmental agency (UK) 2005) science report, an effect of climate change in Salmon fishery was found. Contrary to expectations, there has been no higher size per age caused by warmer river water in the past 20–40 years. This can be explained by the fact that the higher temperature causes metabolism increases that cause the fish not to store more food so that the growth will not be positively affected by the increase in river water temperature. Based on a match-mismatch hypothesis, the survival of the larvae fish depends on its ability to encounter and eat a sufficient amount in order to avoid possible starvation and to allow it to grow (Brander 2001).

In the future, the climate will favor meso-thermal and eury-thermal fish. These species will extend living areas and increase their growth and production, assuming that other limiting factors (e.g. the availability of food) are not affected. To increase the sustainable use of marine resources, the exploitation of fish via both wild capture and aquaculture will be affected by climate change. Adaptation strategies that e.g. target and culture new species should be developed (Graham et al. 2009). The higher water temperature may mean a higher parasite rate in fish populations (Lafferty et al. 1999). In a study conducted at Jyväskylä University, it was found that at a higher temperature (even an increase of 2^{o}C), the number of parasites expressed from mussels (e.g. *Anodonta anatina*) is much more. This means that the more parasites are in the water, the more chance there is that they will become attached to a fish’s body. The other finding of the VACCIA (Vulnerability Assessment of ecosystem services for Climate Change Impacts and Adaptation) report published by the same university is that at higher temperatures, the more chance that the fish embryo will develop defects in its body while growing. The mortality for fish at 14^{o}C has been supported by literature (Guma’a 1978). The expectation of higher temperatures would affect fish stocks in many ways, and their ability to grow without defects or experience shortages of food will likely be emergent issues.

Marine species and their spatial distribution have been seen to decrease in conditions of lower salinity. At higher salinity, higher yearly abundances of sea herring, flounder, cod, and other late immigrants (which probably colonized after the Ancylus lake stage in the Baltic Sea) have been observed. The Baltic Sea currently has the second lowest salinity compared to other seas (Ojaveer et al. 2005). Dab and Plaice are the only fish species able to reproduce in the western and southwestern parts of the Baltic Sea. The western area has a slightly higher salinity and oxygen concentration; however, these fish cannot reproduce in eastern and northern areas of the same sea. Flounder can reproduce up to the level of the Bothnian Sea (west). Less saline waters may cause a decline in marine species, so the fish population will decline in the Baltic Sea. Autumn herring, flounder, turbot, greater sand eel, and sand goby are not able to reproduce in the Gulf of Bothnia, but sprat, cod, four-bearded rockling, plaice, and dab can reproduce in the Gulf of Bothnia, and it is the most reproductive area of the Baltic Sea. The ability to adapt to changes in salinity/oxygen conditions is achieved through the regulation of the specific gravity/egg diameter in species with a floating ability (Ojaveer et al. 2005). Cold-water species are pikeperch, perch, and roach, whereas warm water species include sea-spawning whitefish (Beamish 1995).

A decline or collapse in population might occur under levels of overexploitation that would otherwise be sustainable under more favorable conditions due to environmental change, but climate change also creates unfavorable conditions. Environmental factors must be seen and managed together with their interactions, and strategies adjusted accordingly (Scavia et al. 2002). The average preferred temperature for fish varies from one sea to another, in a range of 2–11°C. NAO (North Atlantic Oscillation) affects fishery production, not only for the fish we want but the total variety population (Brander 2015). Moreover, existing variabilities in Europe in fish larval concentrations (P<0.01) of up to 70% due to zooplankton biomass, temperature, and freshwater flow can be explained with water temperature and zooplankton biomass. While these are the most significant factors for fish growth, in the study of Lara-Lopez et al. (2008), salinity, in contrast, was not significant either spatially or temporally. In both mesohaline and oligohaline zones, the same patterns of fish larvae following zooplankton biomass were observed in European and South African regions. This is reliably explained by the water flow increase (1 month after peak freshwater flow and its association with an increase in nutrient and phytoplankton productivity following the freshwater input), causing an increased availability of food in the water and also higher average temperatures (15°C). It can be said that this reflects the influence of temperature on larval recruitment and seasonal fluctuations of zooplankton populations, and the temperature has a much more significant effect than freshwater flow (Lara-Lopez et al. 2008).

6.2 Changes in environment

Environmental changes are other aspects affected by climate change. The description given here is short and precise, focusing on the aspects of wind, temperature, and soil.

6.2.1 Changes in climate conditions and the temperature

The wind energy industry impacted the ongoing climate change (in most areas declining in capacity in wind power and some areas increasing capacity) by changing the inter-and intra-annual variability of wind resources and their geographical distribution (Pryor et al. 2010). The global wind power decline can exceed 15 % per century. On average, 5–15% declines are observed to cause a hotter environment. It is possible that there might be higher wind flows in some areas of the world (Barton 2014). Winter duration, air, water temperature, and the surrounding temperature can be affected by wind power. If it increases, it will benefit wind power plants. Water temperature varies less than that of air temperature (Environmental agency (UK) 2005). Winds have dominated and caused differences between the western and eastern coasts of the Gulf of Bothnia, and thus can affect the water temperature (Beamish 1995). With some areas becoming ice free, this means that when the ice melts or no ice accumulation occurs, this will lead to a wind energy increase. In the Gulf of Bothnia in the northern Baltic Sea, sea ice days are predicted to decline from 130–170 days to 0–90 days in 2071–2100 (Pryor et al. 2010). This prediction leads us to conclude that the winds in the Merten Talo area are also predicted to increase. The surrounding temperature is affected by evaporation, precipitation, water temperature, plant coverage, humidity, typology, sun exposure, cloud cover, GHG, CO_2 emissions, and other related factors. Thus, global warming is causing the surrounding air to be warmer.

Urban areas with more compacted city structure they can cause urban island effect. Urban island effect is the temperature in city areas became warmer than those of rural areas. The city of Vantaa change in its climate was studied in terms of weather parameters such as temperature, humidity, wind speed, and precipitations done by Saranko et al. (2020). Urban island effect causes temperature increase by 0.5 – 1 ^{O}C both in January and July in the city of Vantaa influenced by the urban morphology, the same article states that. Lakkala et al. (2020) study climate change by measuring UV (Ultraviolet) change and comparing them in different places. CO_2 was found out to be the largest climate response emission gas in the Finnish atmosphere along with CH_4 and BC (Black Carbon, affects mainly in winter), both of these gases have relatively significant warming impact in winter and less impact in summer (Kupiainen et al. 2019). These gases influence global warming by causing and facilitating the greenhouse effect. Based on Kupiainen et al. (2019), mitigation of carbon dioxide is crucial in reducing Finnish emission climate impact. Doing so helps reduce mainly global warming on a world scale. Cooling can be caused by some the gases such as ammonia (NH_3), which is generated mainly from agriculture (Kupiainen et al. 2019). Forest management is crucial in managing the influence of climate change in the forest industry, which is affected by the CO_2 concentrations in the atmosphere (Mäkelä et al. 2020).

6.2.2 Soil

The soil can become waterlogged and saline due to the seawater. Soil loss decreases the production capacity of the land. Soil and other natural resources have been exploited for a long period of time (Schwab et al. 1996). Soil surface management reduces erosion by wetting (wetlands) and drying (dams). Vegetation and cloddy conditions are a way to avoid wind erosion. Tillage (the activity or process of preparing land for growing crops) must be done as soon as it rains. Tillage, when the soil is dry, may break up the surface crust or crust clods leading to a more erodible surface. Such tillage can also cause surface drying, which is affected by wind erosion. Under higher erosion, tillage can expose less erodible, damp clods on the surface, thus decreasing soil erosion and increasing soil roughness (Schwab et al. 1996). This is not allowed in Merten Talo because it is a nature conservation area. GHG and methane can sometimes be created from soil. This happens when plants and leaves decay in the soil, accumulating carbon in the soil that will then will be released by evaporation.

The soil consists of the surface, the topsoil, the subsoil, and the parent material (Soil for Schools 2016). Pollution can be prevented by soil because it filters pollutants by nature, and the microbes of the soil will break down harmful substances like pesticides. The soil functions can be described as follows.

<u>Soil and economy</u>: Farming is the way most economies function in developing nations. Therefore, the soil contributes much as an economic tool. Organisms in soil: As mentioned earlier, soil filters pollutants and is a living place for a variety of creatures. A spoonful of soil contains over 4 billion microorganisms. Some of the microbes degrade pollutants and some degrade minerals to free up nutrients for plants. Soil and water: Infiltration and percolation are the steps of water movement in the soil. Soils have the ability to minimize the causes of flooding by nature. Soil pollutant control: The soil filters pollutants. Soil and archelogy: This benefit is the preservation of historical objects. Hence, as the soil has very little oxygen, less decomposition occurs and the soil acts as an information source to reconstruct past environments.

7 THE MICROCLIMATE AND ITS RELATION TO CLIMATE CHANGE

This section is mainly referenced from Hogan (2010). "Microclimate is a set of meteorological parameters that is characterized a localized area" (Hogan 2010). Involved factors are surface temperature, relative humidity, wind speed, solar insolation, and precipitation. A microclimate appears/exists in areas with size from one square meter to 100 km^2. Natural environmental factors for a microclimate are topography, sun angle exposure, latitude, soil type, vegetation cover, as well as other meteorological factors such as cloud cover, regional precipitation, and high-altitude wind characteristics. Topography, vegetation cover, and the type and density of vegetation are the most important factors for the microclimate. The microclimate also affects air pollution dispersal, noise pollution, thermal pollution, and other environmental factors (Hogan 2010). Understanding its impact upon habitat and biodiversity is important because plants and animals are mostly affected by microclimate factors. In addition, it has a big impact on agricultural output and on human comfort.

Microclimate relationships to climate change: There are two different relationships. First, the measure of climate change on the world and local scales is dependent on data acquisition in the microclimate settings. Second, the impacts of climate change differ on proximate locals with relation to their differing microclimate, meaning that the impact of climate change depends on the type of microclimate observed (Hogan 2010). The microclimate influences major ecological processes such as production, mineralization, and the spread of disease, insects, and natural distribution of phenomena and events (e.g. fire outbreaks). On a broad scale, roads can also influence microclimate and other landscape features at more than a 100 m resolution.

8 ADVANTAGES OF CLIMATE CHANGE FOR ENERGY USE

What are the energy usage methods that may be used to extract renewable energy in the Merten Talo area? The possible seaside renewable, advantageous energy alternatives would be:

- UTES (underground thermal energy storage)
- ATES (aquifer thermal energy storage)
- BTES (borehole thermal energy storage)
- GEU (groundwater energy utilization)
- Water heat exchanger in the sea
- Wind energy
- Solar energy
- Asphalt energy

UTES: underground thermal energy storage system. These are energy alternatives based on thermo-geology and the energy below our feet in the soil. There are energy sources that are a part of our earth system. UTES can be classified as an open or closed system. Open systems can be ATES (aquifer thermal energy storage systems) which use an aquifer as an energy source. The closed BTES (borehole thermal energy storage system) uses circulating coolant under the soil to gain a higher temperature so we can later extract the heat. Climate change is advantageous to both open and closed systems because the soil temperature is rising as the surrounding temperature is increasing. These systems can also be used for cooling purposes.

ATES: aquifer thermal energy storage system. The aquifer underground is higher in temperature than the surface temperature. The effect of environmental temperature on groundwater/ aquifers only affects until 14–16 meters of depth, and after that depth, the environmental temperature change has no effect on the ground temperature. Due to climate change on the ground, the aquifer is therefore expected to be at a higher temperature if it is not too deep. The system is to pump water from an aquifer that is higher in temperature to the surface, then extract the heat using a heat pump or heat exchanger, and then return the water to the aquifer in a different location. The water will remain in the soil until it recharges, and is then pumped again to extract the heat energy. The current global temperature is rising so that the aquifer temperature is expected to increase and thus increases our chance to get heat energy from aquifers. The process can be used for different purposes such as household heating systems or district heating systems. It is applicable all over the world, and Sweden is the leading country in the usage of UTES.

BTES: borehole thermal energy storage system. This system is used to heat water or coolant using the heat developed in the soil. The ground is at a much higher temperature than the surface temperature. By circulating the coolant or water in underground pipes around 2 m deep, the heat of the soil can be collected or harvested, then delivered to the surface by a heat pump or heat exchanger. Therefore, we can collect and use the heat energy from underground. There are a different kinds of borehole tubes, such as horizontal slinky (coiled types of tubes) and normal straight tubes that are vertical. The slinky type is said to be much more efficient and there are different kinds of slinky tubes that can be applied for this purpose. It is also possible to store energy in this device.

GEU: Groundwater energy utilization is a way of extracting or gaining heat energy from groundwater. From one area, warm groundwater will be pumped to the surface. The heat will be utilized by a heat exchanger, then the cool water will be dumped in another location where it is kept for a while waiting for heat recharge for future use, A more detailed explanation, and illustration can be found in Arola (2015) and Girgibo (2020b).

Water heat exchangers in the sea: Installing the water heat exchanger under the seawater (at least 4 m deep), the seawater heat is pumped to the house using heat exchanger fluid. This can be used for cooling in summer time and heating in wintertime. For this system, the current climate change has an advantage because of the fact that the seawater temperature is increasing, and it is expected to stay warm for longer periods of time in the future.

Wind energy: Wind turbines can be used to collect wind energy from the surrounding environment. There is a possibility to implement a wind turbine in the 'House of the Sea' area. Climate change has increased the wind patterns in some areas (including the Merten Talo area) (Brännbacka 2015), but less windy conditions are expected on a world scale (Barton 2014). Wind turbines can be implemented in open sea or ocean, or also on land.

Solar energy: Solar energy is collected using solar collectors (heat) or solar panels (electricity). The summer time in northern areas is sunnier (longer time/day) than in southern areas. In addition, there is an expectation due to climate change that as a sunnier and warmer environment evolves, it will become more effective to install solar energy devices. It has also been discussed how the roofs of buildings can be used to install solar collectors. Moreover, solar heating for water can be stored in borehole storage systems for future use in connected systems, and this is planned for the Merten Talo site.

Asphalt energy: Generally, black objects absorb solar energy and white objects reflect the radiation back to the atmosphere. The asphalt energy system collects the heat from under the asphalt. The possibility to retrieve heat energy from this is quite obvious, and it is possible to implement an asphalt energy system in the present area. But in Merten Talo, the extent of the asphalt is not that much, so the use of an asphalt energy system might not be practical. In addition, the rocky area near the building door might pose a difficulty to install an asphalt energy system.

Demonstrative energy: there are also several types of ‘fun experience’ planned for the site in the form of energy demonstrations. These include, for example, self-producing energy, knowing the force of the wind, visiting animals virtually, human beings as a heat source, automation and energy consumption, energy contour simulation games, ice change videos, the art of transparent solar panels, the change of landscape throughout the year, and contact react pike. These will be demonstrated in the exhibition housed in Merten Talo.

9 REGIONAL RENEWABLE ENERGY SOLUTIONS FOR THE FUTURE USING CLIMATE CHANGE AS AN ADVANTAGE

This section deals with different kinds of new energy solutions for the future. These energy solutions utilize climate change effects as an advantage. These have possibilities to be implemented in the city of Vaasa, and some might also be used in the Merten Talo project. Using climate change effects as an advantage perhaps seems suspicious because we always hear about the damaging effects of climate change. For sure, it is true that the bad effects of climate change are massive. However, the idea of using climate change as an advantage mainly focuses on utilizing the water and ground temperature increase caused by global warming as a heat energy source. Three of the next described energy resources (Water heat exchanger, ATES (Aquifer thermal energy storage systems), GEU (Groundwater energy utilization)) use this existing water and the ground temperature increase as an advantage. This results in efficiency and capacity increases in these energy resources due to the global warming effect. The European Union's commitment to using renewable energy as future energy sources is promising and has led towards implementing systems and conducting related projects now, as well as in the future. When using these renewable energy solutions, climate change effects are not used only as a resource, but also contribute to combating climate change. These renewable resources are not producing air pollution or CO_2 emissions. Replacing one fossil fuel method with renewable energy resources will reduce the current level of emissions, and will contribute to combating the main cause of global warming; namely the greenhouse effect.

9.1 Water heat exchanger

The first new energy resource described here is the water heat exchanger, which has been developed by the Finnish company GeoPipe. The product’s name is the WHCEP-MINI 9.6 kW water energy exchanger (*vesistöenergiavaihdin*). This is a new water heat exchanger that utilizes the thermal energy of water bodies (lakes, rivers, and sea). This water heat exchanger has an energy capacity of 9.6 kW. The plastic tube is made of PE100 (polyethylene) plastic, which will not break due to freezing. Compared to stainless steel, the conductivity of the plastic is very low. The plastic type is made from the same graded material as the waste water system pipes used under water bodies, and there is no contamination problem to the ecosystem from this equipment (GeoPipe 2016).

Figure 11 shows the water heat exchanger that was planned in the past to be installed in Merten Talo. After installation, due to disagreement with the project owners, now this equipment has been lifted up from the sea and brought to the University of Vaasa at the current time. The total length is around 109 m and the gap between the circular sections is 40 cm. An installation depth of 3 m is the minimum recommended for use (the recommended depth in the Baltic Sea is around 4 m). The reserve is about 60 cm when the water surface varies by up to 100 cm. The diameter of the sweeper is about 130 cm. The water from the water bodies passes through the sweeper where water or a water-ethanol mixture circulates inside the tubes to extract heat from the water passing outside in the big circular section. Possibly, a heat pump can be installed along with this instrument to collect heat directly from the exchanger. This water heat exchanger can be used for both heating/cooling purposes. Usually in Finland, heating is required in winter and when necessary can be used for cooling in summer. Figure 11 shows the water heat exchanger for the Merten talo project.

Figure 11. Water heat exchanger planned to be installed in the Merten Talo area [photos taken by the left picture Nebiyu Girgibo (19.09.2017) and the right picture Anne Mäkiranta (29.11.2017)].

One of the reasons to use this kind of water heat exchanger is to use the effects of climate change which have caused water temperatures to increase, to an advantage. The temperature increase due to the global warming effect of climate change can offer benefits in terms of heat extraction capacity and availability, especially when there is likely to be less ice on top of the water body in the future. When the temperature of the water is expected to rise, it means that more heat energy can be extracted using water heat exchangers.

9.2 Wave energy

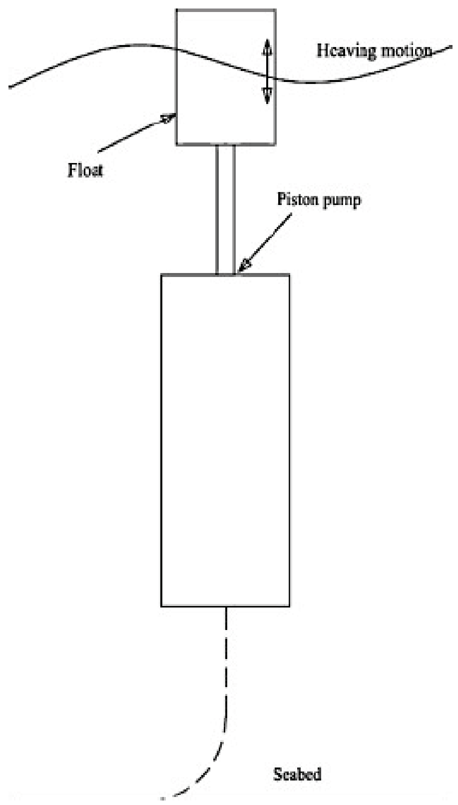
Wave energy is a renewable energy resource that has not been explored to any wide extent (Bernhoff et al. 2005). According to Bernhoff et al. (2005), wave energy mainly focuses on open waters. However, a large portion of potential wave energy resources are found in sheltered waters and calmer seas, and these usually exhibit a milder, but still steady wave climate. The potential of wave energy is estimated to have similar economic potential as wind or hydropower (10000–15000 TWh), and can afford energy security in the archipelago and coastal areas (Heino 2013; Bernhoff et al. 2005). Wave energy is one of the energies generating systems that can take advantage of climate change effects. The decline of sea ice in water bodies creates open water. This creates an opportunity for utilizing wave energy throughout the year. There are already companies working with wave energy on a big scale such as Waveroller (located in Portugal and connected to a grid), and Wavepower. From wave energy production, the Baltic Sea is a promising water body having an economic potential of 24 TWh of energy (Bernhoff et al. 2005). The Baltic Sea can contribute to future renewable energy production by wave energy. The city of Vaasa is a potential area for such installations and the utilization of wave energy. However, areas such as northern Europe will derive greater benefit from wave energy due to their high winter electricity requirements.

In addition, to a lack of emissions and the large capacity of the resource, wave energy has several other advantages. Compared with solar and wind energy, wave energy has a higher energy density and more occurrences that are readily predictable. In winter when storms are frequent, wave energy produces even higher power. Wave energy is predictable for one to two days in advance because of satellite measures. This predictability will allow less spinning reserve, which is commonly required to support more intermittent renewable energy resources (Heino 2013). However, the environmental impact of wave energy plants should be carefully investigated before implementing large-scale systems (Bernhoff et al. 2005), and a site feasibility study is therefore required. Any installation in shallow areas must be avoided because it can cause biological growth to occur on the equipment, and with strong waves, the sediment might cause problems in the function of the equipment (Heino 2013). Hexagonal types of wave energy equipment are much more efficient, and this must be considered when choosing an instrument (Bernhoff et al. 2005). In addition, Heino (2013) notes that due to the climate change effect, some areas of the Baltic Sea will become totally ice-free, which is advantageous for wave energy.

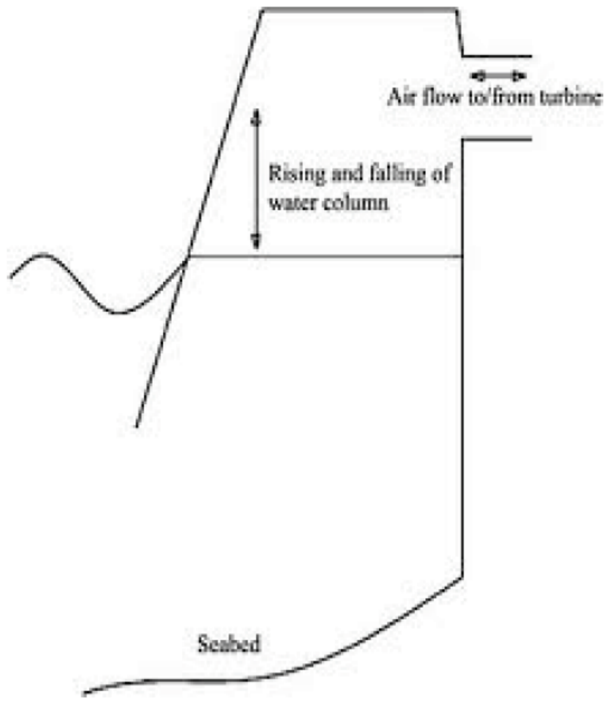
There are different types of wave energy technologies for collection systems. According to Heino (2013), wave technologies can be categorized into six different devices.

a. Point absorber: This is a device located on the surface of a wave water body (see Figure 12(a) below for an illustration of the Wavebob point absorber). Its area is smaller compared to the length of a wave. It is floating and the upper body oscillates and moves up and down with the influence of subsea pressure. It can possibly move in all directions. Energy production is based on transforming these movements against some kind of resistance. This can take different forms depending on the configuration of resistance, based on the power take-off and the type of device-to-shore transmission (Heino 2013).

b. Oscillating water column (OWC): According to Heino (2013), an OWC comprises a partial structure forming an air chamber, with an underwater aperture. The system is run by air pressure compressed in the closed space of the air chamber of the aperture. As can be seen in figure 12 b, the enclosed air is compressed when the wave is higher. That leads air to be pumped into the outlet, which is connected to a turbine. At the time of lower waves, the outside air is drawn back into the empty space through the turbine.



(a)



(b)

Figure 12. a) The Wavebob point absorber; b) Sketch of an oscillating column wave energy converter (Heino 2013).

c. Flap/surge devices: These types are designed to be situated at the shoreline in shallower water, because of conditions where the circular movement of water particles takes place in deep water then become elongated into horizontal ellipses (surge) (Heino 2013). The energy is gathered from the horizontal to-and-from movements of water particles within waves. This is a fairly recent advancement, where wide flaps are used that pivot about a rotor and use the wave movement to drive a piston pump to generate energy (Heino 2013). See Figure 13 for an illustration.

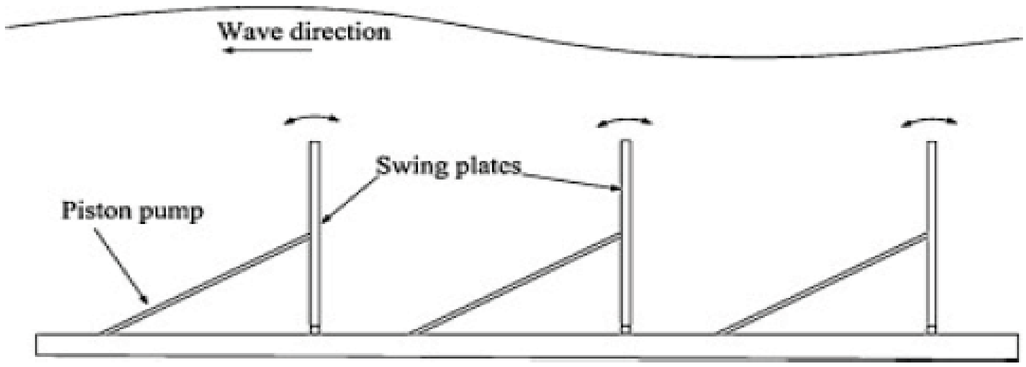


Figure 13. Drawing of the Wave Roller system (Heino 2013).

d. Attenuator/contouring devices: These devices effectively 'ride' the waves, and the instrument uses elongated floating devices that extend parallel to the wave direction (Heino 2013). Movement within the device is generated when the incoming wave passes along the device (see Figure 14).

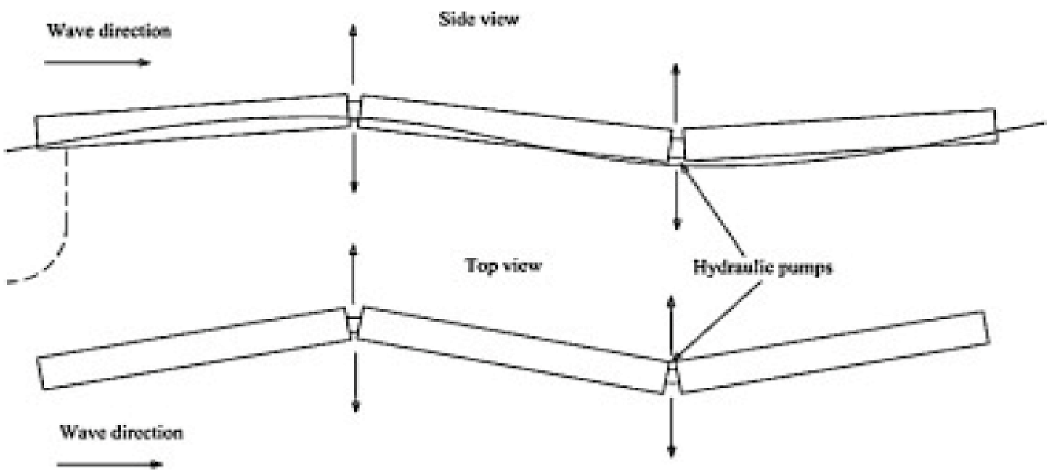


Figure 14. The Pelamis wave energy convertor attenuator device (Heino 2013).

e. Overtopping devices: Part of the incoming water is elevated above the natural height by using a ramp on the device. This helps to fill a raised reservoir. From the reservoir, the seawater is allowed to return to the sea through a low-head turbine. Figure 15 shows the Wave Dragon overtopping device.

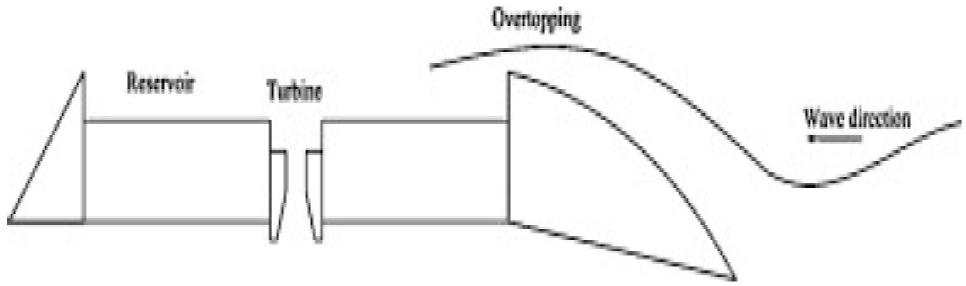


Figure 15. Drawing of the Wave Dragon overtopping device (Heino 2013).

New forms of deep-water wave energy utilization (similar to the Surge device explained above)

In Turkey, Wärtsilä has installed new deep-water wave energy utilization equipment. The system has been installed under water and transfers ground ocean wave motion into electrical energy. The equipment test was done in Portugal in 2012–2014. The size of the equipment is 10 m high and 18 m wide. This seems to offer a promising new technology for converting deep-water wave energy into electrical energy (Yle news 2017).

9.3 ATES (Aquifer thermal energy storage systems)

ATES is an open type of UTES (underground thermal energy storage systems). In this system, open aquifer water is used as a thermal energy source to utilize the aquifer water temperature for household and district use. The aquifer water can be pumped to a household heating system, and after heat extraction, it can be dumped in another location a considerable distance away from the pumping point. The process helps to mix the now cold water with other aquifer water so that it will recharge for the next circulation at the new dumped location. The use of ATES is described in the groundwater report of Girgibo (2020b). ATES usage is not new as an energy resource and has been utilized well for many years, for example in Germany (Girgibo 2020b).

In aquifers, water is trapped underground between rooks and faults. This water is readily available and has a higher temperature than the surrounding environment. There are confined and unconfined aquifer systems. A confined aquifer is composed of material hanging between layers of aquiclude or aquifuge. An unconfined aquifer is composed of the saturation layer formed by the water table upper surface and aquifers partly filled with water (Girgibo 2020b - see also Figure 2 in the same paper). During the drilling process, when installing ATES or other underground thermal energy-systems, care should be taken not to contaminate the underground water systems.

ATES are useful in areas where there is a possible high temperature aquifer close to city centers. Currently, it is quite common to connect households to private heating systems such as underground heating systems or ATES as an energy resource and makes the households self-sufficient. ATES systems are much utilized in Sweden and are considered to be the future renewable resource. As well, climate change effects or global warming that causes groundwater to be at a higher temperature, make this system worth considering as a thermal energy source for the future. ATES systems can be utilized in the city of Vaasa as well in the Merten Talo area. This is one of the energy systems that will probably be proposed in dissertation work conducted at the University of Vaasa, Electrical and Energy Technology Department by Nebiyu Girgibo.

ATES is very similar to GEU (groundwater energy utilization) systems - see section 9.4 of this report. In ATES, the system uses aquifers as a heat energy source, whereas GEU utilizes groundwater energy for heating or cooling purposes. These systems (among others) can be suggested for use in the city of Vaasa area. Another connected idea is to use aquifers or groundwater to heat up borehole systems due to the natural heat convection from the sounding groundwater systems to the borehole. This type of heat storage has been illustrated in the conference conducted in the city of Turku, Finland about borehole systems and other possible underground heat storage utilizations.

Overall, these five energy resource systems (water heat exchanger, wave energy, ATES, GEU, and vertical turbines) are promising renewable resources, that can also be used as seaside energy solutions.

9.4 GEU (Groundwater energy utilization)

GEU is an open-loop energy system, where groundwater is used for household or district heating purposes. The groundwater is pumped from one location and after the heat is exchanged, it will be dumped in another location for recharge. Arola (2015) has studied this system in Finland and found that the city of Vaasa is one of the potential areas for GEU. GEU systems are an essential and significant source of energy in Finland (Arola 2015). GEU is especially useful in city areas if there is potential groundwater for utilization. The GEU system is a way to use the natural groundwater temperature for heating purposes. Hence, as climate change is causing higher heat in the ground, the future capacity of local groundwater energy unitization is very high. This makes it a system that will benefit from climate change effects, mainly global warming. In other words, the GEU system uses climate change as an advantage. Connecting this paper to the dissertation of Arola (2015) could be useful to demonstrate how the use of GEU could be implemented in the Vaasa region, mainly in city areas.

One reservation of GEU systems is that mineral accumulation might clog and corrode the GEU system over time. Warm groundwater is much more affected by microbes and pathogens. However, this open-loop system is much more effective in avoiding the leakage of oils and other fluids that can be caused by closed-loop systems. The system also can be used for both heating and cooling as ATES. The thicker the water column, the higher the temperature level (Girgibo 2020b). The use of GEU or ATES is seen as an attractive alternative whether the city area has an aquifer and groundwater to be utilized. The use of GEU is highly recommended in the groundwater report by Girgibo (2020b).

9.5 Vertical wind turbines

Wind energy is the kinetic energy of moving air (Brännbacka 2015). The amount of energy mainly depends on the wind speed, but the air density can also lightly affect it. The wind conditions have been expected to increase due to climate change in some areas (Brännbacka 2015), but the total world wind power has been expected to decrease (Barton 2014). According to Ali (2012), there are two kinds of wind turbines. These are Horizontal axis wind turbines (HAWT) and Vertical axis wind turbines (VAWT). The focus in this paper is on Vertical axis wind turbines. The VAWT has two basic types of airfoils (blades): lift (perpendicular to airflow) and drag (in the direction of airflow). The vertical wind turbines at the University of Vaasa are small energy sources to be used, for example, for battery charging. Uses in other areas of the world are currently developing, for example in a water heater using vertical wind turbines (Brännbacka 2015). The disadvantage of the University of Vaasa's vertical wind turbines is the small amount of energy they can generate.

There are different kinds of wind patterns around the world. The wind in offshore regions is much better than onshore, because of a lack of obstacles (such as buildings, trees etc.) or flat areas. The use of wind turbines offshore yields much more power than onshore. The onshore wind turbines have their own advantages: lower costs of installation and maintenance, easy access to the grid, and less cost and easy foundation of installations. The advantage of using VAWT is more in utilizing all directions of the wind than those of HAWT types, shown in figure 16 illustrated by Marmutova (2016), and is also suitable to install in a building that is easy to access for maintenance.

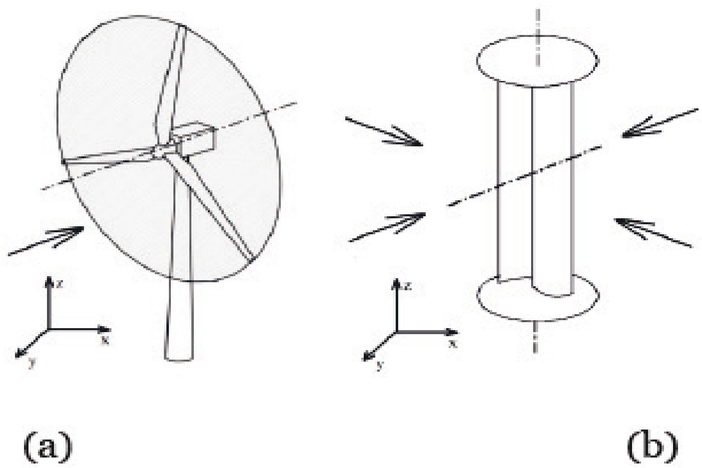


Figure 16. The advantage of using all directions of wind in VAWT (b) rather than a few directions of wind in HAWT (a) (adapted from Marmutova 2016).

According to Brännbacka (2015), there are 8 different companies that produce vertical wind turbines. The Finnish wind turbine company is called Windside. Figure 17 shows the Windside type of vertical wind turbine and the two-scoop Savonius type wind turbine. The Windside type is considered to be an improved version of the Savonius type wind turbine and was patented by Risto Joutsiniemi in Finland in 1985. The amount of energy production is 20 W – 75 kW. According to Brännbacka (2015), the older Finnish vertical wind turbine is the Savonius type wind turbine invented by Finnish captain S. J. Savonius in 1922. One project in the UK produced a 12 V capacity VAWT, using both drag and lift forces of the wind. It does not require any yaw machine because there is no need to follow the wind direction to generate energy. Figure 17 (d) shows the two-scoop Savonius type wind turbine to illustrate this type. The development of the Windside type turbines (mainly WS-0.30B and WS-4B) has been covered in the dissertation by Brännbacka (2015). The Savonius type wind turbine development has been covered in the dissertation by Marmutova (2016), both in the University of Vaasa.

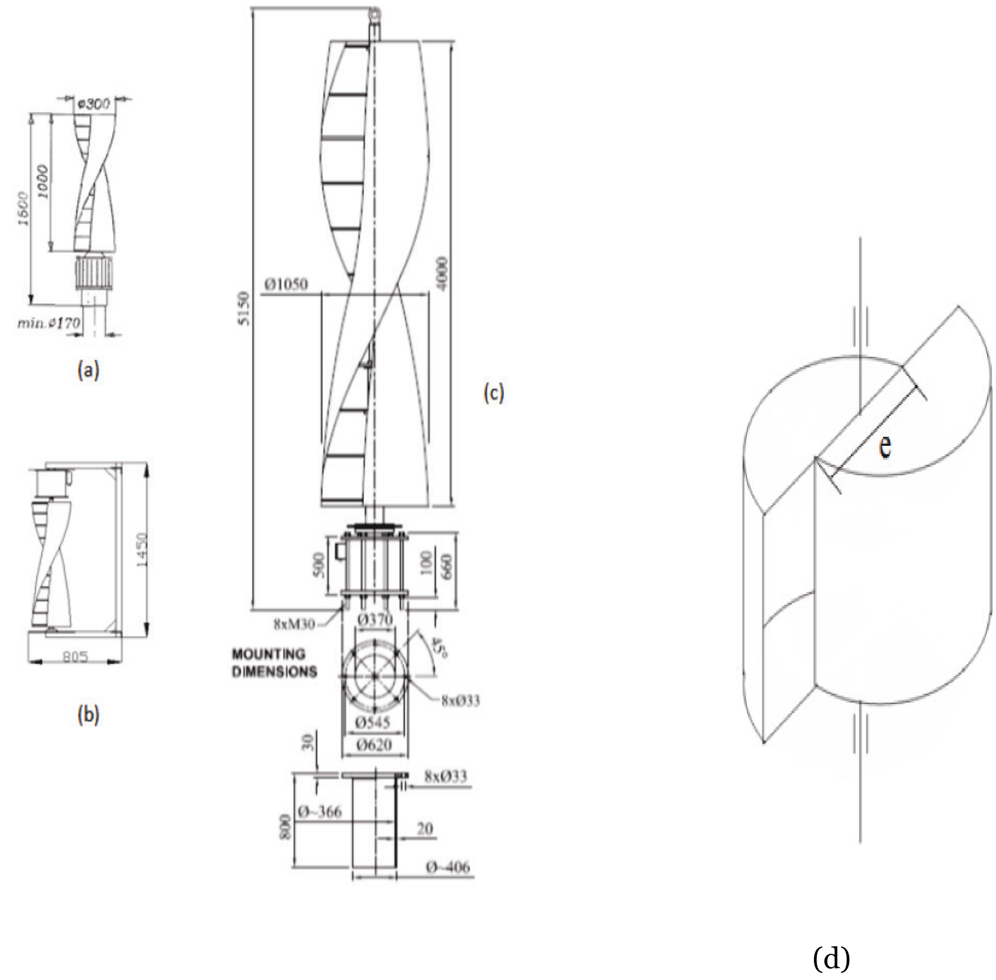


Figure 17. Windside type turbines. (a) type WS-0.30B; (b) type WS-0.30A; (c) type of WS-4B and (d) show the schematic drawings of two scoop Savonius–type wind turbines (the figures presented here are borrowed from Brännbacka (2015) (a-c) and Marmutova (2016) (d) respectively).

The Energy production with 24 V is 7 % higher than that of 12V capacity VAWT, when comparing with and without the new star-delta energy production at 24 V (Brännbacka 2015). When automatic reversible star-delta switches were used instead of a star connection, it was found that the annual yield from small wind turbines increased more than 9% (Brännbacka 2015). Generating wind energy at a local level will minimize loss and reduces the unnecessary transmission of electricity over long distances (Marmutova 2016). In the same dissertation, Marmutova (2016) told that to install these wind turbines in cities, the following conditions must be attained: less noisy types of wind turbines, social acceptability and aesthetic view, integration into architectural systems, and an increased efficiency to utilize local wind resources.

Based on Marmutova (2016), in city sites, the most favorable areas for the installation of VAWT are the roofs of buildings, masts, and wind tunnels between traffic tunnels and buildings. During implementation, three things to consider are technical and economic issues, environmental considerations, and creating a dialogue and consultation process with local inhabitants and planning authorities (Marmutova 2016). The technical issues involve the selection of the wind turbine, the availability of infrastructure for installation, and electrical connection. The economic feasibility issues include the income from the forecasted generating power by power plants, other valuable benefits and subsidies that may be available, and the expense of construction and maintenance. The environmental considerations can involve the following five issues. 1. The physical characteristics of wind turbines and their land use. 2. The effect of wind turbines on the local flora and fauna. 3. Visual and landscape assessment. 4. The noise of wind turbines can be irritating. 5. The potential interference the wind turbines may have on an airport or military radar (Marmutova 2016).

There are six advantages of Savonius type wind turbines (Marmutova 2016): (1) The Betz limit for VAWTs, which is bound to be 20%, is exceeded by S-shaped Savonius wind turbines. However, the Betz limit statistically predicted for the maximum power coefficient theoretically available by HAWT is 0.593, and is not applicable for Savonius wind turbines. (2) The system can be used without control used for HAWT, as the Savonius wind turbine is capable of following changes in speed and direction. (3) A space between blades that allows the air to pass for the returning blade will decrease the negative air pressure in the next blade so that the rotation frequency increases. (4) The starting torque can be lower than the moment of resistance of the generator at some rotor positions. (5) The Savonius wind turbine rotor follows wind direction changes quickly. (6) The two-rotor setup is superior to three- or four-blade rotors, due to the blocking effect of the oncoming blade making it less efficient.

9.6 KNBNNO-material

Based on the discussion by Zhou et al. (2016), perovskite (a type of ferroelectric material) has been given notable study in recent times. In Zhou's paper, the production of KBNNO ($[KNbO_3]_{0.9}[BaNi_{1/2}Nb_{1/2}O_{3-\delta}]_{0.1}$) material by PLD (pulse laser deposition) method was developed for the first time. This finding leads to the University of Oulu finding KNBNNO material (Wallenius 2017). It is good to notice that KBNNO and KNBNNO do not differ significantly from each other. According to the news, the KNBNNO material can produce electricity from three sources: motion, light, and heat, which was hailed as a completely new finding in the area of energy collection. The applications of this material are in watches, mobile phones, textiles, shoes, to replace batteries, and for sidewalk areas where energy can be gathered from the motion created by walkers and sunshine at the same time.

The cost now for a piece of material the size of a coin can be only a few cents. However, additional costs would be incurred in manufacturing, labor, and electricity because it not yet in the production process. A time estimate for starting production ready for use will be around 5 years according to Dr. Yang Bai from the University of Oulu. However, it is good to feel that bringing this new technology product to service will help to address many of the challenges faced by the companies who will implement this technology.

According to Bai et al. (2017), the properties of the material area “a remnant polarization of 3.4 µC/cm^2, a pyroelectric coefficient of 26 µC/m^2 K, piezoelectric coefficients d_{33}~ 23 pC/N and g_{33} ~ 4.1 X 10^{-3}Vm/N, and a direct bandgap of 1.48 eV have been measured for the KBNNO ceramics”. In this first study for the hybrid energy harvesters which convert different energy sources into electricity simultaneously, there were significant improvements compared to other components (e.g. ZnO and AlN). In addition, it uses various energy sources for electric sourcing simultaneously. The bulk ceramics of KBNNO (x=0.1, 0.1KBNNO) has two differently fabricated sub-components (I and II). Component I was strictly according to the formula $0.9KNbO_3$-$0.1BaNi_{1/2}Nb_{1/2}O_{3-\delta}$ (equivalent to $(K_{0.8}Ba_{0.1})(Nb_{0.95}Ni_{0.05})(O_{3-0.025})$, and component II had the resulting formula of $(K_{0.8}Ba_{0.1})(Nb_{0.95}Ni_{0.05})(O_{3-0.075})$ (see the production steps and results in detail in Bai et al. (2017)). Further device fabrication and component optimization are on-going at the University of Oulu.

9.7 Solar systems

The ongoing doctoral dissertation work of Girgibo suggests the use of solar systems in the Merten Talo project as well. One of the suggestions at the beginning was the combination of a solar heater system for water, then the warm water will be stored in borehole systems in the summer time and used in winter for house heating purposes. The other suggestion was using a solar electric generator in the Merten Talo gas stations for charging electric cars. In addition, another suggestion was to use a solar photocell electric generator to produce electricity and to use various combinations with other heating systems.

The advantage of solar heat injected into boreholes is a reduction in borehole length because of the increase of the ground temperature near the boreholes (Bernier & Shirazi 2007). Based on findings in the same paper, the relation between solar collector areas (m^2) to borehole length (m) is 5 m^2 and a borehole depth of 94 m, and 10 m^2 when the borehole depth is 85 m. This shows a relation between the two methods, where the higher the collector size, the lower the required depth for the borehole. The suggestions for Merten Talo at the current time are that one borehole is connected to the solar domestic hot water system, and the other borehole is connected to the water system that heats the house. The house heating system is heated in the borehole by using a solar domestic water system as a heat source. The current suggestion is not connected to a heat pump. Bernier and Shirazi (2007) show a system where the house is heated in summer by solar system sun as a heat source, and in winter it is heated by a heat pump and by ground heat at the borehole when the heat pump is turned off. In summer, the solar heat was used to charge the ground borehole as well as the heat pump for winter storage.

Solar-powered charging stations (SPCS) must be located in parking lots to produce electricity for the grid and as additional suitable infrastructure for charging electric vehicles (EV) (Robinson et al. 2014). Various technologies are available for solar car charging stations. TuDelft (2016) presented a new option where a charging station is combined with a street light, working by conductive charging and while the driver is present as a normal charging station. As well as being connected to the road which charges the car while driving by inductive charging, the system is also connected to a smart grid where one can control the charging state by mobile phone while working on other tasks. Parking and charging stations are much more efficient and are recommended rather than just a charging station (Robinson et al. 2014). When charging income for the planned station, it seems that charging for electricity is suitable, because there might not be so many cars that want to park if income is solely produced by parking space occupancy. On other hand, as the Merten Talo area is a little out of the city there might not enough electric cars, but the cost of charging can be balanced if the price tag placed on the amount of electricity used for charging is suitable.

According to Li et al. (2013), there is a possibility of combining both solar and wind energy resources for charging electric vehicles. The design described in this study had key components including a wind turbine, PV modules (which receive the most amount of solar radiation), batteries, an inverter, and other controllers were considered (see Figure 18 for illustrations). The combination of solar and wind works very well because in times of high solar intensity, there is less wind power. On other hand, in low solar intensity, there is a higher amount of wind power, and using batteries in combination can create an optimized 24 hr charging station that works alone (Li et al. 2013). Figures 2 and 3 of their paper show the daytime capacity of solar and wind throughout the year. This system reduces the production of carbon emissions significantly, and offers an ideal plan for the Merten Talo project, and is worth considering.

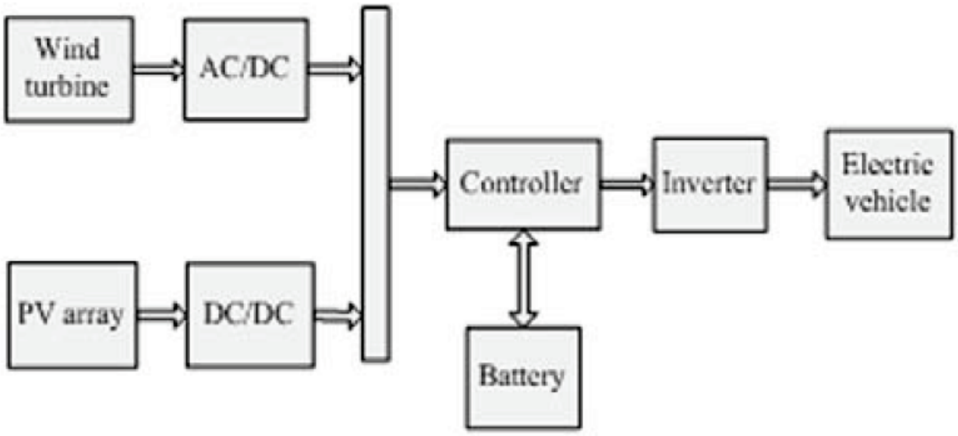


Figure 18. Diagram of the solar-wind hybrid power station designed and presented by Li et al. (2013).

10 THE THICKNESS OF SEA WATER ICE ON THE SHORE

Most of the ice in the sea is mobile ice or 'pack ice' which circulates in polar oceans, driven by surface currents and winds. It is inhomogeneous, in that it differs in thickness and age, snow cover, size/coverage, etc. between meters to hundreds of kilometers (IPCC 2007). The thickness of ice cover on the shore of seawater is between 3 m in southwestern Finland, to 6 m in northernmost parts of the Baltic Sea, and on average 4 m (Beamish 1995). Specific data from Cheng (2002) is available for the location 63.1°N, 21.2°E; which is near our site (see the coordinates in section 5), and shows that the average ice thickness is 38.6 cm along with an average snow thickness 4.3 cm (42.9 cm when combined). The mean water level relative to the ice surface is -1.4 cm. Therefore, by combining the data of Beamish (1995), Cheng (2002), and the IPCC (2007), the sea ice thickness in the current site ranges from 42.9 cm – 4 m of sea ice. The total sea ice volume ranges from 0.019–0.025 (10^6 km^3), the total sea ice area ranges from 19–27 (10^6 km^2), and the potential sea level rise (SLE) in (m) is approximately zero (IPCC 2007, Table 4.1 data).

Globally, more ice will melt each year than is replaced. The result of this melting would be that areas experience runoff from the ice and glacial melt will experience drought once all the ice is gone. The consequences would be a possible water shortage for irrigation, and dam water and reservoirs that would run dry due to a shortage of water. In North America and Europe, glacial runoff is used to supply irrigation, sustain fish runs, and provide hydroelectric power for large metropolitan areas. When the runoff decreases, there will be troubles with energy, and urban and agricultural infrastructure (Climate Institute 2010). In lake water and ice research done by Huttula et al. (1992), it was found that the water thermal stratification will be considerably steeper, and the thermocline will be 5–8 m higher than the present climate. The surface water temperature will increase by about 5–6°C, and the water temperature in the hypolimnion will be about 2–3°C colder than the present climate. It is forecasted that in Finnish latitudes, climate change will have a major effect on snow and ice cover, and will have mixing and stratification effects (Huttula et al. 1992). Based on previous studies, the ice cover period in Finnish waters will be 40–60 days shorter, clouds might be unpredicted, and the water temperature of lakes will be affected due to their sensitivity to solar radiation and wind speed.

In summer time, the wind speed and sun radiation affect environmental studies, and therefore in wintertime, ice cover study is a much more reliable process. Based on IPCC (2007) data, 71% of the earth is covered by oceans, 7% of which are mainly covered in sea ice in winter. 10% of the land surface is covered in ice. Definitions: Land is any part of the earth's surface not occupied by a body of water, and is affected by issues of land cover, orography, surface temperature, and soil moisture. The atmosphere is the gaseous envelope that surrounds the earth, and involves climatic features such as air temperature, precipitation, radiation, and clouds. Oceans serve to cover three-quarters of the earth's surface with salt water, with climatic features such as sea level, surface temperature, salinity, and circulation. Frozen ground or permafrost is the frozen ground found in arctic or subarctic regions and perennially frozen subsoils that are involved in heat and gas exchange. Snow cover is the snow that covers land and impacts upon surface energy, water balance, and runoff. Glacial/ice shelves are an ice sheet that projects into coastal waters so that the end floats (mass balance). River and lake ice are ice on a stream of continuously flowing water in channels or standing water, affecting energy exchange and runoff routing. The sea ice is frozen ice on the surface of the sea. It is part of the cryosphere, and interacts with the climate, influencing surface energy balance, growth, and melt (definitions derived from Cheng (2002) flow chart info; dictionary.com (2016)). Figure 19 shows the components of the cryosphere and their time duration (IPCC 2007).

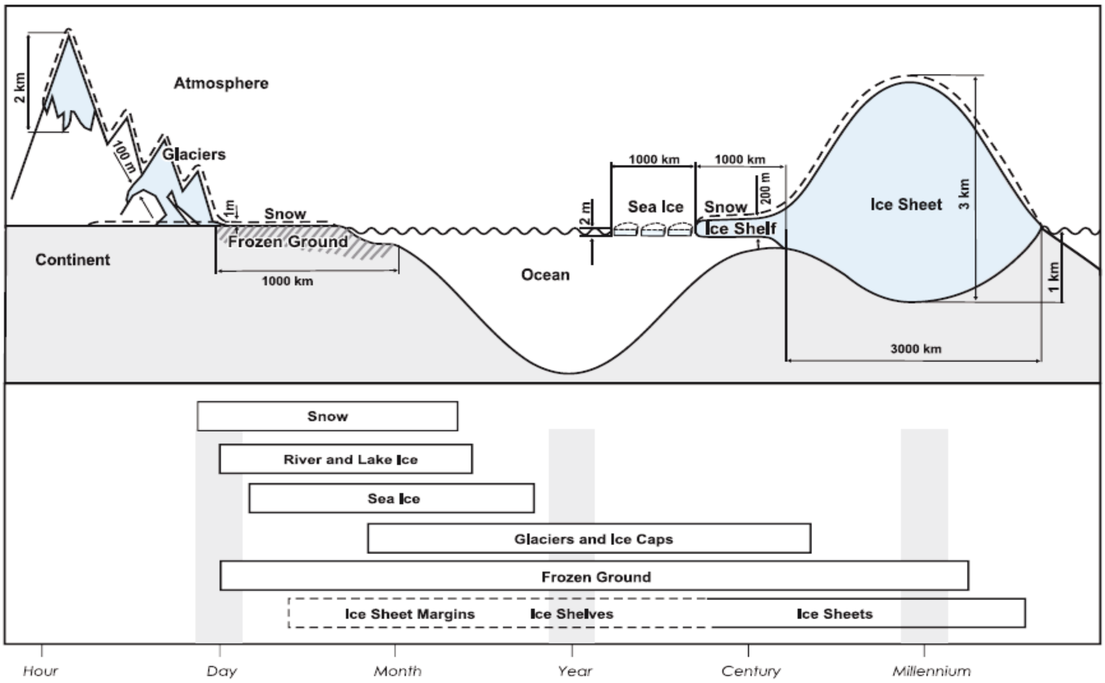


Figure 19. The components of the cryosphere and their time duration (IPCC 2007).

According to IPCC (2007), satellite studies undertaken from 1966 to 2005 show how the ice cover has decreased by at least 5 %. The spatial variability is observed in the freezing and breakup days of lake and river water. As the satellite studies show, there is an extent of decline of 7.4% ± 2.4 % per decade since 1979. Since 1978, a continual decline in annual mean ice extent of 2.7% ± 0.6 % has been observed per decade. From 1987 to 1997, a decrease in ice thickness ranging between 0.6–0.9 m has been shown by model-based data. In the same period, the submarine data shows a likely decline of 1 m in sea ice thickness. Melting of ice in the areas of Alaska, the Arctic, and the Asia high mountains is the biggest reason for sea level rise. The Greenland and Antarctic ice sheet melt are very likely to have contributed to sea level rise from 1993 to 2003. The arctic sea minimum extent in 1980 was 7.5 million sq. km, but now in 2020, it declines it to 3.5 million sq. km (BBC news 2020). Since the 1980s, in the Arctic, the temperature increased 3°C on the top of the permafrost layer. From 1993 to 2003, assuming a midpoint mean plus or minus uncertainties and a Gaussian error summation, a total of 1.2 ± 0.4 mm yr^{-1} SLE sea level rise is contributed by the overall cryosphere and the amount of snow and ice on the earth melting.

According to the findings of the IPCC report, the current site sea-ice depth is in the same range of thickness (42.9 cm up to 4 m). Based on the data of Leppäranta et al. (1988), the total ice thickness in the Vaasa region is between 30–90 cm. However, specific area measurements must be conducted to know the exact thickness and coverage area of the ice. The total coverage of the sea ice area in the world was in the 19–27 (10^6 km^2) range. A thickness investigation was carried out in the area because of the need to know how deep the heat exchanger must be installed. Based on this study, the depth must be at least 4 m deep from the surface of the seawater. A study like that of Cheng (2002) shows that sea ice modeling in the area would provide the opportunity to discover how climate change has affected the sea ice. As is already known, the bottom of the sea in the Vaasa area is full of big rocks causing difficulties for boats to drive through and also to install a sediment energy system. It is even said that anyone sailing must know the area and the route, otherwise navigating larger craft in the area is not possible.

The study conducted by Leppäranta et al. (1988) further explored the issue of Baltic Sea ice formation. In their paper, different charts and maps were presented with some explanation about the area of Baltic Sea ice formation and some useful data. Their phase chart 3 shows the archipelago is frozen over in northern Härnösand. The previous Figure 5 shows the Bothnian Sea, Bothnian Gulf, and the Gulf of Finland. Phase chart 3 in Figure 20 shows the different kinds of ice types in the Baltic Sea. The current project area is shown in red brackets. The unbroken and stationary ice cover ideates that the Merten Talo area is covered with a 'Fast Ice' type, and it is possible to walk on fast ice once it is thick enough. The fast ice cover is formed rapidly during the freezing period. It remains unchanged throughout winter and starts to melt in the spring on the shoreline. An average of 10–20 % of the total thickness of the ice is 'Snow ice', and the ice grows downward towards the bottom because the water below the ice loses its heat (Leppäranta et al. 1988). The general sea cover by Fast ice is called drift ice, and it will remain unbroken until it compiles, cracks, and piles up to form ridges over 10–30 km.

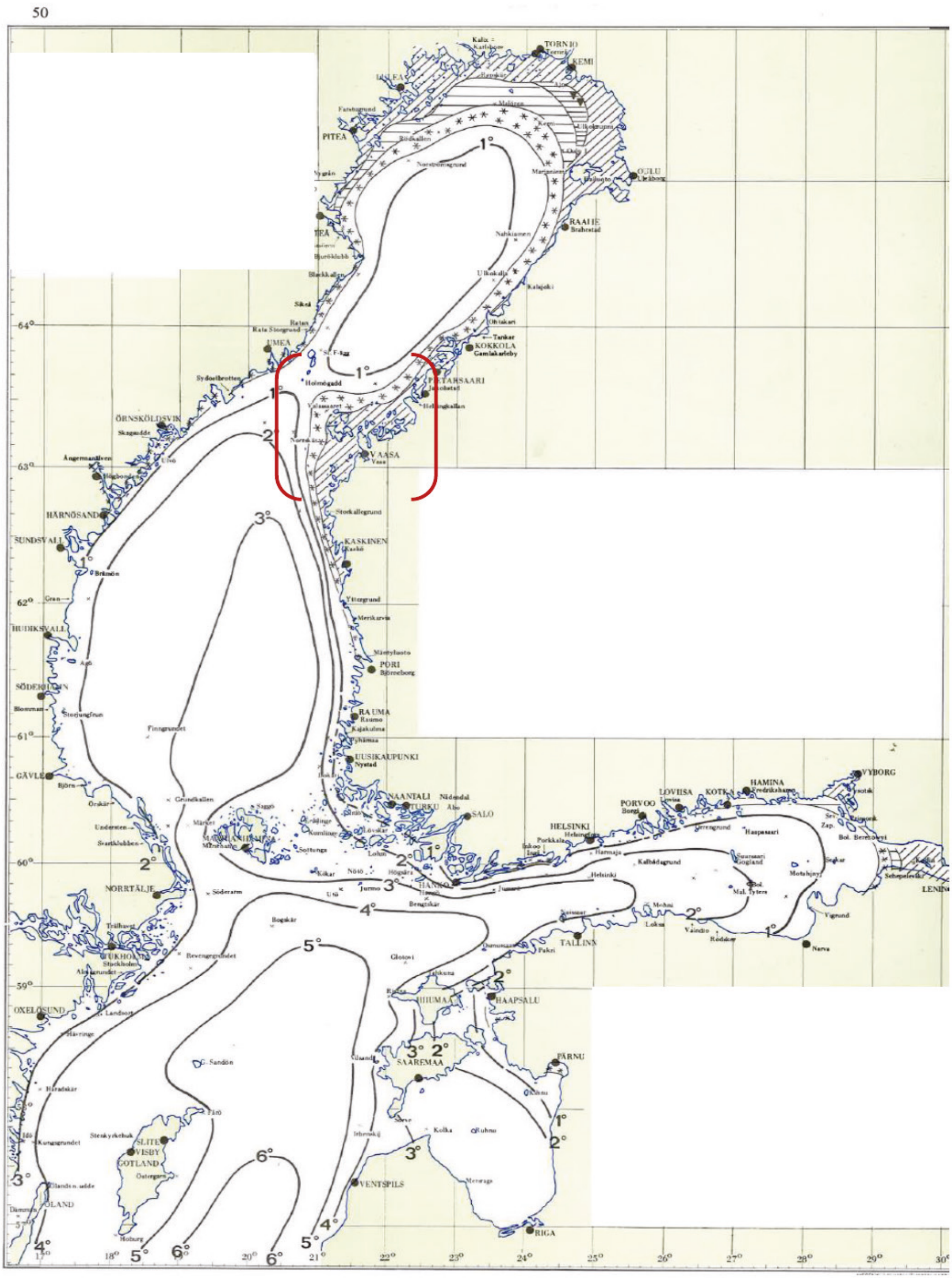


Figure 20. Phase chart 3 in the Bothnia Sea/Bay: the archipelago is frozen over in northern Härnösand. Notice the island of Replot (Raippaluoto in Finnish) enclosed in red brackets next to Vaasa is a ‘Fast ice’ covered area (taken from Leppäranta et al. 1988).

The above phase chart and the other phase charts and figures Leppäranta et al. (1988) were compiled from a data bank gathered from the 1940s, and 1963/1964 – 1979/1980, a total of 17 winters. In December, the quark area and the innermost part of the Gulf of Finland freezes. Before that in November, the Baltic Sea starts to freeze at its northern point. The Archipelago Sea does not freeze until the middle of January. The Gulf of Finland and the Bothnian Sea do not freeze completely every winter. The warm air coming from the mainland melts the ice. In the Bothnian Sea and the Gulf of Finland, the ice melts in April, and on the Baltic Sea, the ice properly starts to melt in March. The Ice of the Gulf of Bothnia finally breaks up in May. Because of this, in the Merten Talo area, the melting time falls between these two times starting from April and extending into May. The ice cover period ranges from a minimum of 1 week up to 6 months: 4–6 months in the Bothnian Gulf, 2–4 months in the Bothnian Sea and the Gulf of Finland, and 1–2 weeks in the middle of the Baltic Sea. The present site on average has a 3–5-month ice cover period (Haecky 2000).

On average, the coast freezes for a 3-month period (Leppäranta et al. 1988). Some of the climatic importance of sea ice are a) Its area (the fraction of the ocean coved by the ice); b) Its extent (the area enclosed by the ice edge-operationally defined as the 15% concentration contour); c) The total area of ice within its extent (i.e. extent weighted by area) - the area of multi-year ice within the total extent. d) Its thickness (together with the thickness of snow cover). d) Its velocity. f) Its growth and melt rate (and hence salt or freshwater flux into the ocean) (IPCC 2007). Consequently, the ice contains fewer amounts of microbes compared to open water. When the ice melts, the microbes in the ice will fall to the water making the open water flourish more because of the increased number of microbes.

11 THE LAND UPLIFT EFFECT

Land uplift takes place in Finland, the Mekong Delta of Vietnam/Cambodia, and in the US, Canada, Switzerland, and the UK. Land uplift has been of interest for some 300 years, and around 50 well-known scientists have studied the phenomenon since the beginning of the twentieth century (Kääriäinen 1953). The possible estimation of land uplift has been discussed in the same literature.

<u>Cause of land uplift</u> (Kääriäinen 1953):

1. The contents attract water, and the larger the content, the more water it attracts. This phenomenon depends on many things like how dry the content is, and how much water there is in the content as the more water in it, the more rain drops it attracts.

2. If the mass of land and its attraction is small, the sea in its vicinity sinks, and the land seems to rise.

3. The phenomena are the attraction of ice masses in polar regions causes water to move towards the pole, then, as the glaciers melt, it gradually recedes.

4. The shrinking of the earth's crust causes vertical movements.

5. The cold ice masses of the Ice Age have cooled down the earth's crust, and after the ice melts, the earth starts to warm up.

6. Changes in volume taking place in connection with crystallization processes beneath the earth's crust have caused land uplift.

7. The earth's crust moves due to periodic variations, causing the folding and levelling out of mountain ranges which also influences weather formation.

8. The ice mass weighs on the earth's crust and is supposed to be flexible so that when the ice melts gradually, this causes a rising up of land to reach an equilibrium.

9. There is a possible connection between earthquakes and land uplift.

Earthquakes cause some of the land uplift in Finland (notably in the Kuusamo region of southern Lapland), and at also the end of Lake Vänern in Sweden, i.e. at both ends of longish land uplift regions. Two of the most common ways of determining of land uplift are by precise levelling (Kääriäinen 1953) and by tide gauge (Vermeer et al. 1988).

<u>Finland land uplift</u>: In the Vaasa region, the land uplift is 1 m per century. However, in some areas, measurements of even 2–3 m per century have been obtained (Kääriäinen

1953). According to Löfman (1999), the land is rising in relation to sea level by several millimeters per year in Finland. In the Vaasa area, the land will rise 4.3–6.1 mm/yr, and in Finland, the present rate of uplift is 3–8.8 mm/yr (Okko 1967 table 3). Kääriäinen (1953), Okko (1967), Vartiainen (1980), Vermeer et al. (1988), Löfman (1999) and others have proved that land uplift affects Finland and is stronger in coastal areas.

Northern Europe was covered by big glacial ice around 11 300 years ago (Heinsalu 2001), and this depressed the Earth's crust by several hundred meters. As the ice sheet was melting, a strong rebound caused the crust to rise up. Now the land rise is slow compared to past times. In 1700, the rate of land uplift was twice as big as the current rate (Kääriäinen 1953), but it still has an effect on the sea level of the area. Based on the literature of Löfman (1999), land uplift in the Hästholmen area (in Sweden) is affected by the sea level rise. However, the *glacio-eustatic* (defined as the uptake or release of water from glaciers and polar ice causing a change in sea level) rise in sea level has clearly been lower than the *glacio-isostatic* (defined as the continuous movement of land once burdened by ice-age glaciers) land uplift. The Kvarken archipelago together with the High Coast in Sweden gained world heritage status for the effects of uplift (Kvarken Archipelago and Merten Talo 2016).

The geodetical value of absolute land uplift is the rate at which the surface land crust is going away from the central Earth's crust or from a specifically given niveau. To express the phenomenon as an equation: if Y_s is the sea level constant at the present altitude of a shore formed t years ago, the amount of uplift occurring during t years can be seen in $Y = Y_s - H_s$, where Y is the amount of uplift, Y_s is the sea level constant at the present altitude of a shore formed t years ago, and H_s is the sea level measured at a vertical distance. Therefore, the sea level and crustal are included in the altitude of the raised shore surfaces. The correction of the shore altitude by H_s is necessary for any estimation of the amount of uplift occurring during a given span of time by means of dated shorelines (Okko 1967).

Based on Figure 21, the Merten Talo land uplift is about 8–9 mm/year relative to mean sea level (representing the uplifted oldest shores of the Litorina Sea, it has been nearly constant between the rates of uplift in different places since the development of the Litorina limit and block movement was considered (Okko, 1967)). The past uplift of the shoreline was in the range of 2.9 mm/yr to 8.6 mm/yr, and the steepest inclined part of the Litorina graph showed a 6.1 mm/yr to 8.6 mm/yr range of uplift (Okko 1967).

Therefore, our current site uplift ranges from 2.9 mm/yr up to 9 mm/yr, based on the table data of Kääriäinen (1953 p. 26). In the study, the precise levelling of the Vaasa region is 8.77 ± 0.30 mm/yr, and the area of Finland increases by 1000 km^2 per century, two-thirds of which resulted from land uplift, and the rest formed by sediment brought by rivers and the vegetation effect (Kääriäinen 1953). Figure 21 shows the *Fennoscandia* area. The possible uplifting measurements are presented in red curved lines and numbers on the figure. Data on land uplift can be gathered by using current data and historical data. Data gathering on land uplift started around 1800, and the first data in Finland was likely recorded in 1892. The historical data was based on measurement by oceanographic, hydrographic, and geodetic methods. However, scientific opinions are divergent in Finland as to how prehistoric land uplift data is gathered.

Merten Talo is one of the areas where land uplift takes place, and hence, any shoreline sea level movements also affect it. Coral reefs are one of the indicators of present-day land rise, and while they used to be found at 300 m depths, they currently survive even in 30 m deep sea water. Many species become adapted to living the near surface in other parts of the world. Heinsalu (2001) found that the sea level on the western coast of Finland is 20 cm higher than on the eastern coast of Finland, but this difference has no effect on the calculation of land uplift. Uplift of this area started during the late-glacial periods about 1200 years BC. The land uplift has not been continuous, but rhythmic during this time (Heinsalu 2001). The first elastic compressibility of the surface layers of the earth's crust was a violent jump, like land uplift observed after the ice disappears. After around 6500 BC, rapid elastic uplift of the earth's crust in the center of the uplift region has been observed (Heinsalu 2001), and the rhythmicality of land uplift is demonstrated by the appearance of distinct shorelines at regular spacings, and the absences in between. Since 6800 BC, the rise is around 250–280 m. From 6800BC to the present age, the remaining uplift is 180–210 m. This data refers to the center of the uplift region. However, due to intensive land uplift, the shoreline displacement was seen to be regressive around the Yoldia Sea stage in the Baltic Sea basin even in northern Estonia, and the amplitude of the regression amounted to some 25 m (Heinsalu 2001).

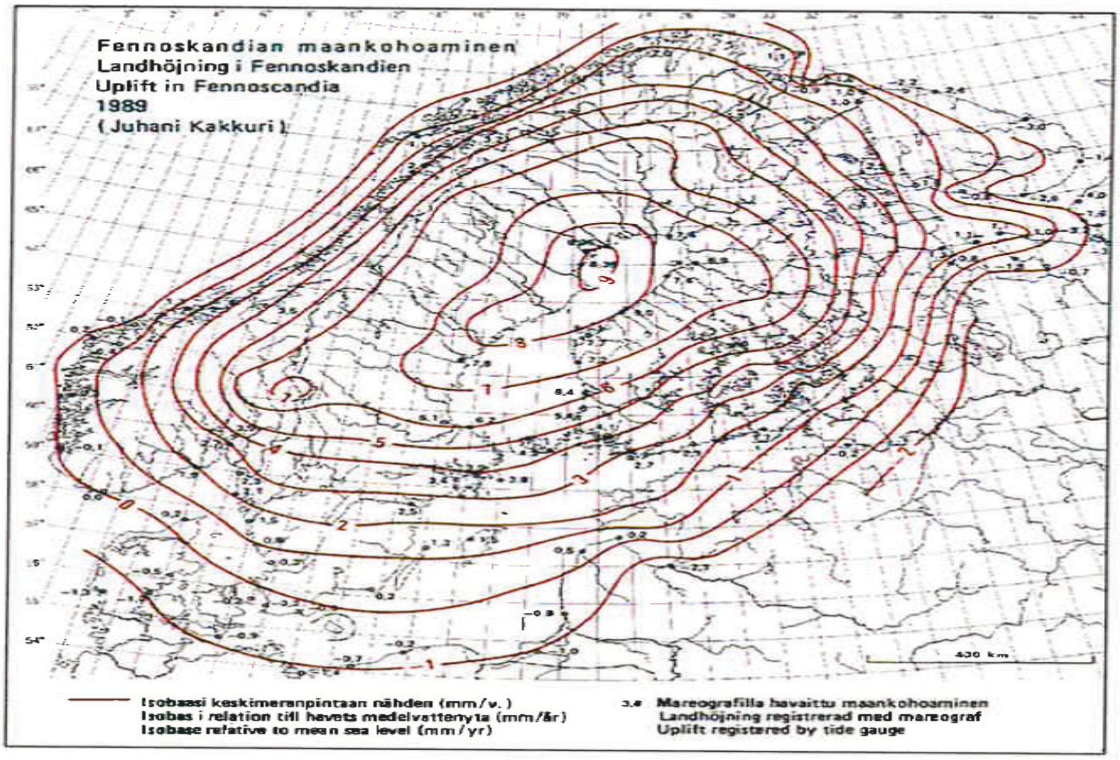


Figure 21. The current land uplift in *Fennoscandia* (scanned from the literature of Löfman 1999).

<u>Mekong river land uplifts (historical example of land uplift)</u>: The Mekong is one of the largest river deltas and is located in the south of Vietnam at a location of 8° 30' to 11° 00' N and 10° 30' to 106° 50' E. It has a monsoon rainy season of 6 months, with a mean annual rainfall of around 1700 mm. In the delta, the rainfall exceeds more than 2000 mm (along the Gulf of Thailand). The temperature is rather warm at 27–30°C, and the annual evaporation in the area is 1020–1240 mm. The river delta pro-graduation has produced a great flat plain of 62 520 km² (the Mekong River Delta). 52 100 km² of this area is in Vietnam and the rest in Cambodia. The population in the delta area is approximately 14.8 million. At 4300 km, the Mekong is the longest river in Asia. The extent of its fast land increase could be due to a very high sediment supply deposing on the slight inclination of the receiving basin, or non-tectonic movements, relative sea level changes, and widespread mangrove forests playing an important role in enhancing sediment accumulation (Nguyen et al. 2000). Figure 22 shows the location of the Mekong River Delta, which starts from Tibet and ends in Cambodia. "Mekong Delta began to form only 6,000–7,000 years ago when sea level rose to its present level after. A rise of some 130 meters took place over the preceding 12,000 years, after the last glacial maximum period" (Geology 2012).

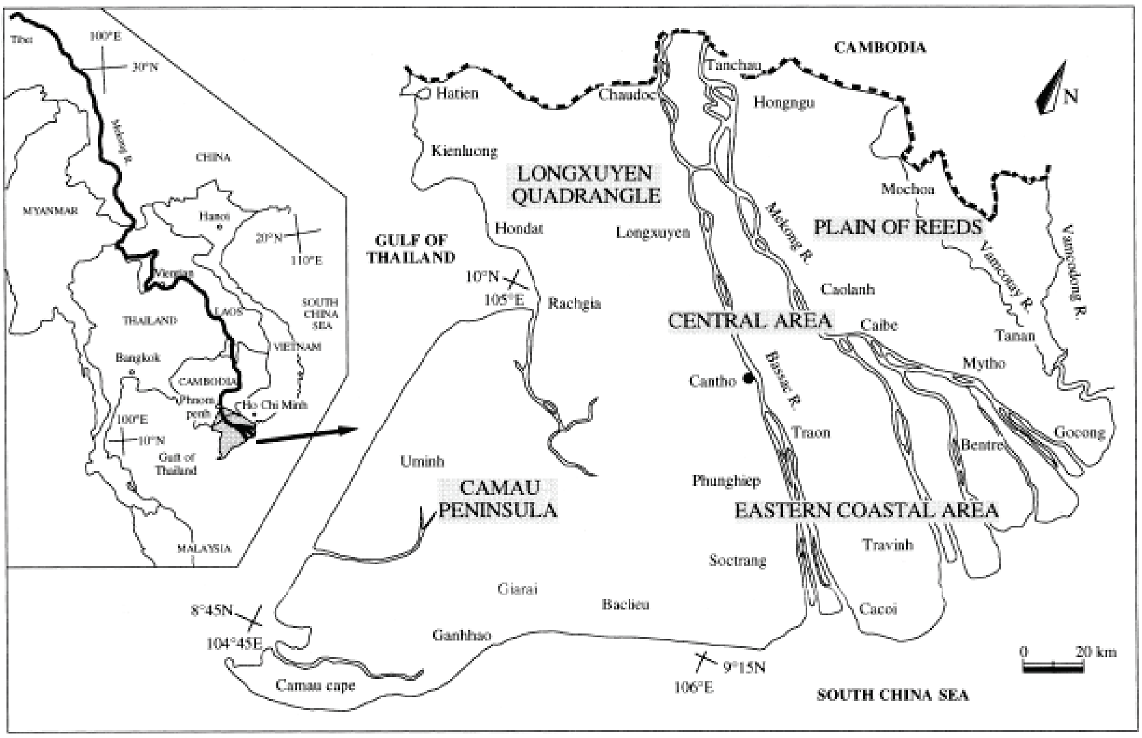


Figure 22. The location of the Mekong River Delta. Inset shows the location of the Mekong River and Mekong Delta in Southeast Asia (Nguyen et al. 2000).

The uplift history of these regions may be partially contained in the geometry of the associated river systems. The tectono-geomorphic studies of fluvial systems have concentrated on the identification of the active geologic structure and the relative rates of uplift across the structures using longitudinal river profiles. Including approximately 2000 m of surface uplift in eastern Tibet, disruption of the paleo-drainage occurred by river capture and reversal prior to or coeval with the initiation of Miocene uplift. The uplift occurring in long wavelengths (>1000 km) mimics the present low-gradient topographic slope (Clark et al. 2004). Approximately 0.1 mm/yr (0.07–0.2 mm/yr) is the rate of average surface uplift in the area of the Yangtze River, which is close to the Mekong Delta uplift.

When comparing the uplift of the Vaasa region in Finland with that of the Mekong area, the average land uplift in the Vaasa region is 8.77±0.33 mm/yr whereas the Mekong area uplift is only approximately 0.1 mm/yr. This may be the main reason that the Finnish Kvarken archipelago and Sweden High Coast were chosen as world uplift notice areas. The other known official areas for land uplift worldwide are Iceland in the Atlantic Ocean and areas of Bangladesh.

12 DISCUSSION

The effects of climate change cause much more dramatic effects than shown in any other situation. The main alterations of climate change are to the ecosystem that is affected by anthropogenic factors, and it is considered as a key threat to biodiversity and the structure and function of the ecosystem (Graham et al. 2009). A study conducted by the Environmental Agency in the UK has found that in higher emission scenarios the temperature increase is likely to be eight times higher than normal. However, even in low emission scenarios, the temperature increase in water will be significantly affected in the next century. Consequently, the participation of humans in enacting a CO_2 emission decline and combating climate change is essential. Increment in economy level 5 to 15-fold by the year 2050 – 2100 (Pirilä 2000). It is expected the dabbling of the world population (World meters 2016). Climate change has a significant effect on the ecosystem (Beamish 1995). On the World heritage gate area, the climate change effects are the same as the rest of the world effects. According to Ojanen and Minkkinen (2020), conclusions peatland rewetting is beneficial and important for mitigating climate change. New ways to mitigate climate change are developing to some level all over the world.

Based on the article of Beamish (1995), the world is just starting to understand the impact of specific climatic factors on the ocean and other water resources. Those factors determine climate variability. In Europe, it is possible that in the future, there will be no suitable areas for species to flourish, which also means a shortage in living areas for people (Arau´jo et al. 2011). The way we live and cultivate our soils is changing. In addition, our climate is expected to alter across the world. Every individual has to do something, but on a world scale, the Kyoto agreement is one-step forward in combating climate change. Controlling the way-we live is the best choice among the choices we have before us. If we choose to use hybrid, electric, or alcohol for powering cars, we may minimize CO_2 emission even though these options have their own forms of pollution. We must replace the usage of oil, gas or coal fuels with renewable energy. Changing to renewable energy is one way to act, so the Merten Talo project is a perfect example because it plans to replace fossil energy usage with renewable energy. The local restaurant in Merten talo site has been responsible for reducing waste by building its own cleaning facility which makes the restaurant environmentally friendly. Moreover, there are possible upgrades to make the restaurant further active in combating climate change. This report is another way of conveying knowledge to readers and motivating individuals to combat climate change.

Why care about climate change? Because climate change affects every individual, so we have to act upon it. Climate change combat starts with the care to know, then to do something about it. To care about the environment and water resources is a part of carrying about climate change, and has come to go hand-in-hand with caring about nature. The more exposure the climate issues get, the more chance these issues will be solved as more people come to care about the subject. The more education is focused on climate change, the better people's understanding becomes. The World Heritage Gate project is one-step forward in combating climate change in the local area.

Possible future energies can take advantage of climate change effects. Ground soil and groundwater heat are increasing due to the increase in earth temperature if it is near the surface up to a 14–16-meter depth. Solar intensity is increased due to increased greenhouse gases. The water temperature in our sea is increasing, which supports the installation of water heat exchangers. Open water increases or water with ice levels decline due to climate change warming can promote the usage of wave energy. In addition, some areas experience higher amounts of wind, which makes it practical to install wind turbines. To avoid the turbulence of wind which is seen in the area, vertical wind turbines can be installed to counter the unpredictable wind patterns caused by climate change. The possible energy resources that can benefit from climate change or use climate change as an advantage in the Merten Talo project are Water heat exchangers, GEU, ATES, wave energy, vertical wind turbines, and solar systems. Almost all of these energy resources can help to decrease the carbon-equivalent and/or overall carbon emission by adapting, combating, and mitigating climate change. One way of doing this is to replace grid electricity, which is usually produced with higher amounts of carbon emissions (Jiang 2018), or reducing carbon emissions by replacing other carbon-emitting heat or electricity-producing solutions.

The climate change effects for Merten Talo are that the incoming river gets much volume and velocity with turbulence. The sea level of the Baltic Sea is increasing, and both the river and sea water become warmer. The acidity of the sea is increasing along with oxygen depletion and salinity decrease. A higher level of parasite influent and phytoplankton blooming is expected to happen. The precipitation is going to increase in winter and its severity will also increase. Erosion and flooding are also expected to happen. Severe drought is also expected to affect Finland in some pats because of climate change (Veijalainen et al. 2020). Ground water movements both to the sea and away from it are expected, and together with a wider spread of pollution. Fish stocks will be affected negatively by temperature increase, oxygen depletion, phytoplankton blooming, and salinity decline. The environmental conditions are changing, and the surrounding air will become warmer and windier. Moreover, soil and water pollution will increase, and the warmer conditions facilitated by climate change increase the leakage and spread of waste. Many external forces, from the micro to the mega-scale, can influence the long-term variability of the marine biological environment (Beaugrand et al. 2003). In addition, wind speed is one of the main forces which is expected to increase. This leads us to implement the use of wind turbines. However, it will also influence water temperature, the circulation (waves and other water movements), and the decline in sea ice accumulation.

The advantageous energy usages are as follows. Hydropower is a possibility but limited in this area. The warming of the seawater supports the installation of water heat exchangers in the sea. The possible use of wetlands is recommended to avoid erosion and floods. Ground water circulation by ATES (aquifer thermal energy source), BTES (borehole thermal energy source), and GEU (groundwater energy utilization) usage can be useful and is advantageous because of the ground water temperature increase due to climate change. The warmer temperature also facilitates biogas production. The restaurant and the future fish farm can be a good source of waste for a biogas plant if it is implemented in the second phase of the project. Solar energy is a good source for energy extraction by solar panels and a combination of solar and wind for a charging station. The use of a wind turbine is also advantageous because wind power is going to increase on the site. Moreover, asphalt energy is the other useful way to gather energy because of the inclination of temperature, and the sun will facilitate its capacity. In Merten Talo, is not possible to use sediment energy because of the rocks on the sea bed, but it is expected to be of benefit as temperatures increase.

Water resources are one of the most influenced environmental units. This area has not yet been studied in any great depth, especially the marine environment compared to other emission-affected areas. Even though there is currently no plankton bloom in the area, it is expected to increase in the future. Until then, the temperature increase affects the fish stock. The temperature will also affect the parasite influent, leading to the contamination of species such as fish and mussels. The parasite levels have not yet increased in the Merten Talo area due to phytoplankton availability, but due to the temperature increase, this is likely to change. The cause of sea level increases in the area is the ice melt, water expansion due to heating, glacial melt, the increase of water runoff, the loss of ice mass from Greenland and Antarctica, severe precipitation in the area, and other factors (Climate Institute 2010).

The microclimate is a set of meteorological parameters that characterize a localized area (Hogan 2010). Relative humidity, surface temperature, wind speed, solar radiation and precipitation are factors affecting the microclimate. The relations of climate change to microclimate are the measure of climate change globally and on a local scale. They are dependent on data acquisition microclimate settings. The differential impacts of climate change appear to alter the overall microclimate. Generally, the seawater of Finland is going to have higher plankton blooming, but this may not be seen in the Merten Talo area. The fish stock in the area and as an international case is affected by the water temperature, salinity, oxygen depletion, and parasite influent. The current knowledge is that in Merten Talo, the fish are fresh, are not affected by pollution or other environmental stresses, and have not travelled long distances. However, in the future, they might need to travel long distances which will increase their potential exposure.

In the matter of inheritance, it is currently considered that the usage of renewable energy is advantageous. For example, the local restaurant has its own water and wastewater cleaning system, and the use of biogas might be adapted in the second phase of the project. The current project is proceeding because of the willingness of the inheritance area towards using renewable energy, and the restaurant is giving positive feedback on the implemented initiatives. In addition, the current potential renewable energy solutions possibly to be installed in current and future times are ATES (aquifer thermal energy source), BTES (borehole thermal energy source), solar energy, a wind turbine, a heat exchanger in seawater, and asphalt energy.

The demonstrative energies to be highlighted in the project are 1. Self-producing energy. 2. Knowing the force of the wind. 3. Visiting animals virtually. 4. Human beings as a heat source. 5. Automation and energy consumption. 6. An energy contour simulation game. 7. Ice change video. 8. The art of transparent solar panels. 9. Change of a landscape within a year, and 10. Contact react pike.

In this area, the sea ice thickness ranges from 42.9 cm – 4 m, and the thickness varies in a time range (in years). The thickness of the ice is a consequence of past growth, melt, and deformation, so it acts as an important indicator of the climate conditions (IPCC 2007). The Merten Talo sea ice is called Fast ice, which thickens and varies very rapidly, and one can walk upon it in a short time. Above it is a cover called 'Snow ice' which is 10–20 % of the total thickness. The heat exchanger must be installed down to 4 m deep according to the manufacturers. The sea has an average ice coverage of 3–5 months in the Merten Talo area.

The Merten Talo land uplift is caused by the melting of the ice age in the *Fennoscandia* area. After the ice melted, the crust started to expand. Finland is highly affected by land uplift, and its study was started in the 19th century in Finland, and some 300 years ago in other parts of the world. The current uplift is much less compared to the previous uplifts, and the rate of uplift is higher than that of sea level rise. The current site uplift ranges from 2.9 mm/yr up to 9 mm/yr, based on previous data (Kääriäinen 1953 p. 26). A precise levelling can be seen in the Vaasa region of 8.77 ± 0.30 mm/yr. The uplift here is 9 mm – 1 m per century, but in some places in Finland, even 2 – 3 m per century has been observed. The area of Finland increases by 1000 sq.km per century, with two-thirds of this resulting from land uplift, and the rest sediment brought by rivers and the vegetation effect (Kääriäinen 1953).

The need for energy production will increase due to climate change (Venäläinen et al. 2009). The demand for heating energy is going to decrease by an average of 10% in the years 2021–2050 compared to the period of 1961–1990. However, hydropower potential will increase 7–11%, and the climatological potential of peat increase in production by 17–24%. The climatological potential of biomass (mainly wood) will increase by 10–15 % and the climatological potential of wind power increase by 2–10%. Figure 23 is derived from the same publication (Venäläinen et al. 2009), and shows the average percentage increase in climate change influence on energy production and heating energy demand. Due to the uncertainties in estimations of the magnitude of climate change, the results are preliminary.

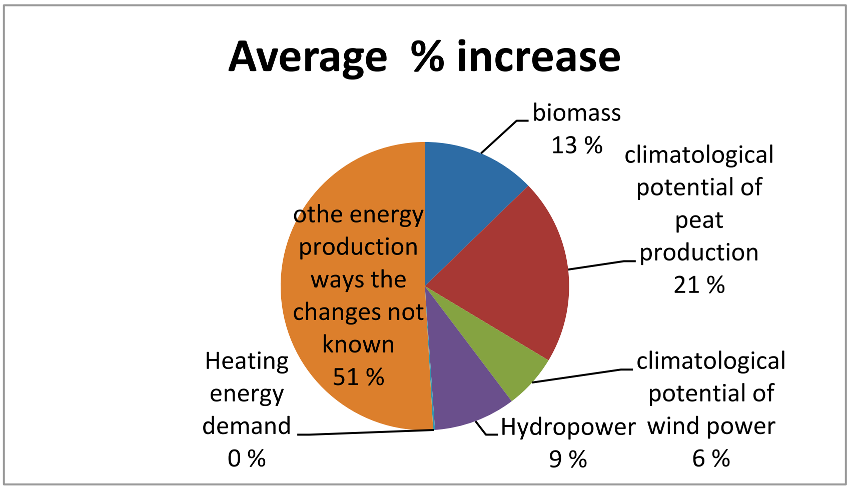


Figure 23. The data shows the average percent increase in 2021 – 2050 the influence of projected climate change on energy production potential and heating energy demand (Derived from Venäläinen et al. 2009).

Climate change is real. It is happening now and the GHGs produced by human activities are significantly contributing to it (Omer 2008). The use of renewable energy in buildings is the main intended outcome of the project and allows us to contribute towards fulfilling the global promises and the active participation in combating climate change. Further collaborations and acts to combat climate change on the part of the participant companies who will be featured in the exhibition are expected to happen. This paper is intended as an information source and motivator in initiating readers to act on climate change by any means possible, without considering how little their efforts will affect the worldwide situation. This report presents the effects of climate change in water and the environment for Kvarken, archipelago. Moreover, it suggests the use of climate change effects as an advantage for energy production.

12.1 Hypotheses confirmation/falsification

Null hypothesis H_0: There will not be any change in one or some of the next hypotheses.

There are no hypotheses found to show no change to occur, and each hypothesis was confirmed or falsified based on the literature investigations carried out.

> H_1: The incoming river potential will increase due to climate change, and the outcomes of hydropower will increase in the area.

As expected, the incoming river potential and turbulence will increase due to the melting of ice, seawater expansion due to temperature, and Antarctica ice melt. However, the hydropower potential will not expand due to the fact that the streams in the area are quite small and unable to be used as hydropower sources for electricity production.

> H_2: The sea level will rise, the wind will increase, and these changes will affect the islands of the archipelago.

There is an expectation that the sea level will rise as expected in the rest of the world. Moreover, the finding makes us conclude there will be much more sea level rise to come and the islands of the archipelago will be affected by this effect. On other hand, the overall world wind power will decrease according to our sources, but the archipelago area wind power will increase. Therefore, both the sea level and wind power increase will affect the islands. It is even possible that the islands' wind power may be so powerful that it might not be possible for the wind turbine to function as usual.

> H_3: Precipitation, erosion, floods, and ground water will dramatically increase due to climate change.

As expected, the level of precipitation will be increasing, but its patterns will be unpredictable. Floods will be increasing in the islands, mainly due to the increase in sea level. There will be erosion and the pattern are expected to increase, based on the compiled literature reviews. In addition, the movement of ground water will be unknown and might vary with increase or decrease, but it will certainly be polluted by the seawater and by river water inlet.

> H_4: Phytoplankton will increase and the fish community will decline due to the increases in temperature.

The phytoplankton will bloom more often and in a higher volume than before. The fish community will be affected, but there is no specific finding that reliably predicts the size increase or decrease in this study.

> H_5: The land uplift will continue to increase whether there is climate change or not, and the sea ice will shrink due to the melting effect.

The land will rise without the effects of climate change to some extent, which is not totally true. This is because the source of land uplift in the area is totally unrelated to climate change. However, sea level rise due to the climate change effect might decline the land uplift level in some areas of the world. As a global expectation, the sea ice will decrease or shrink in the same way as predicted for the rest of the world.

> H_6: The potential of energy will decrease, and the surrounding temperatures will increase due to global warming.

The increased potential of energy expectation of this study was proved wrong, and the heating demands will in fact decrease. Moreover, the surrounding temperature will increase as expected due to global warming and the effects of climate change.

13 CONCLUSIONS

The purpose of the study was to identify the climate change effects in the environmental and water resources in Kvarken, Archipelago, Vaasa region, Finland. The following are the main findings of the study. Sea level rise, increase in volume, turbulence, and velocity is expected to happen in the waters of Raippaluoto. Due to salinity and nutrient intrusion, both the soil and freshwater will be polluted. Incidences of flooding and erosion are expected to rise. Much more in Northern Finland, but everywhere in the country, precipitation is predicted to increase. The cyanobacterial abundance is increasing, and the Merten Talo is expected to have higher blooming in the future. The area's fish stock will be affected by both temperature and cyanobacterial blooming. There will be higher average levels of wind, so the Merten Talo area will favor wind turbines. The sea ice is decreasing, and as already noticed in other parts of the world. The surrounding temperature is going to increase due to global warming. The use of microclimate in further climate change studies is suggested. With concern about combating climate change, the possible use of climate change as an advantage must be studied and implemented.

The ways of energy production are going to increase in the years 2021–2050, but a decrease in heating demand is also expected due to climate change. The thickness of ice is expected to decline over time causing an increase in wind power and wind disturbance to seawater. Furthermore, the resulting open water facilitates cyanobacterial blooming, oxygen availability, and temperature rise.

Over long periods of time, the levels of vegetation near the sea have increased following the land uplift. Sustainability along with adaption must be implemented throughout the country, and also globally. More sophisticated studies are recommended regarding the application and installation of possible new future energy resources, especially focused on securing renewable energy and combating climate change. The energy solutions planned for Merten Talo considers the area’s potential and are designed to show how the advantageous effects of climate change can be used for energy production. Most of these energy solutions employ new technologies that are hoped to reduce cost, increase efficiency, and minimize carbon emissions by acting as adaptive solutions for climate change.

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Girgibo, Nebiyu Wolde

2021, Vaasa, Finland

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