

# Adapting to Climate Change in Iceland

## CoastAdapt report



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## SUMMARY

- This report is a part of CoastAdapt, a transnational project that aims at developing and implementing a range of adaptation strategies and tools to enhance adaptation to climate change in coastal communities.
- The aim of this report is a) to give an overview of the existing knowledge of the impacts of climate change in Iceland and b) to give an overview of the status of the development of adaptation strategies and measures in Iceland.

### **Impacts**

- A comprehensive report on the expected impacts of climate change in Iceland was published by the Ministry for the Environment in 2008 (Björnsson et al., 2008). The first part of the current report is built on this work.
- Climate change is not likely to have severe economic impacts in Iceland in the short term. In fact, the short-term effects are likely to be favorable for agriculture and energy production.
- There is more uncertainty about the fisheries, which account for a large part of Iceland's exports. Warming is likely to lead to greater productivity in the ocean, but this might be halted by increased acidification of the oceans. Ocean acidification is a growing concern in Iceland.
- Glaciers cover 11% of Iceland. They have been melting and it is expected that they will disappear in the next 150-200 years.
- It is likely that warmer winters and expanding forests contributed to the settlement of 35 new bird species in Iceland in the 20th century. However, most stocks of sea birds are in decline, probably due to changes in the marine ecosystems.
- There is still uncertainty concerning the impacts of warming on roads in Iceland. The main challenge is seen to be more frequent freeze-thaw cycles. In the past 15 years, the Road Administration has observed increasing mid-winter "spring thaw" events that lead to faster deterioration of the roads.
- Melting of the polar ice will open up new routes of transportation by sea. Increased traffic in the high north may bring new opportunities for Iceland to provide diverse services to the vessels.

## Adaptation

- The government issued a Climate Change Strategy (CCS) in 2007, focusing on mitigation measures. In general, climate policy in Iceland deals with mitigation, but adaptation may be an emerging issue. Iceland has no politically endorsed National Adaptation Strategy like many other European countries do.
- Climate adaptation measures in the CCS mainly involve the mapping of climate impacts. This was done in a report published in 2008 (Björnsson et al., 2008).
- There are indications that adaptation is seen as a relatively straightforward task in Iceland, in the sense that science will provide answers to politics. At the same time, the political, cultural and societal dimensions are played down. There is thus a need for increased knowledge on the different aspects of climate adaptation.
- The low strategic importance placed on climate adaptation may be due to the fact that short-term impacts of climate change have mostly been considered economically positive. This has influenced the framing of adaptation in the Icelandic context.
- Within the energy sector emphasis has been placed on predicting and adapting to potential changes in energy resources. An important part of this work was conducted in collaboration with Nordic energy companies (the project Climate and Energy Systems (CES)).
- Relevant information and tools, such as maps and databases, are needed to develop strategies and action plans. Lacking maps of flooding areas makes it for instance difficult to enforce building regulations and plan how cultural heritage may be protected.
- Ocean warming has caused the migration of an estimated fourth of the Atlantic mackerel stock into Icelandic territorial waters. Iceland has requested a share in the joint quota of Norway, the Faroe Islands and the EU. The negotiations have not been successful and in the past years Iceland has unilaterally given out quotas for their own catch. This has led to an international dispute and shows the multi level nature of climate adaptation. While some measures focus on local or national issues, other challenges may be on multi-national levels.
- Acidification of the ocean is a growing concern in Iceland. Dissolving carbon dioxide from the atmosphere lowers the pH of the seawater. While the effects of acidification on marine organisms and ecosystems are not fully understood, their implications may be very serious.
- The growth and productivity of plants has increased with warming in the past years. This has had a positive effect on the recovering of eroding land, a process that needs to be more closely monitored. Invasive species, plants, fungi and insects, are an increasing threat addressed in the revision of the Nature Conservation Act. The Agricultural University of Iceland has studied growing possibilities of cultivating barley and other cereals. The production of barley has increased dramatically and is expected to continue to do so.
- In the transport sector, roads must be prepared to withstand more frequent freeze-thaw cycles and rising sea levels must be taken into account when roads are designed. Expected sea level rise is already accounted for in the construction of harbour facilities and the maintenance and reconstruction of old ones.

- Marine transport in the Arctic Ocean is expected to increase with the melting ice in northern regions. There is a need to enhance marine safety, take actions to protect the environment and build up marine infrastructures in the Arctic. The Icelandic government is taking part in international cooperation in this field.
- Adaptation to climate change involves the whole society. While some programs of public participation focus on involving stakeholders in decision making, others may focus on expert-lay cooperation in monitoring, understanding and reacting to environmental changes. Interesting examples of such collaboration can be found in the Icelandic Glaciological Society and in programs involving farmers in soil conservation.
- Because of frequent volcanic eruptions, earthquakes, avalanches and melt-water floods, Icelanders have considerable experience in dealing with natural disasters. As extreme weather events may increase with climate change, threatening coastal communities, it was decided to include civil protection and community recovery after trauma in the CoastAdapt project (see separate reports).
- People are aware of the importance of climate adaptation in various fields in Iceland and considerable knowledge on related issues exists. However, the knowledge is dispersed and better overview is needed over ongoing adaptation projects. Improved tools such as maps and databases are needed in order to address adaptation.

# 1 INTRODUCTION

In the last couple of decades mitigation has been the main concern of climate policy. Recently, with influential reports such as the Stern Review on the Economics of Climate Change (2006), the attention has turned towards adaptation. This reflects the fact that impacts of global warming are already observed around the earth, and even if mitigation efforts prove successful there will be a time-mismatch as today's actions to decarbonize take at least several decades to have a discernible effect on climate (Pielke et al., 2007). It is likely that some level of adaptation will be necessary in most parts of the world.

Agder et al. (2005) define adaptation to climate change as "an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of climate change or take advantage of new opportunities" (p.78). Adaptation is thus not only about reacting to negative changes, but involves recognizing the benefits as well. Whether adjusting to negative or positive impacts, adaptation relies on extensive knowledge of ongoing changes in natural systems and the capacity of society to react to these. It is not sufficient to gather information, an effort must also be made to ensure that experts, policy makers and the public have access to it.

Adaptation is not a technical task. Effective adaptation is not carried out by climate experts, it involves the participation of various groups in the society. Hence, adaptation policies need to include measures to involve the public, both in producing knowledge and making decisions. Adaptation can be a highly political issue. Choices between different paths in adapting are not necessarily straightforward or uncontroversial. Adaptation measures may affect people differently. Therefore functional political institutions and an inclusive political culture may be of key importance in adaptation. Moreover, adaptation issues may move beyond local and national levels to include foreign relations (Barnett, 2003).

Science alone will not provide answers to adaptation issues. Experience has shown that increased knowledge may increase the demands for effective political institutions and an inclusive political culture (see e.g. Jasanoff, 2004). Indeed, there has been a growing concern about public participation and stakeholder involvement in environmental issues, including climate change (Few et al., 2007; Irwin, 2006; Burton et al., 2002). Adaptation may also be limited by social and cultural factors, such as values and perceptions of risk (Adger, 2009).

This report is a part of CoastAdapt, a transnational project focused on adaptation measures on the local level. The CoastAdapt cooperation was initiated by the local authorities of the Outer Hebrides off the west coast of Scotland after a severe storm hit the islands in 2005. The aim of CoastAdapt is to develop, implement and make accessible a range of adaptation strategies and tools to enable people living in coastal communities to deal with the impacts of climate change. Two municipalities in southern Iceland, Árborg and Mýrdalshreppur,

take part in the project. One of the project aims is to give an overview of existing knowledge on climate impacts and adaptation strategies in several pilot sites in the North Atlantic. This report provides an overview of the status of knowledge on climate impacts and adaptation issues and measures in Iceland. The report is not intended to be comprehensive, but rather to draw forth some of the main concerns for climate adaptation in Iceland.

The next chapter is a summary of the impacts of climate change in Iceland, mainly based on a report published by the Ministry for the Environment in 2008 (Björnsson et al. 2008). Chapter four then gives an overview of the key adaptation issues in the Icelandic context.

## 2 CLIMATE CHANGE IMPACTS IN ICELAND

The Icelandic Minister for the Environment established a scientific committee on climate change in the autumn of 2007 to provide a summary of the existing knowledge on possible impacts of climate change in Iceland. A report was issued the following year (Björnsson et al. 2008). This chapter is a short summary of the main results found in the report with additions where appropriate.<sup>1</sup>

### 2.1 TEMPERATURES AND PRECIPITATION

- Average annual temperatures in Iceland have risen by 0.7°C per century since 1800. Sea ice that used to be common in the vicinity of Iceland has nearly disappeared in the past 30 years.

- It is likely that average temperatures will continue to rise in the coming years by about 0.2°C per decade. Winter temperatures will rise more than summer temperatures.

- Precipitation is expected to increase by about 0.4% to 0.8% per decade. The winters will be warmer with less snow, and warm summers will be more common.

- Storms will most likely stay similar or decrease.

- Warming in Iceland has been faster in the recent years than predicted the IPCC models. Recent warming is most likely due to a natural local conditions accompanied by the influence of global warming. The expected warming in this

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<sup>1</sup> The additions are referred to specifically. The main material is from Björnsson



century is likely to be uneven, with alternating slow and rapid warming periods (Björnsson et al., 2011).

## 2.2 SEA TEMPERATURE AND SALINITY

- The observed average sea temperature and the salinity of the sea south and west of Iceland were higher in 1998 and 2008 than in the decades before.

## 2.3 SEA LEVEL RISE

- The sea level in Reykjavík rose on average by 3.6 mm annually from 1956 to 2007. Accounting for the average subsidence in the Reykjavík area the average annual rise is 1.5 mm, which is in accordance with IPCC predictions.

- From 1997 to 2007 the sea level rise was more rapid, or 5.5 mm annually on average.

- Other events affect sea level rise in Iceland. In the southwestern parts, including the capital area, the land is subsiding, whereas the southeastern coast is rising, reducing the effects of sea-level rise in these areas.

## 2.4 GLACIER MELTING

- Glaciers that now cover about 11% of the surface of Iceland have advanced and retreated with time. They were considerably smaller during the settlement period some 1100 years ago. During the periods of colder climate they grew and reached their maximum in the late 19<sup>th</sup> century.

- Most of the Icelandic outlet glaciers retreated slowly in the beginning of the 20<sup>th</sup> century, but during a warm period between 1920 and 1960 the retreat accelerated. From 1960 to about 1990 the climate cooled again, the glaciers stopped retreating and some even advanced during this period.

- The retreat started again in the 1990's and has been rapid since the turn of the century (see picture 1). It is expected that the down wasting of the glaciers will increase in the 21<sup>st</sup> century resulting in their disappearance in the next 150-200 years (Jóhannesson et al., n.d.).



*Picture 1: Fjallsárlón lagoon in front of the glaciers Hrutárjökull and Fjallsárjökull in southern Vatnajökull glacier. Both glaciers have retreated fast in the past years. Photo: ÁJ*

## 2.5 HYDROPOWER PRODUCTION

- The Icelandic economy relies on hydropower. Hydropower provides about 73% of the electricity while 27% are geothermal. Roughly 80% of the energy produced by hydropower is sold to heavy industry, mostly aluminum smelters (Landsvirkjun, 2010a). Aluminum accounted for 43% of Iceland's exports in 2010 (Statistics Iceland, 2011).
- The runoff from Icelandic glaciers has increased in the past years due to warmer weather. This has resulted in increased production of energy compared to what was expected.
- Warming is likely to have substantial impacts on hydro-resources in Iceland. A simulation that assumed a mean warming of 2.5-3° C between the periods of 1961-1990 on the one hand and 2071-2100 on the other, projected a 25% increase in runoff in that time (Jóhannesson et al., n.d.).

## 2.6 THE FISHERIES

- Fish accounts for about 39% of Iceland export revenues (Statistics Iceland, 2012). About 30 species of fish and invertebrates are exploited commercially and the annual catch increased from about 200,000 ton in the early 20<sup>th</sup> century to around 2 million ton in the beginning of the 21<sup>st</sup> (Astthorsson et al., 2007).

-In the 20<sup>th</sup> century, changes in sea temperature proved to have extensive effects on the fisheries. The temperature of the ocean around Iceland has been rising since 1996. In the same period the stocks of some commercial species, such as haddock, saithe and monkfish, have grown.

- The reaction of marine ecological systems to increasing temperatures is hard to predict. Nevertheless, the overall productivity of the oceans around Iceland is expected to increase. The warming of the ocean has probably contributed to the fact that herring has now recovered after extensive overfishing in the 1960's. Coldwater species such as capelin has moved further north. Southern species such as haddock, whiting, saithe, herring and monkfish that have traditionally mainly been found south of Iceland are now caught north of the country as well (Gíslason, 2011).

- The effects of ocean acidification on marine systems are highly uncertain. New research suggests that this might be a more serious threat than previously believed (Rummukainen et al., 2010; Ministry for the Environment, 2010b).

## 2.7 AGRICULTURE AND FORESTRY

- A warming climate will, in general, have positive effects on plant growth in Iceland. The effects of the warming in the past 15 years are observed in increased production of the vegetation. This is likely to continue. The conditions for agriculture and forestry have improved and are likely to continue to do so (see picture 2).

- Traditionally, Icelandic agriculture has for the most part been based on sheep farming and dairy production and more recently, industrial poultry production. Some hardy vegetables such as potatoes and carrots are grown outdoors while tomatoes, peppers and cucumbers are grown in greenhouses. The production of hay for animal feed increases by about 16% with each °C of warming.

- If the climate warms by 1.5 to 2° C° in the next decades new crops and commercial plants may be able to grow in Iceland, including oats, barley, wheat and berries. Conditions for the production of potatoes, carrots and turnips are likely to improve (Gudleifsson, 2004).

- One study showed that given a certain increase in CO<sub>2</sub> levels and an average temperature increase of 2-4° C, the growth of black cottonwood (*Populus trichocarpa*) is likely to increase by 26% to 35%.

- On the downside, pests such as non-indigenous insects are likely to increase and introduce new challenges to agriculture and forestry in Iceland (Gudleifsson, 2004).



*Picture 2: Birch in Bæjarstaðaskógur, Morsárdal, southern Iceland. Locals have noted a substantial change in the growth rate and distribution of birch trees in the past 10-15 years.  
Photo: Áj*

## 2.8 FOOD SECURITY

- Climate change may affect food security in Iceland, but according to a report published in 2011 it is difficult to predict whether these changes will be positive or negative. Agriculture and fishing are expected to become more productive, but there is still much uncertainty about the effects of potential acidification of the ocean and of sea level rise and melt water floods on farmland (Bailes and Jóhannesson, 2011).

## 2.9 BIRD LIFE

- Warmer winters along with the growing Icelandic forests are likely to have contributed to the settlement of 35 new bird species in Iceland in the 20th century. However, most stocks of sea birds are in decline, probably due to changes in marine ecosystems (see picture 3).



**Picture 3:** *The arctic tern (Sterna paradisae) is particularly vulnerable to environmental changes due to its short nesting period. Widespread breeding failures that have been reported from around Iceland in the past years may be linked to a lack of sand eel in the oceans (Vigfúsdóttir et al., n.d., University of Iceland, 2010).*

*Photo: Bjarni Reyr Kristjánsson*

## 2.10 ENVIRONMENTAL RISK

- The effects of climate change on environmental risk or natural hazards in Iceland are uncertain. Snow avalanches are expected to be less frequent. However, due to a reduction in the suspended load of the Icelandic glaciers on volcanoes some increase in volcanic activity and melt water floods may be expected. Floods due to thawing may also present an increased risk. Bush and forest fires may increase.

## 2.11 ROADS AND TRANSPORT

-There is still uncertainty concerning the impacts of warming on roads in Iceland. The main challenge is seen to be more frequent freeze-thaw cycles. In the past 15 years, the Road Administration has observed an increase in mid-winter “spring thaw” events that lead to excessive deterioration of the roads. An automatic monitoring network for frost depth in the road sub-base and a daily prognosis model based on weather forecasts have been developed to enable a more effective axle-load management of the roads (Nordic, n.d.).

-Research is being conducted on how roads will be affected by glacier melting and increased annual runoff on river channels. Sudden snow melts and intense precipitation may cause an increase in flooding events that exceed the drainage capacity of bridges and culverts. Sea level rise may also threaten roads in low lying coastal regions (ibid).

- The melting of the polar ice will open up new sea routes of transportation. Increased traffic in the High North may bring new possibilities for Iceland to provide diverse services to vessels, but places simultaneously increased threats of environmental disasters.

## 2.12 CONCLUDING SUMMARY

- On the whole it can be said that in the short-term climate change is not likely to have severe economic impacts in Iceland. In fact, the short-term effects are likely to be favorable for agriculture and energy production. There is more uncertainty about the fisheries, which currently account almost half of Iceland's exports. Warming is likely to lead to greater marine productivity, but this might be haltered by increased acidification of the oceans, which is of growing concern in Iceland.

- In the long run, climate change is likely to alter both the landscape and ecosystems of Iceland. Glaciers are retreating fast and vegetation grows at higher altitudes than before. Migrating species may place challenges to the existing ecosystem, both with new settlers and species that cannot withstand the change in the climate.

## 3 ADAPTATION TO CLIMATE CHANGE IN THE ICELANDIC CONTEXT

### 3.1 INTRODUCTION: ICELAND'S CLIMATE CHANGE POLICY

The government of Iceland issued a Climate Change Strategy (CCS) in 2007. The main objectives and measures are classified under five themes (Ministry for the Environment, 2007):

- The Icelandic government will fulfill its international obligations according to the UN Framework Convention on Climate Change and the Kyoto Protocol.
- Greenhouse gas emissions will be reduced, with a special emphasis on reducing the use of fossil fuels in favor of renewable energy sources and climate-friendly fuels
- The government will attempt to increase carbon sequestration from the atmosphere through afforestation, revegetation, wetland reclamation, and changed land use.
- The government will foster research and innovation in fields related to climate change affairs and will promote the exportation of Icelandic expertise in fields related to renewable energy and climate-friendly technology.
- The government will prepare for adaptation to climate change.

As these objectives portray, Iceland's climate change policy is mainly focused on mitigation issues. The first three objectives and partly the fourth all relate to climate mitigation. It is only in the last point that attention is pointed toward adaptation. Iceland has no politically endorsed National Adaptation Strategy as many other EEA member countries do (European Environment Agency, 2011; Ribeiro et al., 2009).

The measures related to adaptation in the CCS are three:

- A scientific committee is to be established to assess the impacts of climate change in Iceland in the near future. The committee is to define important adaptation areas.
- Sea level rise should be accounted for in urban planning and coastal structures. The probability of flooding should be assessed.
- The opportunities and threats of increased marine traffic in the Arctic region should be assessed (Ministry for the Environment, 2007).

The scientific committee mentioned delivered their report in 2008 (Björnsson, 2008) (see chapter 2), which gives an excellent overview of important issues relating to likely changes in natural systems and energy production and their immediate effect on industries such as agriculture and fishing. The report assembles existing basic knowledge regarding climate change impacts and provides an important ground for further adaptation measures.

Whether adaptation will emerge as a key strategic issue in Iceland depends on how climate adaptation issues are framed in the near future. In the past, the impacts of climate change have largely been understood as socio-economically advantageous. This is for instance reflected in a speech by former Minister for the Environment Jónína Bjartmarz in 2006:

Iceland is not as vulnerable to the possible impacts of climate change as countries that deal with drought or low lying tropical islands, where nations envision a struggle for their lives because of a rising sea level and increased risks of cyclones. The infrastructures of the society are strong and the nation is rich, but generally it is expected that the poorest nations will struggle the most to adapt to changing precipitation and agriculture and other impacts of global warming (Bjartmarz, 2006, translation ÁJ).<sup>2</sup>

Since Bjartmarz' speech, the Icelandic economy has undergone a dramatic recession, which as had considerable effects on the public sector. This may have lead to a decreased emphasis on issues such as climate change, as hinted at in speech by Hafdís Gísladóttir, who was at the time the political advisor of the Minister:

Some will ask whether we can afford to act on climate change in this recession. It is clear that the space for action is currently limited even in actions that are expected to be economically rewarding in the long term (Gísladóttir, 2011).

However, concerns about adaptation seem to be growing and new framings of the issue might be emerging. It has been pointed out that the fact that the Icelandic economy is rests mainly on two industrial sectors, fisheries and aluminum production, may increase its vulnerability (Kristófersson, 2011). In addition issues like the acidification of the ocean receives increasing attention (see e.g. the Ministry for the Environment, 2010b).

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<sup>2</sup> „Ísland er ekki jafn viðkvæmt fyrir mögulegum afleiðingum loftslagsbreytinga og t.d. lönd sem glíma við þurrka eða láglend eyríki í hitabeltinu, sem sjá jafnvel fram á baráttu fyrir tilveru sinni vegna hækkunar sjávarborðs og aukinnar hættu á fellibyljum. Innviðir samfélagsins eru sterkir og þjóðin rík, en almennt gildir að fátæk lönd munu eiga erfiðast með að laga sig að breyttu úrkomumynstri og ræktunarskilyrðum og öðrum fylgífiskum hnattrænnar hlýnunar.“



Adaptation is also brought forward in international cooperation, for example in matters of the High North addressed by the Arctic Council. In the High North Policy of the current government adaptation issues are addressed although they are not explicitly framed as such (Alþingi, 2011b). A report published in 2009 on Icelandic interests and cooperation in the High North deals with adaptation issues, such as the socio-economic impacts of melting ice, increased marine traffic in the High North and needs for increased cooperation on environmental issues in the Arctic. However, these are not specifically framed in terms of adaptation (Ministry of Foreign Affairs, 2009).

At the local level little information on adaptation and related actions is very scarce. Stefán Gíslason at Environice Consulting conducted an informal survey in all 77 Icelandic municipalities in February 2010. He received responses from 21 of those. Four municipalities responded that they “had done something” to adapt to climate change, whereas 17 responded that they “had done nothing”. None of these had a climate adaptation strategy in place, and only one, the capital Reykjavík, had a strategy focused on mitigation<sup>3</sup> (City of Reykjavík, 2009).

Preparing this report included interviews with several persons within the Icelandic administration, municipalities and research institutes. Most of them were genuinely concerned about climate change, especially impacts such as ocean acidification, melting of the glaciers and decreasing sea bird stocks. Some pointed out that it was necessary to go beyond thinking only about the short-term effects within Icelandic national boundaries, to a focus on Iceland as a part of a global community dealing with serious socio-environmental challenges. In the 2012 New Year’s Address, Prime Minister Sigurðardóttir placed more emphasis on climate change issues than she or her predecessors have done on such occasions before.<sup>4</sup> This may indicate an increasing concern within the administration.

Despite the low emphasis on climate adaptation in policymaking, a number of issues related to adaptation are being addressed in different institutions and sectors in Iceland. The following is an attempt to give a general view of some of these.<sup>5</sup> This is not intended to be a comprehensive summary, but rather to give a

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<sup>3</sup> Personal communication with Stefán Gíslason on December 17<sup>th</sup> 2010.

<sup>4</sup> Thanks to Árni Finnsson for pointing this out to me.

<sup>5</sup> This section is partly built on conversations with experts from the following organizations (in alphabetical order): the Agricultural University of Iceland, Árborg Municipality, the Archaeological Heritage Agency, the Association of Municipalities, the Civil Protection Department of the National Commissioner of the Icelandic Police, the Environment Agency of Iceland, the Icelandic Maritime Administration, the Icelandic National Planning Agency, Ministry for Foreign Affairs, Ministry of the Environment, Ministry of Fisheries and Agriculture, Ministry of Industry, Energy and Tourism, the Ministry of Transport, Communication and Local Government, the Icelandic Meteorological Office, Mýrdalshreppur Municipality, Reykjavík Municipality, the Soil Conservation

general idea of the issues at stake and the status of climate adaptation in Iceland. However, before turning to adaptation, a short overview of measures relating to mitigation will be provided.

### 3.2 MITIGATION

The CCS declares an aim of 50-75% reduction of greenhouse gas emissions (GHG) before the year 2050 and states that Iceland will take part in a European effort to reduce GHG by 30% by 2020. At the time the CCS was issued, the Minister for the Environment established a committee to suggest how GHG could be reduced and explore sequestration potentials. The committee concluded the work with a report in 2009 (Davíðsdóttir et al., 2009).

The report shows GHG emissions in Iceland rose by 32% from 1990 to 2007. The largest contributor to the increase was heavy industry. GHG emissions from the ferrous alloys industry rose by 91% and by 72% from the aluminum industry. Emissions decreased only in two industries during the period: agriculture (7%) and fisheries (18%) (ibid: 11).

In November 2010 the Government adopted a plan to achieve GHG reduction goals based on the report (Ministry for the Environment, 2010a). Ten steps towards reduction were identified as well as a variety of other measures to accomplish the goal. The main steps include adopting emissions trading systems and a carbon tax, increased emphasis on clean transport and building up forestry and soil conservation. A committee including representatives from all of the ministries will issue an annual evaluation of the action plan. The first evaluation is expected in January 2012.<sup>6</sup>

The Environment Agency of Iceland (Umhverfisstofnun) is in charge of producing emission data for Iceland by maintaining a greenhouse gas inventory. The results are published annually (see Hallsdóttir et al., 2011). The latest issue shows that GHG emissions in Iceland rose by 35% from 1990 to 2009. The energy sector is the largest contributor to GHG emissions in Iceland followed by industrial processes. Together these account for almost 80% of the GHG emissions in Iceland (ibid).

A Transportation Strategy (Samgönguáætlun) for the years 2011 to 2022 includes steps towards more sustainable transportation, such as improving bicycle trails, increased education about sustainable transportation and

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Services of Iceland the University of Iceland and Vegsýn (that cooperates with the Icelandic Road Administration).

<sup>6</sup> Personal communication with Thorsteinn Tómasson at the Ministry of Fisheries and Agriculture, January 16, 2012.

development of economic incentives to stimulate the use of public transportation and discourage the use of private cars (Alþingi, 2011a).

Measures to decrease GHG have been particularly effective in the fisheries. The Icelandic fishing fleet's mean annual consumption of fossil fuels is around 175 thousand tons with carbon emissions of about 550 thousand tons. The Icelandic Maritime Administration (IMA) has experimented with alternative fuels for the Icelandic fleet in order to decrease the dependency on fossil fuels and reduce CO<sub>2</sub> emissions. Since 2008, the IMA has collaborated with the Agricultural College of Iceland in developing bio-diesel from Icelandic rapeseed (Bernóðusson et al., 2010).

### 3.3 ENERGY PRODUCTION

Seventy-three percent of electricity in Iceland is produced in hydropower stations and 27% with geothermal vapor (Landsvirkjun, 2010a: 15). Around 80% of the energy produced in hydropower stations is sold to heavy industry, mostly aluminum smelters (picture 4).



*Picture 4: Búrfell Hydropower Station in Þjórsá, southern Iceland.  
Photo: Ásgeir Eggertsson/Landsvirkjun*

As the runoff of glaciers increases with more rapid melting, the capacity of hydropower stations also increases. Landsvirkjun produces about 96% of all hydropower in Iceland. In recent years, the company has observed increasing runoff in its power stations and takes into account when planning new constructions (Landsvirkjun, 2010b). The runoff is expected to increase by 16% until the year 2050, although the current technology can only handle an increase of about 6% (Blöndal Sveinsson, 2010). Technological measures are being planned to accommodate these changes.

As the glaciers melt, the water they produce initially increases but ultimately decreases again. The runoff is expected to peak in the period between 2030 and 2090. After that the runoff will decrease and is expected to be at its current state again around the year 2150.<sup>7</sup> In about 200 years the Icelandic glaciers will have all but vanished completely (Björnsson et al., 2008). Picture 5 shows volunteers and employees from Landsvirkjun Power Company collaborate in measuring the mass balance of the glacier Vatnajökull in the spring of 2009. Mass balance measurements have been performed on Vatnajökull every spring for a number of years. They provide important information about the difference between melting and sublimation.



*Picture 5: Mass balance measurements performed on Bárðarbunga in Vatnajökull in the summer of 2009. Photo: ÁJ*

In 2003-2006, Nordic Energy Research along with the energy sector in the Nordic countries funded a project called Climate and Energy (CE) led by the National Energy Authorities in Iceland (Orkustofnun) that aimed at assessing the impact of climate change on renewable energy resources in the Nordic countries. This included hydropower, wind power, bio-fuels and solar energy. The collaboration resulted in a report published by the Nordic Council of Ministers in 2007 (Fenger, 2007; Icelandic Meteorological Office, 2007). A new project, Climate and Energy Systems (CES), was launched in 2007, led by the Icelandic Meteorological Office in cooperation with Nordic Energy Research and the Nordic energy sector.<sup>8</sup> The two projects show that the predicted climate changes

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<sup>7</sup> Personal communication with Óli Grétar Blöndal Sveinsson, January 27<sup>th</sup>, 2011.

<sup>8</sup> The Icelandic partners in addition to the Meteorological Office were: Institute of Meteorological Research (Reiknistofa í veðurfræði), The National Energy Authority (Orkustofnun), Landsvirkjun, the University of Iceland and Hugur Ax Software Solutions.

in the next 40 years will have considerable effects on energy supply in the Nordic countries.<sup>9</sup>

An Icelandic project was conducted parallel to CES (Loftslagsbreytingar og áhrif þeirra á orkukerfi og samgöngur – LOKS). LOKS was funded by Landsvirkjun, the National Energy Authority (Orkustofnun) and the Icelandic Road Administration (Vegagerðin). Like CES it aimed at projecting changes in energy resources in the first part of the 21<sup>st</sup> century and suggest adaptation measures (Icelandic Meteorological Office. N.d. b).

### 3.4 SEA-LEVEL RISE AND FLOODS

#### 3.4.1 SEA-LEVEL RISE AND COASTAL FLOODS

Many factors influence the stress that rising sea levels impose on coastal areas. In Iceland, many coastal regions are made of solid rock, which reduces the risk of coastal erosion. Moreover, most coastal areas in Iceland are undergoing glacio-isostatic uplifts, reducing the negative effects of sea level rise (Björnsson et. al, 2008: 97). However, the most densely populated areas in the southwestern part of Iceland happen to be subsiding and therefore the most vulnerable to rising sea levels. Low-pressure storms are common in Iceland. Furthermore, the average wave height in the waters around Iceland is comparatively high. The combination of these factors contributes to stress and rapid weathering of the coastal areas.

The highest risk of coastal floods is when high surf is combined with low-pressure storms, in particular when they coincide with a high tide. The risk of coastal flooding is currently (independent of sea level rise) highest in the SW regions of Iceland, because of storm directions and low-lying land. Severe coastal floods occur in this area on average every 11 years. Levees and piers have been put up in various places, but these do not provide protection against serious floods, as happened in the capital area in 1799 and inundated areas that are now densely populated parts of the city<sup>10</sup> (Valsson, 2005). Valsson (ibid) points out the need to rebuild defenses around the low lying center of Reykjavík, in order to avoid negative impacts of the expected sea-level rise.

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<sup>9</sup> The results of CES are presented in 286 publications (Gjærde, 2011). These can be found at: <http://en.vedur.is/ces/publications/>

<sup>10</sup> Levees can, in certain instances when water flows over them, hinder the water from flowing out again, thus aggravating the flooding situation (Valsson, 2005).

It should be noted that climate change is not expected to lead to increased storminess in and around Iceland.<sup>11</sup> Increased risk of coastal floods in southwest Iceland would mainly be due to sea level rise coinciding with land subsidence.

Two reports were published in 1992 and 1995 in response to severe coastal floods in the 1980's and early 1990's. They include predictions about rising sea levels (Skipulag ríkisins, 1992; Vita- og hafnarmálastofnun et al., 1995) and information on how to reduce coastal flood damages. Possible impacts of climate change on sea level rise as predicted in the first IPCC reports in 1990 are discussed, including maps of risk areas in Reykjavík. Suggested countermeasures are based on expected sea level rise of 0.66 meters until the year 2100, an estimate that still stands (Björnsson et al., 2008: 105). Flood risks were reevaluated in 2008, showing that despite minor changes in expected sea level rise and land subsidence, the overall results of the earlier estimates were still valid.<sup>12</sup>



*Picture 6: Coastal defenses in Stokkseyri, southern Iceland. Photo: ÁJ*

Since 2008 the Icelandic Meteorological Office is responsible for risk assessment of natural hazards, including coastal floods. Building scenarios or mapping future impacts of sea-level rise has not yet begun at the IMO, but the need is recognized. Thus, the reports from 1992 and 1995 are still the latest information on coastal floods in Iceland.

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<sup>11</sup> Personal communication with Halldór Björnsson at the Icelandic Meteorological Office, Dec. 20<sup>th</sup>, 2010.

<sup>12</sup> Personal communication with Gísli Viggósson at the Icelandic Maritime Administration, Jan.27<sup>th</sup>, 2011.

Coastal defenses have been built in various areas to prevent flooding. Picture 6 shows levees in the village Stokkseyri in Árborg, one of the CoastAdapt test sites.

### 3.4.2 RIVER FLOODS

While increased melting of glaciers is known to increase the flow in glacial rivers, the relationship between river floods and warming is more uncertain. Winter floods will probably be more common, and this may reduce spring floods. Increased autumn precipitation is likely to raise the risk of flooding.

Glacial rivers in Iceland often shift their course as they cross sand plains formed by glacial melt water floods. In the past this caused problems for agriculture and land-use, as the rivers flowed over fertile land, destroying vegetation. In the 20<sup>th</sup> century, effort was made to build defenses to keep the rivers from spilling over fields and roads. Climate change might add to this challenge because as the glaciers retreat, new landscapes emerge, affecting the direction of the flow. This has for example taken place in the river Skeiðará in southern Iceland. In the past years, as the glacier Skeiðarárjökull has retreated, end moraines have directed the melting water further to the west, thus drying up the old riverbed. The Skeiðará Bridge, Iceland's longest bridge, inaugurated in 1970, now stands on dry land (see picture 7).

Melt water floods due to eruptions may become more frequent, with the possible increase in volcanic activity (Björnsson et al., 2008).

Attention was drawn to flood risk as several major rivers<sup>13</sup> flooded in Iceland in December 2006. It was acknowledged that more information on floods as well as an improved warning system were needed. Accordingly, the Icelandic Meteorological Office (IMO) launched a project to map food danger zones along several major rivers. Warning systems were improved to alert the IMO in case of floods in Hvítá in Árnassýsla, Norðurá in Borgarfjörður, Héraðsvötn in Skagafjörður, Hvítá and Ölfusá in Árnassýsla, Norðurá and Hvítá in Borgarfjörður, Eyjafjarðará in Eyjafjörður and Skjálfandafljót in northern Iceland. An alarm system was already in place for Héraðsvötn in Skagafjörður (Icelandic Meteorological Office, n.d. a). These alarms typically give local authorities several hours to react to the risk before the floods reach inhabited areas.

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<sup>13</sup> The most severe floods were in Hvítá in Árnassýsla, Hvítá in Borgarfjörður, Héraðsvötn in Skagafjörður and Skjálfandafljót in northern Iceland.





*Picture 7: The Bridge over Skeiðará in July 2010. Photo: ÁJ*

The IMO flood project's main aim was to map the floods of 2006 and gather information about earlier floods in selected rivers. The information is partly available to the public at the website [www.natturuvefsja.is](http://www.natturuvefsja.is).

In addition to mapping floods, the IMO and the University of Iceland have collaborated in a study on the public perception of flood hazards and flood risk in the lower Ölfusá basin in Árborg municipality. The results indicate that knowledge of flooding is largely based on people's personal experience of such events. There is lacking transfer of knowledge to younger people and newcomers. In general, there seemed to be poor awareness of past inundations in the Árborg area (Pagneux et al., 2010).

### 3.4.3 FLOODS, BUILDING REGULATIONS AND DEFENSIVE MEASURES

According to Planning Regulations from 1998, flood areas should be marked on Municipal Plans (and land use restrictions specified in natural hazards zones). Defenses that are in place or planned should be specified. The regulations prohibit planning of building plots in places that have been damaged in natural disasters. Lack of both information and maps of disaster prone areas has made it difficult enforce these rules. These are both scarce and scattered in different organizations and the responsibility for producing such knowledge is unclear. This is especially the case with coastal floods, while river floods have been dealt with extensively in a recent IMO project. It is worth noting that in times of changing climate and rising sea levels, looking at the past may not necessarily be



the best way to predict the future. The regulations do not account for future uncertainty in relation to climate change.<sup>14</sup>

In the absence of a centralized mapping effort, municipalities lack information which makes it difficult to enforce regulations. Two reports on coastal floods published in 1992 and 1995 (Skipulag ríkisins, 1992; Vita- og hafnarmálastofnun et al., 1995) include a number of suggestions on how to take predicted sea-level rise into account and prevent damage from coastal floods. On the southwest shore, new buildings standing 50 to 200 meters from the shoreline, or even further in unprotected areas, must be raised by half a meter to 4.6 – 4.8 meters (suggestions vary in different regions). These suggestions have been adopted as a directive but do not have a legal status.<sup>15</sup>

### 3.5 THE MACKEREL DISPUTE

In the past years, the stock of mackerel in Icelandic waters has increased considerably and it is estimated that about 23% of the stock move currently through Icelandic territorial waters (Ministry of Fisheries and Agriculture, 2011). Ocean warming is thought to play an important role in this development (Committee on the fishing of mackerel, 2011). The increase of mackerel may contribute to the collapse of sand eel which has been observed in recent years, but sand eel is an important feed for sea birds (Mbl.is, 2011). Research indicates that the mackerel increases its weight by 60% during its summer stay in the Icelandic waters (Ministry of Fisheries and Agriculture, 2011).

Iceland has requested to participate in the joint quota of Norway, the Faroe Islands and the EU. The negotiations have not been successful and in the past years Iceland has unilaterally given out quotas for their own catch (Committee on the fishing of mackerel, 2009) which has met with protests in the EU and Norway.

The export of mackerel in 2011 was worth 25 billion Icelandic krónur<sup>16</sup> amounting to 5% of Iceland's exports. The Ministry of Fisheries and Agriculture estimates that mackerel fishing has created around 1000 new jobs. It is thus clear that it is in the interests of Iceland to continue the battle for a share in the joint quota. The same goes for the other parties involved, mackerel is, for example, the most valuable stock in the Scottish fishing industry (Banks, 2011).

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<sup>14</sup> Personal communication with experts at the Icelandic National Planning Agency, February 23rd, 2010.

<sup>15</sup> Personal communication with experts at the Icelandic National Planning Agency, February 23rd, 2010.

<sup>16</sup> 25 milljarðar króna.

Although, the effects of warming on mackerel migration are not certain, the mackerel controversy portrays how climate may affect foreign policy.

### 3.6 ACIDIFICATION OF THE OCEAN

The impacts of climate change on the ocean are not only observed in terms of species composition but also in the ocean's chemistry. As carbon dioxide from the atmosphere dissolves in seawater the pH of the ocean decreases. There is an increasing concern about this process, known as the acidification of the ocean.

One consequence of the increasing acidity of the ocean is related to the formation of shells and plates out of calcium carbonate ( $\text{CaCO}_3$ ). The process where calcium carbonate solidifies is called calcification and is important to the survival of organisms that use calcium carbonate to build their skeletal structures. If solidified calcium structures come into contact with water that is undersaturated in calcium, they become vulnerable to dissolution. Thus, it is vital for marine organisms that form calcium carbonate, such as cold-water corals and sea urchins, that the ocean is supersaturated with  $\text{CaCO}_3$ . As the ocean acidifies, the calcium carbonate saturation decreases. Many of the organisms endangered by ocean acidification provide essential food to other species, so their disappearance may have widespread effects

Biological communities in cold waters are more vulnerable to ocean acidification because calcium carbonate saturation depends on temperature. Research indicates that the calcium carbonate saturation decreases faster in the oceans north of Iceland than on average in warmer waters.

The effects of acidification on marine organisms and ecosystems are still unclear. Experiments indicate that species react in different ways to ocean acidification. However, geo-historical analysis of similar events in the past shows that rapid increase in  $\text{CO}_2$  in the atmosphere can have serious implications for marine life in general (Egilsdóttir, 2011).

There is rising concern about ocean acidification within the Icelandic administration. No specific measures have been taken so far, but the Ministry for the Environment closely follows new evidence on the issue.

### 3.7 SOIL CONSERVATION

Land degradation and soil erosion have posed serious environmental problems in Iceland in the past centuries. Overgrazing has been identified as the main culprit, but other factors, such as cooler periods and melt water floods from glaciers may also be important (Arnalds and Barkarson, 2003). The Soil

Conservation Service of Iceland (SCSI) was founded in 1907 to combat soil erosion and desertification.

A part of the work conducted by the SCSI is based on collaboration with farmers around Iceland, who are provided with seed and fertilizers to help combat desertification on their land. The SCSI also provides expert advice to farmers.

Air temperature has risen in Iceland in the past 15 years causing noticeable increase in plant growth. Many species are found in new areas and higher altitudes (see picture 8). One of the experts interviewed said that desert land seemed to have recovered “at an extraordinary scale” in the past years, although data lacked to substantiate it. Although overall monitoring systems are still to be established, research programs on changes in vegetation are being carried out (Guðbrandsson 2011a, 2011b). In addition to climate change, other factors, like changes in sheep grazing, also affect vegetation and their effects may be hard to separate.



*Picture 8: Birch plants on gravel plain in Örfæfaveit, southeast Iceland in the summer of 2010. Locals describe an extraordinary proliferation of birch on these desert sand planes in recent years. Photo: ÁJ*

### 3.8 INVASIVE SPECIES

Invasive, non-native species such as lupine (*Lupinus nootkatensis*) and chervil (*Anthriscus sylvestris*) have proliferated in the warm period of the past 15 years, in some cases radically altering the ecosystem and leading to a decline in diversity. Invasive species also challenge agriculture as they spread over cultivated land. This is a new threat, as invasive plant species have not been a problem in the past, partly due to climate conditions.

The SCSi and the Icelandic Institute of Natural History recently published a report on the challenges posed by lupine and chervil (Icelandic Institute of Natural History et al., 2010) stating that these invasive species have spread wider than previously thought. The adoption of an action plan to curb the spread of lupine and chervil is recommended. The SCSi is currently developing methods to hinder the spread of lupine (Einarsson et al., 2009; Eyþórsdóttir et al., 2009; Guðbrandsson 2011b, Jóhannesson et al., 2009). New and invasive species of insects and fungi that pose harm to plants have also been proliferating in the past years (Maack, 2012).

The Nature Conservation Act (Náttúruverndarlög) is being revised and will include suggestions on the restriction of non-native species in Iceland (Gísladóttir et al., 2011).

### 3.9 THE CULTIVATION OF BARLEY

Farming in Iceland is vulnerable to changes in climate. Iceland is situated on the boundary of two biomes: the tundra and the boreal forest. During cold periods, the tundra expands and vice versa. The frontier of land suitable to agriculture in Iceland is equally sensitive to climatic shifts (Bergþórsson, 1985). The main crop is hay and the climate is too cold for most types of cereals. However, it is thought that cereals were cultivated in Iceland during the settlement of the country in the 9<sup>th</sup> and 10<sup>th</sup> centuries. In the recent warming period experimenting with cereal production has gained interest. Cereals were produced on around 200 hectares of land in 1991, by 2007 this had grown to more than 3600 hectares. It is expected that conditions for cereal production in Iceland will continue to improve with climate change.

Barley is the main cereal crop and is currently produced mostly for animal feed. The Agricultural University of Iceland has worked on the development of barley for Icelandic conditions since the 1960's (Intellecta, 2009; Tómasson et al., 2011; see also Gudleifsson, 2004). The harvest of barley was about 11,600 tons in 2007, about equal to the amount imported for animal feed (ibid). A Committee on increased corn production in Iceland estimates that the national market for barley could grow to at least 40,000-50,000 tons and even to 80,000 tons in the coming decades (Tómasson et al., 2011).

### 3.10 CULTURAL HERITAGE

The report *Climate Change and Cultural Heritage in the Nordic Countries* was published by the Nordic Council of Ministers in November 2010 (Kaslegard, 2010) with the participation of the Archaeological Heritage Agency of Iceland

(AHAI). In general, cultural heritage in Iceland is not greatly threatened by climate change. In fact, warming may in some ways have positive effects on cultural heritage, for example where increased vegetation reduces erosion in archaeological sites. However, there is still some uncertainty about specific issues such as the effects of rising sea levels. The AHAI experts concluded that while considerable knowledge has been gathered on the impacts of climate change in Iceland, this needs to be translated into maps, databases and other tools that can be used to evaluate impacts on cultural heritage. In this respect, Iceland differed from Norway, Denmark and Finland, where considerable effort has been put into developing necessary tools for effective adaptive measures for cultural heritage.<sup>17</sup>

Among the effects of climate change on cultural heritage is increased vegetation, displacement of vegetation zones and changes in the composition of species. The report takes as example the national park of Þingvellir in Iceland (p. 31), which is on UNESCO's World Heritage list. This was the site of the general assembly in Iceland from the year 930 until the 18<sup>th</sup> century, important events in Icelandic history took place there and it is of major cultural significance for the Icelandic people. Many archaeological traces from the time of the early Alþingi are still visible at Þingvellir, such as numerous ruins of turf and stone houses. As mean temperatures have increased in the past years, the low birch woods have grown considerably and new species have made their way into the area, contributing to significant changes in the landscape. The report concludes that there is great risk that the turf and stone will be overgrown and much less visible. Furthermore, the roots of increasing vegetation may cause damages to the cultural heritage. Countermeasures are being taken in the management of the National Park and non-indigenous species are systematically kept under control (Kaslegard, 2010).

### 3.11 ROADS

The impacts of climate change on roads in Iceland are being registered and countermeasures suggested (Þórðarson, 2010). A major issue concerns the development of road materials and structures that can sustain more frequent freeze-thaw cycles, increased road surface temperature in the summer, and increased precipitation. In coastal areas road construction must take rising sea levels and changing weather conditions into consideration.

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<sup>17</sup> Personal communication with a AHAI expert, January 4, 2012.



**Picture 9:** The road over Mýrdalssandur crosses a flood plain, which is the likeliest runway of melt water during eruptions in the volcano Katla. Such melt water floods can cause heavy damage to roads (Björnsson et al., 2011). Photo: ÁJ

### 3.12 HARBOR FACILITIES

The Icelandic Maritime Administration (Siglingastofnun Íslands) accommodates expected sea level rise in its constructions of harbors. Harbor structures around the country are gradually being raised as sea level rise is taken into consideration when new harbors are constructed and when old ones are renovated (Þórðarson, 2010).

### 3.13 THE OPENING OF THE ARCTIC SEA ROUTES

The retreat of the polar ice north of Siberia opens the possibility for all-year transportation between the North Pacific and North Atlantic via the so-called Northeast Passage. The passage has been used sporadically by small crafts for several years and shipping companies are increasingly looking at the possibility of using the route for large tankers (Black, 2011). This can result in a drastic increase in marine transport traffic around Iceland (Valsson and Úlfarsson, 2009; Maack, 2011). Although this can lead to increased costs for Iceland, for example for the coast guard, it can also provide new sources of income to harbors and coastal communities, especially on the north and east coast (Jónsson, 2006).

The Minister of Foreign Affairs appointed a committee on the interests of Iceland in relation to the opening of the Arctic Sea routes which delivered a report in



2005 (Starfshópur um norðausturleiðina, 2005). The committee concludes that Iceland's global position makes it a good place to provide harbor services to ships in the high north. However the costs and environmental risks accompanying increased traffic and developing harbors in Iceland must be evaluated. Similar conclusions were reached in a conference on the opening of the Arctic Sea route held in Akureyri in March 2007 (Ísinn brotinn, 2007).

The Arctic Council, an inter-governmental forum of eight Arctic states including Iceland published in 2004 the Arctic Climate Impact Assessment (ACIA), which stated i.e. that reduced sea ice would probably increase marine transport and access to resources in the north. In the same year another report, the Arctic Marine Strategic Plan (AMSP), called for a comprehensive assessment of Arctic marine shipping. Following these two reports the Arctic Council launched such an assessment of Arctic marine shipping. In 2009 the Arctic Council Working Group on Protection of the Arctic Marine Environment (PAME) published the Arctic Marine Shipping Assessment Report (AMSA). It recommends actions to increase Arctic marine safety, the protection of the Arctic people and the environment and further strengthening of the Arctic marine infrastructure (Arctic Council, 2009).

### 3.14 PUBLIC PARTICIPATION AND STAKEHOLDER INVOLVEMENT

Stakeholder involvement and public participation is often advocated in climate adaptation policies and programs. While most agree that it is a significant normative goal, the importance of attending to the design of public participation and learning from existing critiques has been stressed. Participation in climate adaptation may be complicated by the fact that future impacts may be uncertain and long-term (Few et al., 2007; Leach et al., 2007). Research on programs to increase public participation show "the public" is often seen as lacking in some sense, either lacking knowledge or trust in science (Irwine, 2006). Some research even indicates that projects that aim at building up trust and cooperation between scientists and lay people may lead to confusion and distrust because the groups have fundamentally different ways of understanding environmental processes (Verran, 2002).

Public participation is most often related to participation in decision-making. However, public participation can also be relevant when it comes to understanding and reacting to environmental changes. This is for instance recognized in Iceland's High North Policy (Ministry for Foreign Affairs, 2009: 59). Building up long-term relationships between experts and the public in understanding such changes can lead to mutual learning and increased trust. This may increase general concern and engagement in environmental issues. In Iceland, there are examples of such long-term and successful collaboration within at least two fields: glacier monitoring and soil conservation.



*Picture 10: A PhD student in geochemistry and two IGS volunteers gather samples from Grímsvötn volcano, Vatnajökull. Photo: ÁJ*

In Iceland the involvement of the public in glacier monitoring has been practiced since the 1930's when the meteorologist Jón Eyþórsson built up a network of local people, mostly farmers, to monitor changes in glacier variability. In 1950, Eyþórsson founded the Iceland Glaciological Society (IGS) that has provided important support to geological research in Iceland, including glaciology. Within the IGS, a long-term relationships were built up between locals, volunteers and scientists, where knowledge did not only pass from the expert to the layperson, but also the other way around. This was important for the geosciences, because the local people often had detailed knowledge of places and environmental changes. The IGS provides an important example of successful long-term projects with public participation.<sup>18</sup>

Another example of extensive public participation is found in The Soil Conservation Service of Iceland (SCSI) which has since 1990 lead the program "Farmers Reclaim the land" (Bændur græða landið). The aim is to involve farmers in reclaiming eroding land, but erosion a serious environmental problem in Iceland. Around 600 farmers participate in the project and the SCSI experts state that the project has had a positive influence on the relationship between farmers and the SCSI. In the past, conflicting interests strained this relationship as grazing is one of the principal reasons for erosion in Iceland. As one expert said in an interview:

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<sup>18</sup> This part is from my own ongoing PhD research, still unpublished.



The hidden benefit [of the program ...] is the changes in knowledge and attitude that have emerged during the cooperation. The employee of the SCSI is no longer seen as the enemy, so to speak. We were seen as an intrusion from the capital, people felt we were interfering in their business and telling the farmers that they were being “bad” to their land. Now, we are just seen as collaborators who work towards a common goal of improving the land. This has led to farmers being much more open to other forms of education too. Now they know their land better.<sup>19</sup>

The collaboration also led to important changes in the SCSI work procedures. In collaboration with the farmers the SCSI developed ways to reclaim land requiring only a fraction of the fertilizer that was used before. Farmers are more engaged and have more ownership in the soil conservation programs. Moreover, there is a two-way learning relationship between the experts and the farmers:

I have learned so incredibly much by spending good time to go on field trips with farmers experienced in soil conservation. It becomes evident that even though they do not have the knowledge found in books, their practical knowledge of the behaviour of the systems is amazing.<sup>20</sup>

Similar programs have been developed in the Iceland Forest Service (Skógrækt ríkisins).

### 3.15 NATURAL HAZARDS AND CIVIL PROTECTION

“The Earth is Faster Now” is the title of a report on indigenous observations of environmental change in the Arctic (Krupnik and Jolly, 2002). The title is a comment made by an Alaskan Inuit, who remarked that weather patterns in her local area in Alaska were changing so fast that traditional ways of prediction no longer worked as they used to. The pacing up of nature is one way to express the local impacts of climate change. The past no longer serves as the same indicator for the future it used to. People expect and prepare for uncertainty.

This may be said to have applied to Iceland since the settlement. Iceland can be described as a “fast moving Earth” with frequent volcanic eruptions and earthquakes (see table 1). It was considered relevant to share with CoastAdapt

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<sup>19</sup> An interview with an expert at the SCSI, February 22, 2010.

<sup>20</sup> An interview with an expert at the SCSI, February 22, 2010.

how Icelanders deal with natural hazards, as climate change may be accompanied with an increased risk of natural disasters in coastal areas. Separate chapters on civil protection and community recovery are included in the CoastAdapt report.

**Table 1:** Natural disasters in Iceland that have had major socio-economic effects since 1970 (based on Gylfason, 2008: 124-125).

2010	Eruption in Eyjafjallajökull, southern Iceland	The volcano erupted in two places. The second eruption lasted from April 14 <sup>th</sup> to May 23 <sup>rd</sup> and was accompanied by immense tephra fall.
2008	Earthquakes in Árborg, southern Iceland	May 29 <sup>th</sup> . 6,3 on the Richter scale. Damage to buildings, infrastructure, roads and bridges, especially in Selfoss and vicinity. Only minor injuries.
2000	Earthquakes in southern Iceland (Holt and Hestfjall)	June 17 <sup>th</sup> (6,5 on the Richter scale) on and June 21 <sup>st</sup> (6,6). Damage to farms, infrastructure, roads and bridges.
1995	Snow avalanche in Flateyri, West Fjords	October 21 <sup>st</sup> . Twenty people lost their lives.
1995	Snow avalanche in Súðavík, West Fjords	January 16 <sup>th</sup> . Fourteen people lost their lives.
1983	Snow avalanches in Patreksfjörður, West Fjords	January 22 <sup>nd</sup> . Four people lost their lives.
1976	Earthquake near Kópasker, northern Iceland	January 13 <sup>th</sup> . 6,3 on the Richter scale. No people were injured but property was destroyed.
1974	Snow avalanche in Neskaupsstaður, eastern Iceland	December 20 <sup>th</sup> . Twelve people lost their lives.
1973	Eruption in Heimaey, Westman Islands	One person died of gas poisoning. 280 homes completely destroyed and another 200 damaged.



**Picture 11:** Newly formed lava field on Fimmvörðuháls, in the vicinity of Eyjafjallajökull, southern Iceland, July 2010. Photo: ÁJ

Climate change may potentially affect the frequency of certain natural disasters. The impact of climate change on natural hazards in Iceland has not been assessed. However, the Scientific Committee on Climate Change (Björnsson et al., 2008) mentions that climate change might influence the following factors:

- Up to 10% increase in eruptions due to the release of the burden of glaciers.
- Hence, an increase in melt water floods.
- Increase in floods from glacial rivers and from ice-dammed lagoons that burst.
- Increase in ablation floods.
- Increase in forest and field fires.
- Decreasing frequency of other types of events, such as snow avalanches.

As natural disasters have been relatively common in the past, climate change is not likely to put increased stress on the organization of civil protection in Iceland. The system functions well and Iceland's experience may prove useful to others.

## 4 CONCLUSIONS

Icelanders in general do not seem highly concerned by climate change. A recent survey indicates that over 60% of Icelanders think that global warming has not seriously impacted their local environment (Capacent, 2010).

In Iceland the focus of climate policy is still mainly on mitigation. There exists no politically endorsed national adaptation strategy. A number of people I spoke with within the administration did not feel that it was pressing for the government to develop a national strategy aimed at adaptation, because for the most part, the short-term impacts of climate change were regarded as economically positive. The industry is generally expected to be able to react accordingly without governmental intervention.

A comprehensive overview of climate change impacts in Iceland was published in 2008 (Björnsson et al.). However, the political and ethical aspects of climate adaptation have not gained much attention in Iceland. Participation is rarely mentioned in relation to climate change policy in the government's strategic documents.

Important climate adaptation measures are being developed within specific sectors in Iceland. The energy sector, for example, has carried out extensive studies on climate impacts on future energy production. The sector is in the process of adapting to these impacts. Another example is that sea level rise is accounted for in the construction of harbors. Moreover, considerable information relating to climate adaptation exists in various fields. Yet, this

knowledge is dispersed and overview is lacking. There is a need for better tools such as maps and databases to address adaptation. No institution on climate research such as CICERO in Norway, exists in Iceland.

There is rising concern about several adaptation issues. New evidence on ocean acidification indicates that this might be a more serious problem than previously thought. There is also a need for information on the impacts of sea level rise, which will probably be greatest in the southwestern part of Iceland, including the capital area. It is clear that action must be taken to protect low-lying areas in Reykjavík in the next decades. There is a need for better and more accessible maps showing the impacts of sea-level rise on the areas that are likely to be affected.

Many of the people interviewed for this report emphasized the importance of looking at climate change from a wider perspective and transcend both national boundaries and short-term perspectives. As a part of the global economy, Iceland is affected by changes that take place elsewhere. Furthermore, Iceland has obligations as a participant in the international community. In the long term, climate change will impact landscape and ecosystems in ways that many will perceive as negative. It is predicted that the glaciers, which constitute an important part of Icelandic natural and cultural heritage, will disappear within the next two centuries, vegetation is changing, new animal species are migrating to the country, marine resources are shifting, sea bird stocks declining and so forth. With the effects becoming more visible, it is likely that climate change will gain increasing attention in Icelandic policy-making.

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