Iceland´s Fifth National Communication on Climate Change

Under the United Nations

Framework Convention on Climate Change

Ministry for the Environment

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Introduction

Iceland's Fifth National Communication to the United Nations Framework Convention on Climate Change describes the trends in greenhouse gas emissions in Iceland, policies and measures to curb emissions and their effect, and other relevant information in line with the guidelines of the Convention.

Iceland has strengthened its governmental infrastructure and policy making in climate affairs in recent years, in order to implement its commitments under the Kyoto Protocol and support intensified action in mitigation and scientific research and monitoring. A new climate change strategy was adopted by the government in 2007, setting the goal of cutting emissions by 50-75% by 2050. A thorough analysis of Iceland's mitigation potential has been conducted by an expert group and on the basis of this a new action plan is being formulated, with the aim of identifying further measures to cut emissions. A carbon tax was introduced in 2009. The government recently announced its intention to participate in a joint effort with the European Union to cut emissions by 30% in 2020, compared to 1990 levels, in the context of a robust new international climate agreement. Iceland is part of the EU´s Emission Trading Scheme, which will become a significant part of Iceland's mitigation profile in the coming years, with the inclusion of aviation, aluminum and ferrosilicon production in the ETS.

Total greenhouse gas emissions in Iceland increased by 32% in the period 1990 to 2007. Emissions per capita increased by 6% in the same period, but emissions per GDP (1990 – 2006) decreased by 23%.

The main reason for the increase in emissions is the expansion of heavy industry in Iceland, mainly in the field of aluminum production. Such projects have a big impact on total emission levels in Iceland because of the small size of the Icelandic economy, despite the fact that these industries use renewable energy, and are required to use best available technology to minimize emissions from industrial processes. In line with decision 14/CP.7, Iceland will report emissions of carbon dioxide from such new projects since 1990 separately for the duration of the first commitment period of the Kyoto Protocol. By applying this decision, it is projected that Iceland will meet its commitments under the Kyoto Protocol despite the predicted increase in overall emissions.

The Icelandic government has engaged in various measures to mitigate climate change by curbing emissions and increase carbon sequestration. Progress has been especially noticeable to date in the decrease of emissions of fluorocarbons from the aluminum industry, and in increased sequestering of carbon from the atmosphere due to increased government funding to afforestation and revegetation. Carbon sequestration is a key factor in Icelandic climate policy, because it complements government objectives of revegetation and afforestation of eroded lands.

Tariffs on non-polluting and low-polluting vehicles have been lowered and the tax system altered to make small diesel-powered cars more competitive than before. Despite this, there has been significant increase in emissions from the transportation sector in recent years. Plans for a revised tax system to further encourage climate-friendly vehicles and fuels are aimed at reversing this trend. New energy-saving technology has been introduced in government-owned ships, and significant gains in reducing emissions from ships are seen as a possibility. The fishing industry has pioneered the use of electricity (from renewables) instead of heavy oil in fish-meal production.

Iceland is engaged in a number of research-and-development projects in climate-friendly technology and renewable energy. Some notable examples are: Deep drilling for superheated geothermal fluid; carbon capture and storage by mineralization in basaltic rock; production of methanol from carbon dioxide in geothermal steam; information technology to reduce emissions from ships; and use of hydrogen as fuel in cars and ships. The eventual success of most of these projects is uncertain, but they signal a commitment by Iceland to seek new ways to cut emissions and be ready to employ new and cleaner technology when it becomes more widely available.

The single most notable feature with regard to Iceland and climate change mitigation is the fact that around 80% of its energy – and almost all stationary energy – comes from renewable resources, hydro and geothermal. This means that Iceland has few possibilities to reduce greenhouse emissions from the production of electricity and space heating, as Iceland had already almost abolished the use of fossil fuels for these purposes in 1990. On the other hand, in perhaps no other field has Iceland a greater potential to contribute to global climate change mitigation than by the export of know-how in the fields of renewable energy and climate-friendly technology. Efforts in this respect have been ongoing for decades – exemplified by the running of the UN University Geothermal Programme and a new UNU Land Restoration Training Programme.

1 Executive summary

National circumstances

Iceland is a parliamentary democracy. Most executive power rests with the Government, which is headed by a prime minister. The population of Iceland is just over 300,000, with almost two-thirds of the population living in the capital, Reykjavík, and surrounding areas.

Iceland has an area of 103,000 km, and is the second largest island in Europe after Great Britain. Glaciers cover more than 10% of the area. Soil erosion and desertification is a problem, and more than half of the country’s vegetation cover is estimated to have disappeared due to erosion since settlement some 11 centuries ago. The country is situated just south of the Arctic Circle but the mean temperature is considerably higher than might be expected at this latitude. Relatively mild winters and cool summers characterize the climate. Iceland is an industrialized country with a high living standard. The country consistently ranks among the top 10 states in the UNDP Human Development Index. Iceland is very dependent upon international trade, and the generation of foreign revenue is highly dependent on natural resources. The fishing industry relies on the rich fishing grounds in Icelandic waters, the aluminum and ferrosilicon industry on hydropower and geothermal energy and the tourism industry on nature and natural beauty. The use of energy is very high per capita, but the proportion of domestic renewable energy in the total energy budget is around 80%, which is a much larger share than in most other countries. The use of fossil fuels for stationary energy is almost nonexistent but fossil fuels are used for transportation. Three features stand out that make the Icelandic greenhouse gas emissions profile unusual. First is the high proportion of renewable energy of the total amount of energy used. Second, emissions from the fishing fleet are unusually high. The third distinctive feature is the fact that individual sources of industrial process emissions have a significant proportional impact on emissions at the national level, due to the small size of the economy.

Greenhouse gas inventory information

The Environment Agency compiles and maintains the greenhouse gas inventory. In 1990, the total emissions of the six greenhouse gases covered by the Kyoto Protocol were 3400 Gg of CO_2-equivalents. In 2007, total emissions were 4482 Gg CO_2-eq, excluding LULUCF. This means that total greenhouse gas emissions in Iceland were about 32% above 1990 levels in 2007. In that period, carbon dioxide emissions increased by 52%, methane emissions increased by 7% and nitrous oxide emissions fell by 2%. Removals of CO_2 from direct human-induced revegetation and reforestation since 1990 are estimated to be 279 Gg CO_2-eq in 2007. Industry, transport and fisheries are the three main sources of GHG emissions, but other sources include agriculture and waste.

Policies and measures

Iceland is a party of the UNFCCC, and Iceland ratified the Kyoto Protocol on May 23, 2002. A new climate change strategy was adopted by the government in 2007, setting the goal of cutting emissions by 50-75% by 2050. The government recently announced its intention to participate in a joint effort with the European Union to cut emissions by 30% in 2020, compared to 1990 levels, in the context of a robust new international climate agreement. Iceland is part of the EU´s Emission Trading Scheme, which will become a significant part of Iceland’s mitigation profile in the coming years, with the inclusion of aviation, aluminum and ferrosilicon production in the ETS. A carbon tax on all fossil fuel emissions was introduced in 2009.

In addition to these economy wide schemes, the Icelandic government has engaged in various measures to mitigate climate change by curbing emissions in individual sectors and increasing carbon sequestration. Progress has been especially noticeable to date in the decrease of emissions of fluorocarbons from the aluminum industry, and in increased sequestering of carbon from the atmosphere due to increased government funding to afforestation and revegetation. A central challenge is to curb and cut emission in the transportation sector, which have grown significantly despite the creation of economic incentives favoring low- and zero-emission cars.

Projections and the total effect of measures

Emissions of greenhouse gases are projected to increase in the short run, to 2020, and then decrease slowly until 2050, with business-as-usual or only minimal measures to curb emissions. There is great uncertainty in projections of GHG emissions, mainly caused by uncertainty over possible new projects in aluminum and ferrosilicon production. If emissions are in accord with projections, Iceland will be able to meet its obligations for the first commitment period of the Kyoto Protocol, even with the planned expansion in energy-intensive industries, with the deployment of Decision 14/CP.7.

It is difficult to estimate the exact effect of most measures on emission levels, with the exception of carbon sequestration by afforestation and revegetation, which will have an estimated mitigation impact of 280 Gg CO_2-eq in 2010. It is also possible to estimate the mitigation impact of decreased emissions by the aluminum industry by comparing the required PFC limit of 0.14 t CO_2-eq/t aluminum with the world median emissions of PFCs for the point fed prebake technology (PFPB), which is best available technology, or the global mean average for aluminum production. The calculation of the impact of strict regulation of these emissions yields an estimated mitigation benefit of 0.13 t CO_2-eq/t aluminum when compared with worldwide users of the PFPB technology or 0,56 t CO_2-eq/t aluminum when compared with the global average. For the total annual production of aluminum in Iceland, 780 000 tons, the benefits of using the limit of 0.14 t CO_2-eq/t aluminum are about 101 000 tons CO_2-eq/year when compared with the world median for PFPB smelters and about 437 000 tons CO_2-eq/year when compared with the world total average. The quantitative impact of other measures is more difficult to estimate.

More effort is needed to reduce emissions. Currently, a new climate mitigation action plan is being formulated on the basis of an expert study on Iceland’s mitigation potential.

Impacts and adaptation measures

A 2008 government-sponsored comprehensive survey by a committee of scientific experts has significantly increased understanding of the likely impact of climate change on nature and society in Iceland. Iceland's glaciers are almost all at present receding. A defining feature of the Icelandic landscape, covering over 10% of the island's area, they could largely disappear in the next century or two. An increase in temperature could have some positive effects on marine resources and fish stocks in the short run. However, more insects could increase risks of disease in both plants and humans. Recent studies show that ocean acidification in the waters around Iceland is about twice the global average. Ocean acidification is a relatively new concern, and in a longer perspective it could become one of the most worrying aspects of climate change for Iceland, along with possible changes in ocean currents, given Iceland's high dependence on living marine resources.

Financial assistance and technology transfer

Iceland's provision of Overseas Development Assistance in general has increased in recent years, and reached 0.48% in 2008. The most notable efforts regarding climate change are the operation of the UN University Geothermal Training Programme and the recently established Land Restoration Training Programme, which became an official UNU training programme in 2010. These programmes provide capacity building for developing countries in the areas of renewable energy and revegetation, where Iceland has expertise.

Research and systematic observation

Funds allocated to research and development were 1% of GDP in 1990 but had reached around 2,7% of GDP in the year 2007, making Iceland sixth among OECD countries in R&D spending per GDP. Icelandic scientists are involved in a number of climate-related research projects. The Icelandic Meteorological Office (IMO) is involved in climate system studies and does some work on modeling and prediction. Icelandic scientists and research institutions are involved in several projects that study the impact of future global climate changes. Important research projects deal with technical aspects of mitigation, including renewable energy and other climate-friendly technology, and methods to increase carbon sequestration, and measure mitigation gains by revegetation and afforestation. The two institutions most important in relation to observation of climate change are the IMO and the Marine Research Institute (MRI). Research affects policy making in various ways, a recent example being results showing drained wetlands being a significant and previously unrecognized emission source. This has made authorities include wetland reclamation as part of a climate mitigation policy and propose wetland conservation and reclamation as an elective activity in a future global climate agreement.

Iceland is engaged in a number of research-and-development projects in climate-friendly technology and renewable energy. Some notable examples are: Deep drilling for superheated geothermal fluid; carbon capture and storage by mineralization in basaltic rock; production of methanol from carbon dioxide in geothermal steam; information technology to reduce emissions from ships; and use of hydrogen as fuel in cars and ships.

Education, training and public awareness

Environmental education in schools has increased in the past decade. The University of Iceland now offers a Master's degree in environmental studies, where climate change is an integral subject. Many upper secondary schools offer courses in the same, or place special emphasis on environmental issues in their curriculum. Studies of environmental issues in primary schools are included in many subjects, especially natural sciences. As renewable energy is used for both space heating and electrical production, climate-related public information and awareness-raising campaigns focus on transportation and on encouraging alternative transport modes to the private car.

2 National circumstances

2.1 Government structure

Iceland has a written constitution and is a parliamentary democracy. A president is elected by direct popular vote for a term of four years, with no term limit. Most executive power, however, rests with the Government, which must have majority support of Althingi, the Parliament. Althingi has 63 members, and parliamentary elections are held every four years. The government is headed by a prime minister, and the executive branch is currently divided among 12 ministers. Judicial power lies with the Supreme Court and the district courts, and the judiciary is independent.

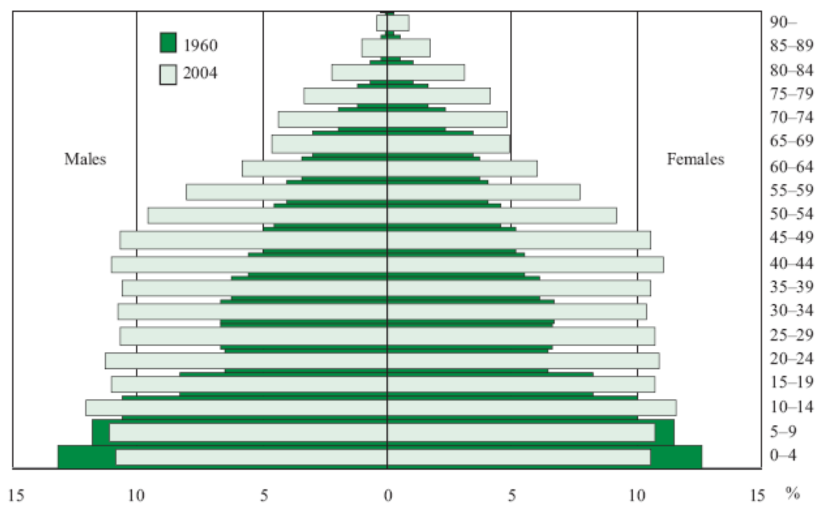
The country is divided into 78 municipalities, and local authorities are elected every four years. The largest municipality is the capital, Reykjavík, with 118,427 inhabitants, but the greater capital area has around 200 thousand inhabitants in 7 municipalities. The smallest municipality on the other hand has only 50 inhabitants. In 1990 the number of municipalities was 204, but an attempt has been made to unite small municipalities, and this has resulted in fewer, but more populous, municipalities. This trend is likely to continue since the tasks of local authorities have grown increasingly complex in recent years. The local authorities have their own sources of revenue and budgets and are responsible for various areas that are important with regard to greenhouse gas emissions. This includes physical planning, granting industry licenses and the design and operation of public transport. Municipalities also play an important role in education.

The Ministry for the Environment is responsible for the implementation of the UNFCCC and coordinated national climate change policymaking in close cooperation with the Ministries of Fisheries and Agriculture, Industry, Energy and Tourism, Transport, Communications and Local Government, Finance, Foreign Affairs and the Prime Minister's Office. Several public institutions and public enterprises, operating under the auspices of these ministries, also participated directly or indirectly in preparing the national implementation policy.

2.2 Population

The population of Iceland was 319,000 in 2008. The population is projected to grow by about 6,5% over the next decade, reaching around 340,000 in 2020. Settlement is primarily along the coast. More than 60% of the nation lives in the capital, Reykjavik, and surrounding areas. In 1990 this same ratio was 57%, demonstrating higher population growth in the capital area than in smaller communities and rural areas.

Population by sex and age 1960 and 2004



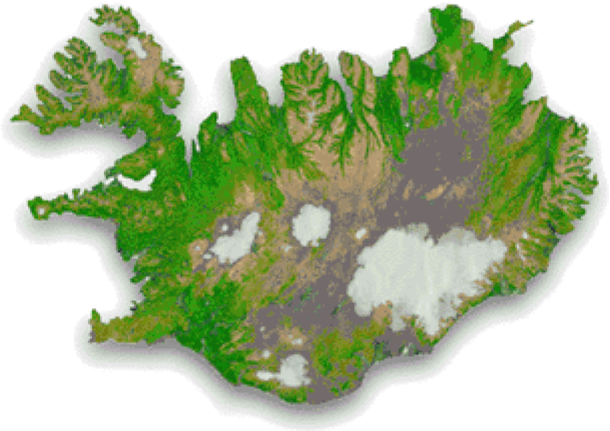
Iceland is the most sparsely populated country in Europe. The population density is three inhabitants per square kilometer. Given the large percentage of the population living in and around the capital, the rest of the country is even more sparsely populated, with less than one inhabitant per square km. Almost four-fifths of the country are uninhabited and mostly uninhabitable, the population therefore being concentrated in a narrow coastal belt, valleys and the southwest corner of the country.

2.3 Geography

Iceland is located in the North Atlantic between Norway, Scotland and Greenland. It is the second-largest island in Europe and the third largest in the Atlantic Ocean, with a land area of some 103 thousand square kilometers, a coastline of 4,970 kilometers and a 200-nautical-mile exclusive economic zone extending over 758 thousand square kilometers in the surrounding waters. Iceland enjoys a warmer climate than its northerly location would indicate because a part of the Gulf Stream flows around the southern and western coasts of the country. In Reykjavík the average temperature is nearly 11°C in July and just below zero in January.

Geologically speaking, the country is very young and bears many signs of still being in the making. Iceland is mostly mountainous and of volcanic origin. The Mid-Atlantic Ridge runs across Iceland from the south-west to the north-east. This area is characterized by volcanic activity, which also explains the abundance of geothermal resources. Glaciers are a distinctive feature of Iceland, covering about 11% of the total land area. The largest glacier, also the largest in Europe, is Vatnajökull in Southeast Iceland with an area of 8,300 km^2. Glacial erosion has played an important part in giving the valleys their present shape, and in some areas, the landscape possesses alpine characteristics. Regular monitoring has shown that all glaciers in Iceland are presently receding.

Rivers and lakes are numerous in Iceland, covering about 6% of the total land area. Freshwater supplies are abundant, but the rivers flowing from the highlands to the sea also provide major potential for hydropower development. Geothermal energy is another domestic source of energy.

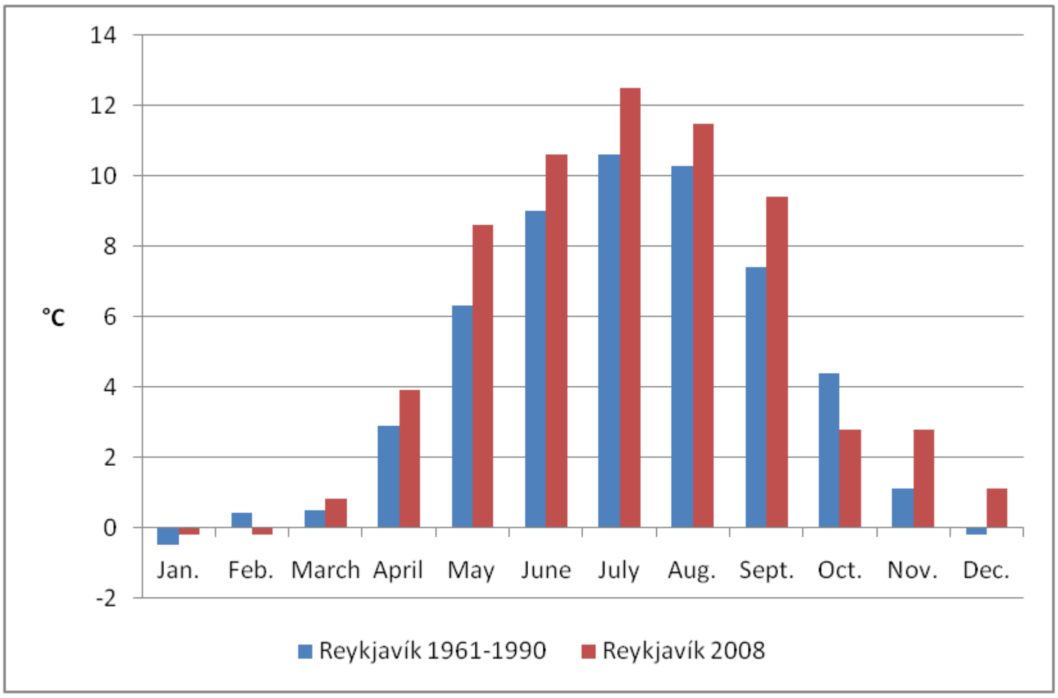


Soil erosion and desertification is a problem in Iceland. More than half of the country's vegetation cover is estimated to have disappeared because of erosion since the settlement period. This is particularly due to clearing of woodlands and overgrazing, which have accelerated erosion of the sensitive volcanic soil. Remnants of the former woodlands now cover less than 1,200 km^2, or only about 1% of the total surface area. Around 60% of the vegetation cover is dry land vegetation and wetlands. Arable and permanent cropland amounts to approximately 1,300 km^2. Systematic revegetation began more than a century ago with the establishment of the Soil Conservation Service of Iceland, which is a governmental agency. Reforestation projects have also been numerous in the last decades, and especially noteworthy is the active participation of the public in both soil conservation projects and reforestation projects.

Iceland has access to rich marine resources in the country's 758,000-km^2 exclusive economic zone. The abundance of marine plankton and animals results from the influence of the Gulf Stream and the mixing of the warmer waters of the Atlantic with cold Arctic waters. Approximately 270 fish species have been found within the Icelandic 200-mile exclusive economic zone; about 150 of these are known to spawn in the area.

2.4 Climate

Iceland is situated just south of the Arctic Circle. The mean temperature is considerably higher than might be expected at this latitude. Relatively mild winters and cool summers characterize Iceland's oceanic climate. The average monthly temperature varies from -3 to +3 °C in January and from +8 to +15 °C in July. Storms and rain are frequent, with annual precipitation ranging from 400 to 4000 mm on average annually, depending on location. The mild climate stems from the Gulf Stream and attendant warm ocean currents from the Gulf of Mexico. The weather is also affected by polar currents from East Greenland that travel southeast towards the coastline of the northern and eastern part of Iceland.



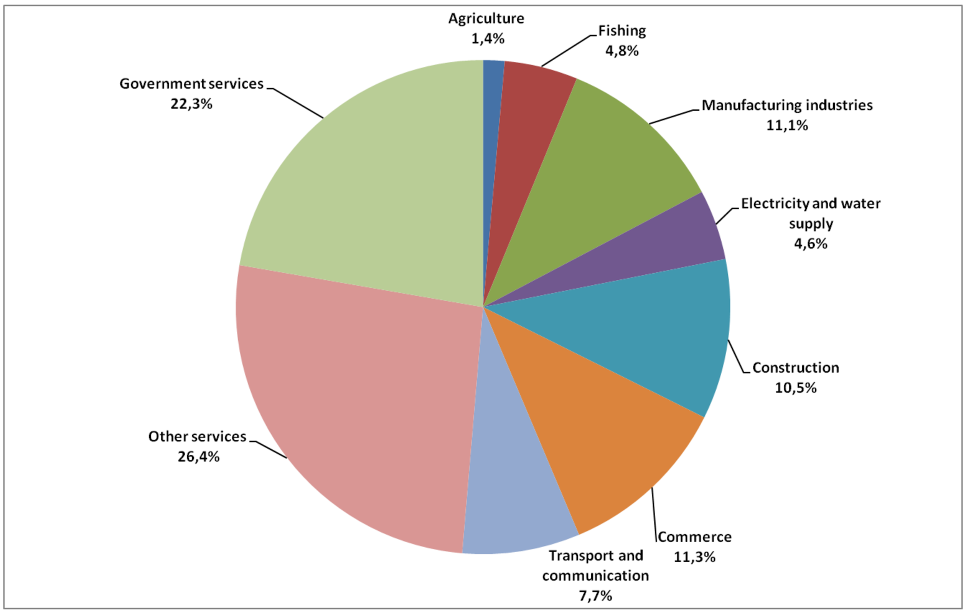
Mean temperature in Reykjavík 1961-1990 and 2008

The amount of daylight varies greatly between the seasons. For two to three months in the summer there is almost continuous daylight; early spring and late autumn enjoy long twilight, but from November until the end of January, the daylight is limited to only three or four hours.

2.5 The Economy

Iceland is endowed with natural resources that include the fishing grounds around the island within and outside the country's 200-mile Exclusive Economic Zone as well as hydroelectric and geothermal energy resources

Policies of market liberalization, privatization and other structural changes were implemented in the late 1980s and 1990s, including membership of the European Economic Area by which Iceland was integrated into the internal market of the European Union. Economic growth started to gain momentum by the middle of the 1990s, rekindled by replenishing fish stocks due to sustainable quota allocations, a global economic recovery, a rise in exports and a new wave of investment in the aluminum sector. During the second half of the 1990s, the liberalization process continued, competition increased, the Icelandic financial markets and financial institutions were restructured and expanded rapidly and the exchange rate policy became more flexible. Iceland experienced until 2007 one of the highest growth rates of GDP among OECD countries.



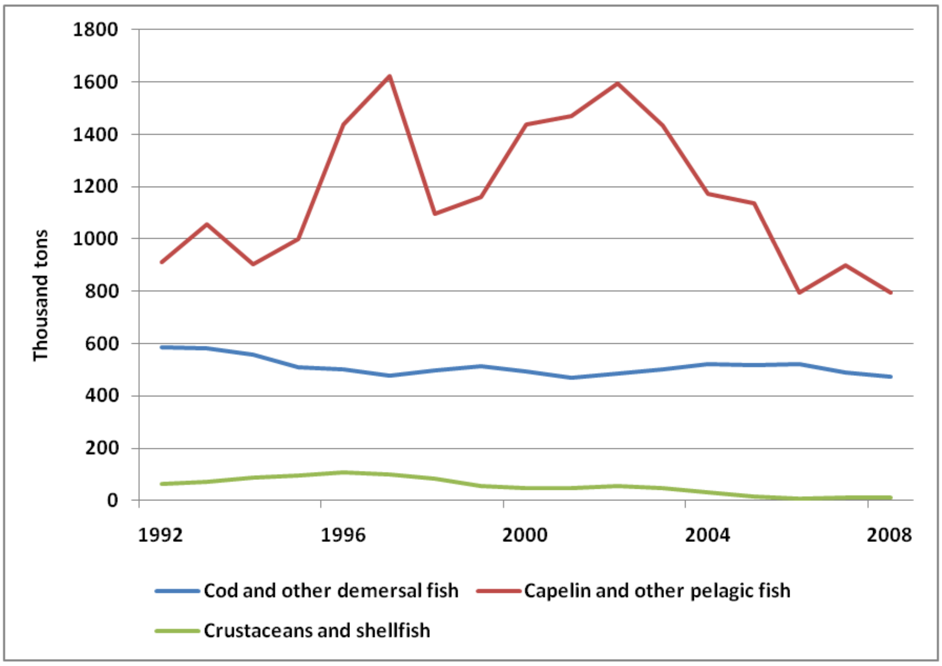
Breakdown of GDP in 2008 by sector

Iceland was severely hit by an economic crisis when it‘s three largest banks collapsed in the fall of 2008. The blow was particularly hard owing to the large size of the banking sector in relation to the overall economy as it had grown to be ten times the annual GDP. The crisis has resulted in serious contraction of the economy followed by increase in unemployment, a depreciation of the Icelandic króna by over 40% in 2009 compared with the 1st quarter of 2008 and a drastic increase in external debt. Private consumption has contracted by a quarter since 2007. In 2009 the GDP contracted by almost 8%.

The large-scale investment projects in the aluminum and power sectors which commenced in 1997 are now operational. In 2008, the total production of aluminum smelters in Iceland was 780,000 tons, up from 270,000 in 2005 and 100 thousand in 1995. Parallel investments in increased power capacity were needed to accommodate for an almost eight-fold increase in aluminum production. Relative to the size of the Icelandic economy these investment projects were very large.

2.6 Fisheries

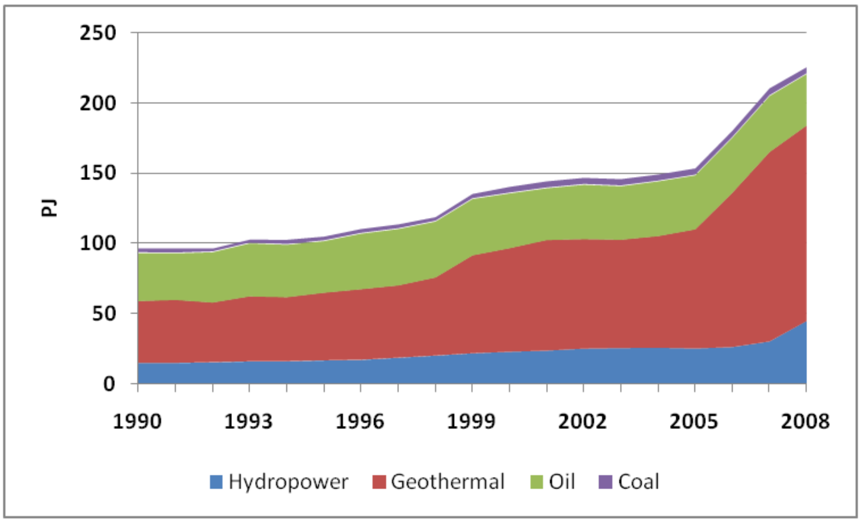
Iceland is the 12th largest fishing nation in the world, exporting nearly all its catch. The marine sector is still one of the main economic sectors and the backbone of export activities in Iceland although its relative importance has diminished over the past four decades. Marine products constituted 36.7% of all exports in 2008, the first time with less share than manufacturing products. A comprehensive fisheries management system based on individual transferable quotas has been developed. Total allowable catches (TACs) are issued with the aim of promoting conservation and efficient utilization of the marine resources. All commercially important species are regulated within the system. In addition to the fisheries management system there are a number of other explicit and direct measures to support its aims and reinforce the conservation and sustainability measures.



Fish catch by Icelandic vessels 1992 - 2008

2.7 The energy sector

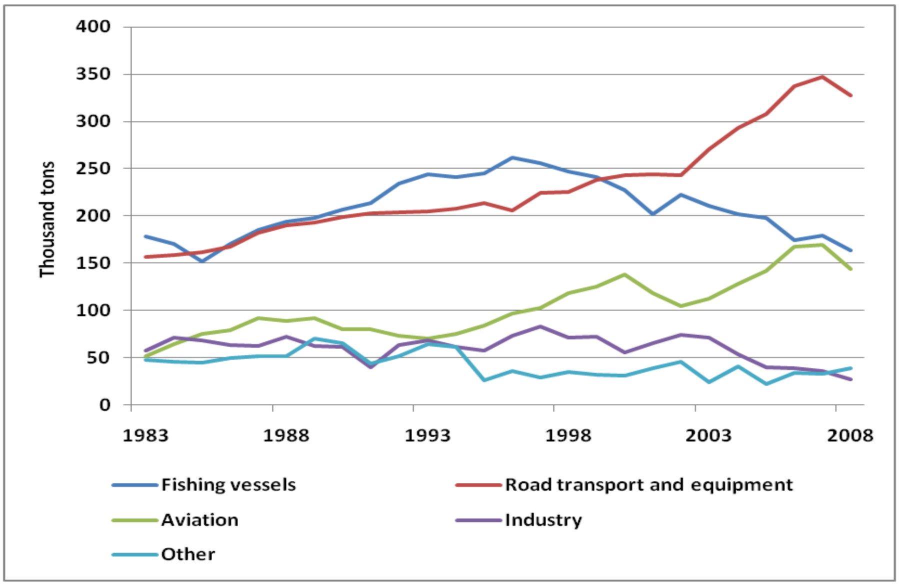
Iceland has extensive domestic energy sources in the form of hydro and geothermal energy. The development of the energy sources in Iceland may be divided into three phases. The first phase covered the electrification of the country and harnessing the most accessible geothermal fields, especially for space heating. In the second phase, steps were taken to harness the resources for power-intensive industry. This began in 1966 with the signing of agreements on the building of an aluminum plant, and in 1979 a ferrosilicon plant began production. In the third phase, following the oil crisis of 1973-74, efforts were made to use domestic sources of energy to replace oil, particularly for space heating and fishmeal production. Oil has almost disappeared as a source of energy for space heating in Iceland, and domestic energy has replaced oil in industry and in other fields where such replacement is feasible and economically viable.



Primary energy consumption in Iceland 1990 - 2008

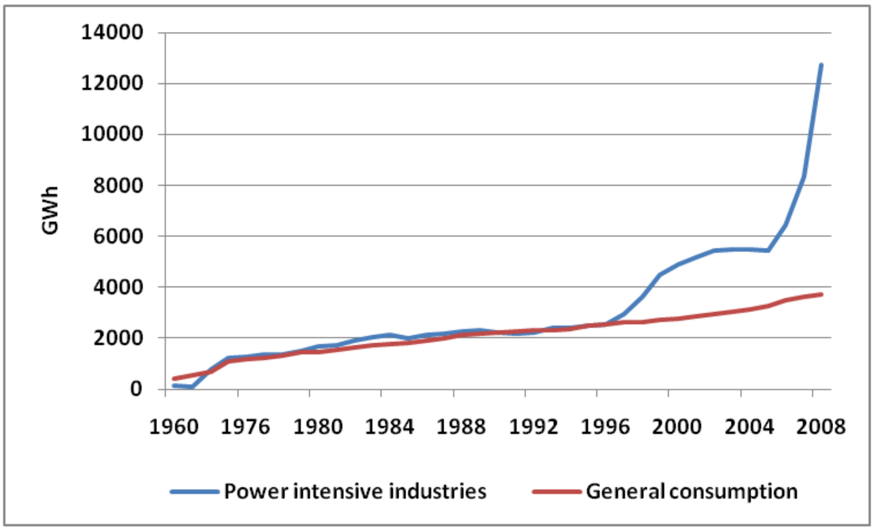
Iceland ranks first among OECD countries in the per capita consumption of primary energy with about 160 MWh per capita, followed by Canada, Luxembourg and Norway with 120 – 125 MWh per capita in 2006. In 2008 the consumption had risen to 205 MWh per capita. Electricity consumption is about one fourth of the total energy consumption amounting to 49 MWh per capita in 2008. A cool climate and sparse population calls for high energy use for heating and transport. Also, key export industries, such as fisheries and aluminum production, are energy-intensive. The increase in the use of electricity in the last decade is largely due to an expansion of energy-intensive industry. Large-scale industry used around 77% of the total electricity produced in Iceland in 2008.

The energy profile for Iceland is in many ways unique. The use of fossil fuels for stationary energy is very small in Iceland. The fishing and transportation sectors use 70 per cent of the oil consumed and 20% is used for aviation. Oil consumption in industry has declined in recent years.



Consumption of petroleum products in Iceland 1983 – 2008

The proportion of energy consumption provided by renewable energy sources is greater in Iceland than in any other country. Today geothermal heat and hydropower account for more than 80 per cent of the country's primary energy consumption. In 2008, the total installed hydropower was 1,878 MW in 31 power plants producing 12,427 GWh. Installed geothermal power amounted to 575 MW producing 4,037 GWh. Iceland is a world leader in the use of geothermal energy for domestic and industrial purposes. Some 90% of all homes in Iceland are heated with geothermal energy, for less than one third of the comparable cost of fossil fuels or electrical heating.



Electricity consumption in Iceland 1960 - 2008

Hydro power developments can have various environmental impacts. The most noticeable is usually connected with the construction of reservoirs, which are necessary to store water for the winter season. Such reservoirs affect the visual impact of uninhabited wilderness areas in the highlands, and may inundate vegetated areas. Other impacts may include disturbance of wildlife habitats, the disappearance or alteration of waterfalls, reduced sediment transportation in glacial rivers downstream from the reservoirs and changed conditions for fresh-water fishing. Geothermal developments may also have environmental impacts, among them the drying up of natural hot springs. Development of high-temperature fields may cause air pollution by increasing the natural H_2S emission from the fields.

2.8 Industry

The largest manufacturing industries in Iceland are power-intensive industries which produce exclusively for export. There has been a considerable increase in manufacturing exports in recent years. In 2008, manufactured products accounted for 52% of total merchandise exports, up from 22% in 1997. Power-intensive products, mainly aluminum, amounted to 39% of total merchandise exports in 2008 but 12% in 1997. The second largest manufactured product in 2008 was ferrosilicon followed by medicinal products. A number of small and medium-size enterprises have emerged in export-oriented manufacturing in recent years, in areas such as medical equipment, pharmaceuticals, capital goods for fisheries and food processing.

The history of non-ferrous metal production in Iceland began in 1970 with the first aluminum smelter, now owned by Rio Tinto Alcan, producing 33 thousand tons of aluminum annually. The annual production capacity of the plant, after four expansion projects, is now about 180 thousand tons. A ferrosilicon plant owned by Elkem started operation in 1979 with annual production of 60 thousand tons of 75% ferrosilicon. The production capacity was increased in 1999 and is now about 120 thousand tons of ferrosilicon per year. A second aluminum plant, owned by Century Aluminum, went into operation in 1998 with an annual production of 60 thousand tons of aluminum. Current production capacity of the plant is 260 thousand tons per year after being expanded three times. The latest large scale project was the Alcoa aluminum plant, which started production in 2007 and has a production capacity of 350 thousand tons of aluminum per year.

2.9 Transport

The domestic transportation network consists of roads and air transportation.. Car ownership is widespread. In 2007, Iceland had 666 passenger cars per 1,000 inhabitants, the third highest ratio among OECD countries. The road system totals 13,000 km, of which 4,300 km are primary roads.

Aviation plays a key role in Iceland. The country's geographical location makes undisturbed international air transportation imperative. Domestic aviation is also important because of long travel distances within the country combined with a small population. An investment in a railway system is therefore not a viable option. Two million passengers in international flights passed through Icelandic airports in 2008, of which 240.000 were transit passengers heading to other destinations. In all 110.000 aircrafts entered the Reykjavík Oceanic Control Area in 2008, up 4.7% from the previous year. Of these 30.000 were flights to and from Iceland and 80.000 overflights. The number of domestic flight passengers in 2008 was around 450.000.

Iceland has numerous harbors large enough to handle international ship traffic, which are free of ice throughout the year. The two main shipping lines operate regular liner services to the major ports of Europe and the US.

2.10 Agriculture, land management and forestry

Approximately one fifth of the total land area of Iceland is suitable for fodder production and the raising of livestock. Around 6% of this area is cultivated, with the remainder devoted to raising livestock or left undeveloped. Production of meat and dairy products is mainly for domestic consumption. The principal crops have been hay, potatoes and other root vegetables. Cultivation of other crops, such as barley and oats, has increased rapidly in the last 10 years and they are now becoming one of the staples. Vegetables and flowers are mainly cultivated in greenhouses heated with geothermal water and steam.

In Iceland the human impact on ecosystems is strong. The entire island was estimated to be about 65% covered with vegetation at the time of settlement in the year 874. Today, Iceland is only about 25% vegetated. This reduction in vegetative cover is the result of a combination of harsh climate and intensive land and resource utilization by a farming and agrarian society over 11 centuries. Estimates vary as to the percentage of the island originally covered with forest and woodlands at settlement, but a range of 25 to 30% is plausible.

Organized forestry is considered to have started in Iceland in 1899. Afforestation through planting did increase considerably in 1990s from an average of around 1 million seedlings annually in the 1980s to 4 million in the 1990s and 5 million in the first seven years of the 2000s. Around 1100-1900 ha was afforested annually in the period of 1990-2007. Planting of native birch has been increasing proportionate to the total afforestation, comprising 24% of seedlings planted in the period 1990-2007. From its limited beginnings in 1970, state supported afforestation on farms and private owned land has become the main channel for afforestation activity in Iceland, comprising about 80% of the afforestation effort today. The total area of forest and other wooded land, as reported in a Country report of Iceland to the 2010 Forest Resource Assessment of FAO, was estimated to be 1% of the land area or 110,000 hectares in the year 2005 and 116,000 hectares in 2010, including plantations covering 30,000 ha (28%) and 36,000 ha (31%) respectively.

The Soil Conservation Service of Iceland, an agency under the Ministry for the Environment, was founded in 1907. The main tasks of the agency is combating desertification, sand encroachment and other soil erosion, the promotion of sustainable land use and reclamation and restoration of degraded land. A pollen record from Iceland confirms the rapid decline of birch and the expansion of grasses in 870-900 AD, a trend that continued to the present. As early as 1100 more than 90% of the original Icelandic forest was gone and by 1700 about 40% of the soils had been washed or blown away. Vast gravel-covered plains were created where once there was vegetated land. Ecosystem degradation is one of the largest environmental problems in Iceland. Vast areas have been desertified after over-exploitation and the speed of erosion is magnified by volcanic activity and harsh weather conditions.

2.11 Waste

Waste generated in 2007 amounted to 533,000 tons, which is almost 50% more than in 1995. The gross domestic product (GDP) increased over the same time period by more than 70% , showing a partial decoupling of waste from GDP. The population of Iceland grew by 17% from 1995, implying a step-up in both GDP and waste per capita. . Increased cooperation between the municipalities by operating joint waste collection schemes and landfill sites has resulted in larger managed landfills enabling shutdown of small sites. Efforts made by local municipalities have also resulted in increased recycling of waste. In 2007, about 64% of municipal waste was landfilled, 28% recycled or recovered, 8% incinerated with energy recovery and less than 1 % incinerated without energy recovery. Of the total amount of solid waste, 35% was buried in certified and managed landfill sites. Waste was responsible for 5% of the total greenhouse gas emissions in Iceland in the year 2007. Emissions from landfills dominated (86%), but wastewater handling and waste incineration accounted for 5% and 9% respectively. The increase in emissions from waste in the period 1995 – 2007 was less than half the increase in waste generated owing to more recycling and technological advances in the handling of waste.

2.12 Other circumstances

The greenhouse gas emissions profile for Iceland is in many regards unusual. Three features stand out. First, emissions from the generation of electricity and from space heating are very low owing to the use of renewable energy sources. Second, over 80% of emissions from energy come from mobile sources (transport, mobile machinery and fishing vessels). The third distinctive feature is that individual sources of industrial process emissions have a significant proportional impact on emissions at the national level. Most noticeable in this regard are abrupt increases in emissions from aluminum production associated with the expanded production capacity of this industry. This last aspect of Iceland's emission profile made it difficult to set meaningful targets for Iceland during the Kyoto Protocol negotiations. This fact was acknowledged in Decision 1/CP.3 paragraph 5(d), which established a process for considering the issue and taking appropriate action. This process was completed with Decision 14/CP.7 on the Impact of Single Projects on Emissions in the Commitment Period (see Annex B).

The problem associated with the significant proportional impact of single projects on emissions is fundamentally a problem of scale. In small economies, single projects can dominate the changes in emissions from year to year. When the impact of such projects becomes several times larger than the combined effects of available greenhouse gas abatement measures, it becomes very difficult for the party involved to adopt quantified emissions limitations. It does not take a large source to strongly influence the total emissions from Iceland. A single aluminum plant can add more than 15% to the country's total greenhouse gas emissions. A plant of the same size would have negligible effect on emissions in most industrialized countries.

Decision 14/CP.7 sets a threshold for significant proportional impact of single projects at 5% of total carbon dioxide emissions of a party in 1990. Projects exceeding this threshold shall be reported separately and carbon dioxide emissions from them not included in national totals to the extent that they would cause the party to exceed its assigned amount. Iceland can therefore not transfer assigned amount units to other Parties through international emissions trading. The total amount that can be reported separately under this decision is set at 1.6 million tons of carbon dioxide. The scope of Decision 14/CP.7 is explicitly limited to small economies, defined as economies emitting less than 0.05% of the total Annex I carbon dioxide emissions in 1990. In addition to the criteria above, which relate to the fundamental problem of scale, additional criteria are included that relate to the nature of the project and the emission savings resulting from it. Only projects, where renewable energy is used, and where this use of renewable energy results in a reduction in greenhouse gas emissions per unit of production, are eligible. The use of best environmental practice and best available technology is also required. It should be underlined that the decision only applies to carbon dioxide emissions from industrial processes. Other emissions, such as energy emissions or process emissions of other gases, such as PFCs, will not be affected.

3 Greenhouse gas inventory information

3.1 Greenhouse gas emissions and trends

The total amounts of greenhouse gases emitted in Iceland in 1990, 2006 and 2007 and the contribution of individual greenhouse gases are shown in Table 3.1. Emissions fulfilling the criteria set forth in Decision 14/CP. 7 are also included. As mentioned earlier, industrial process CO_2 emissions that fulfill Decision 14/CP.7 shall be reported separately and excluded from national totals, to the extent they would cause a Party to exceed its assigned amount.

In 2007, Iceland‘s total emissions of greenhouse gases were 4,482 gigagrams of CO_2-equivalent. The emissions rose by 1,082 Gg CO_2-eq in 2007 compared to 1990 levels, an increase of 32%. Emissions in 2007 fulfilling the criteria in Decision 14/CP.7 were 669 Gg CO_2-eq and stand for 62% of the increase in total emissions between 1990 and 2007. The largest contributor of greenhouse gas emissions in Iceland is the energy sector, followed by industrial processes, agriculture, waste and solvent and other product use. From 1990 to 2007, the contribution of the energy sector to the total emissions decreased from 52% to 50%. The contribution of industrial processes increased from 25% in 1990 to 33% in 2007.

	1990	2006	2007	90-07	06-07
CO_2	2160	3038	3289	52%	8%
CH_4	452	467	484	7%	4%
N_2O	368	338	359	-2%	6%
HFC 32		0.1	0.1		16%
HFC 125		19	20		7%
HFC 134a		12	15		26%
HFC 143a		21	23		9%
HFC 152a		0.1	0.1		-4%
CF_4	355	282	238	-33%	-16%
C_2F_6	65	51	43	-33%	-16%
SF_6	1	7	10	842%	41%
Total	3400	4236	4482	32%	6%
CO_2 emissions fulfilling 14/CP.7		537	669		24%
Total emissions excluding CO_2 emissions fulfilling 14/CP.7		3698	3813	12%	3%

Table 3.1 Emissions of greenhouse gases during 1990, 2006 and 2007 in Gg CO_2-eq

Total emissions of greenhouse gases decreased in Iceland between 1990 and 1994 (with an exception of 1993) and increased thereafter. A sudden 15% increase in emissions was seen in 2006 followed by an increase of 6% between 2006 and 2007. The main reason for the 2006 increase was high PFC emissions from aluminum production startup activities.

Iceland experienced both strong economic growth and population increase between 1990 and 2007, with 75% increase in GDP and 21% increase in population. These were the principal drivers of general increases in emissions, mainly from industrial processes and transport.

During the late nineties large-scale industry expanded rapidly in Iceland. In 1990 88,000 tons of aluminum was produced in one aluminum plant in Iceland. This aluminum plant was expanded in 1997. The single ferroalloys production plant was expanded in 1999. In 1998 a second aluminum plant was established and subsequently expanded in 2006. The sudden jump in PFC emissions in 2006 was mainly caused by technical difficulties during the expansion. In

2007 a third aluminum plant was established. The three aluminum plants produced 781,151 tons of aluminum in 2008, which amounts to almost nine-fold increase since 1990.

3.1.1 Emission trends by gas

The largest contributor to the total GHG emissions is CO_2, as shown in Figure 3.1. The share of other gases was, in 2007, just about equally divided between CH_4, N_2O and the fluorinated gases composed of PFCs, HFCs and SF_6.

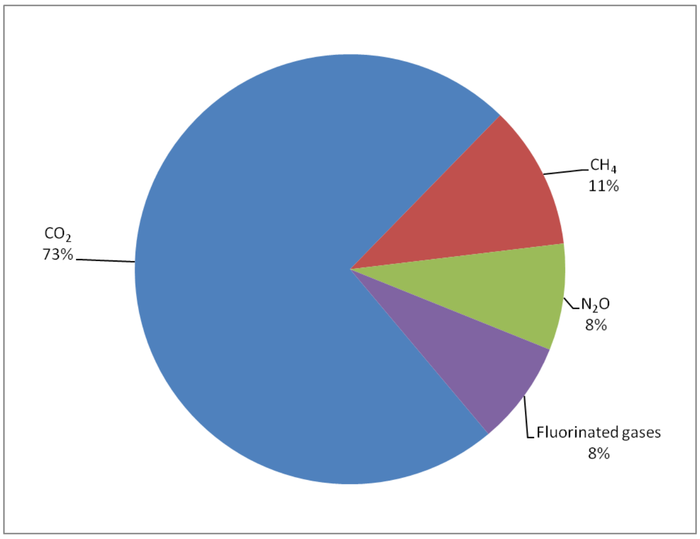


Figure 3.1 Distribution of emissions of greenhouse gases by gas in 2007

Trends in emissions of greenhouse gases in 1990 to 2007 are shown in Figure 3.1 as percentages of the emissions in 1990. The emissions of CO_2 increased steadily during this period with leaps relating to startups of increased production capacity in the non-ferrous metal sector. Most noticeable in the figure are the big changes in fluorinated gases while the levels of CH_4 and N_2O remained fairly stable.

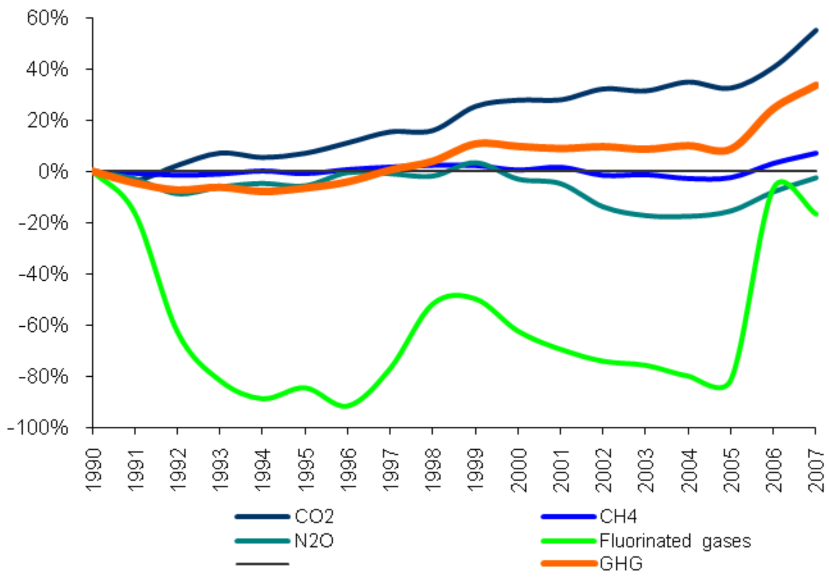


Figure 3.2 Percentage changes in emissions of greenhouse gases by gas 1990 – 2007, compared with 1990

3.1.1.1 Carbon dioxide (CO_2)

The distribution of CO_2 emissions by source categories is shown in Figure 3.3 and trends in CO_2 emissions, depicted as deviations from the emissions in 1990, are shown in Figure 3.4. Industrial processes, road transport and fisheries are the three main sources of CO_2 emissions in Iceland accounting for 80% of the total. Renewable sources are almost exclusively used for generation of electricity and space heating resulting in very low emissions. Emissions from stationary combustion are therefore dominated by industrial sources, with the fishmeal industry being the primary user of fossil fuels. Emissions from mobile sources in the construction industry are also significant. Emissions from geothermal energy exploitation are moderate. Other sources are mainly emissions from coal combustion in the cement industry, and emissions from transport other than road transport.

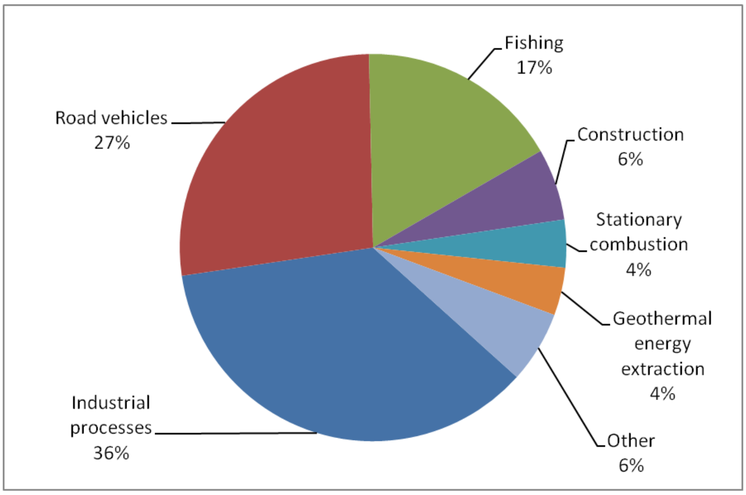


Figure 3.3 Distribution of CO_2 emissions by source in 2007

In 2007 the total CO_2 emissions in Iceland were 3,289 Gg. The emissions were 8% higher than the preceding year and 52% higher than in 1990. The increase in CO_2 emissions between 1990 and 2007 can be explained by the increased emissions from industrial processes (188%), road transport (75%), geothermal energy utilization (127%), and the construction sector (62%). Emissions from fishing declined during the same period by 14%.

During the late nineties energy intensive industrial production started to grow. The aluminum plant and ferrosilicon facility were expanded in 1997 and 1999, and in 1998 a new aluminum plant was established. This new plant was expanded in 2006 and a third plant was established in 2007. The economic growth and the growth in energy intensive industries resulted in higher emissions from most sources, in particular from the industrial processes sector as well as the construction sector. The construction of a new hydropower plant and increased activity in the building sector has contributed to recent increase in emissions from the construction sector.

Between 1990 and 2008 the vehicle fleet in Iceland increased by 81%. Greater number of cars, more kilometers driven per car per year and larger cars contribute to the increased emissions from road transport. Emissions from both domestic flights and navigation have declined since 1990.

Emissions from fishing increased from 1990 to 1996 because a substantial portion of the fishing fleet was operating in distant fishing grounds. From 1996 the emissions decreased again, reaching 1990 levels in 2001. Emissions increased again by 10% between 2001 and 2002, but in 2003 they dropped to 1990 levels. In 2007 emissions were 14% below 1990 levels. Annual changes in emissions reflect the inherent nature of the fishing industry.

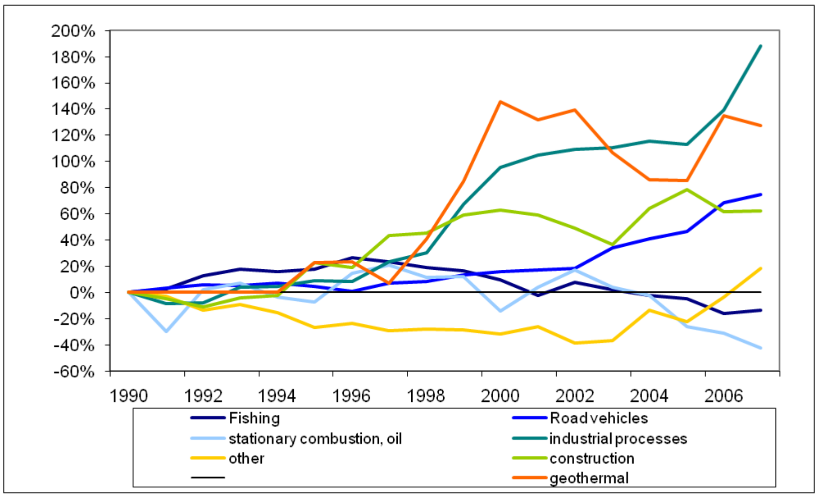


Figure 3.4 Percentage changes in emissions of CO_2 by major sources 1990 – 2007, compared with 1990

3.1.1.2 Methane (CH_4)

Agriculture and waste treatment are the principal sources of methane emissions as shown in Figure 3.5.

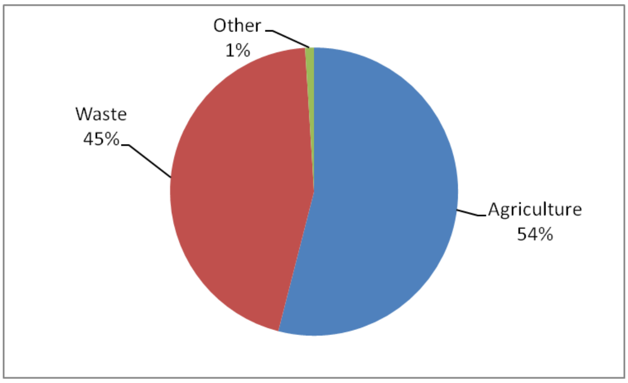


Figure 3.5 Distribution of CH_4 emissions by source in 2007

The trend in methane emissions is shown in Figure 3.6, as percentage deviation from the emissions in 1990. Methane emissions from agriculture decreased between 1990 and 2007 by 11% due to decrease in domestic livestock. Emissions from waste treatment increased steadily from 1990 to 2001. A downward trend in emissions after 2001 is due to increased methane collection from landfills. Increased wastes and malfunctioning in the methane collection system at Iceland's largest landfill are the main reasons for the sharp increase in emissions between 2005 and 2007.

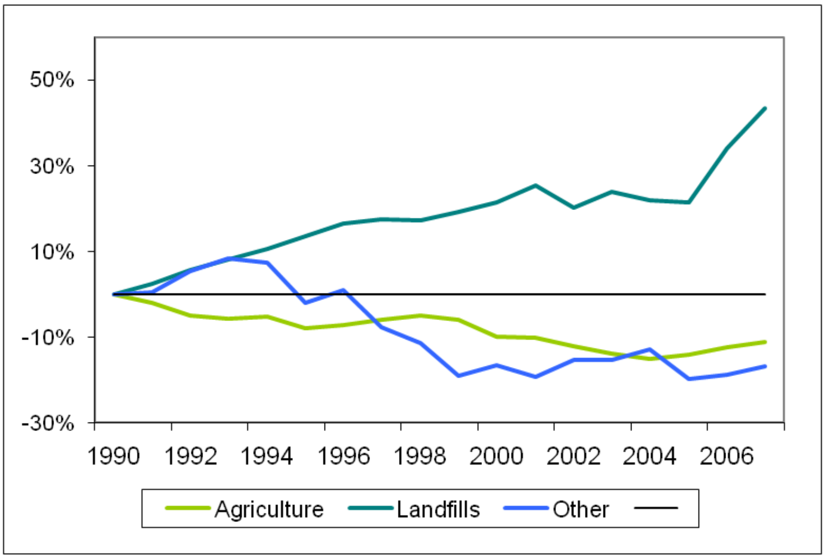


Figure 3.6 Percentage changes in emissions of CH_4 by major sources 1990 – 2007, compared to 1990

3.1.1.3 Nitrous oxide (N_20)

Agriculture accounts for around 76% of N_2O emissions in Iceland, as can be seen in Figure 3.7, with agricultural soils as the most prominent contributor. The second most important source is road transport. Emissions from road transport increased rapidly after the use of catalytic converters in all new vehicles became obligatory in 1995.

The overall nitrous oxide emissions decreased by 2% from 1990 to 2007, owing to a decrease in the number of animal livestock and a closure of a fertilizer production facility in Iceland in 2001.

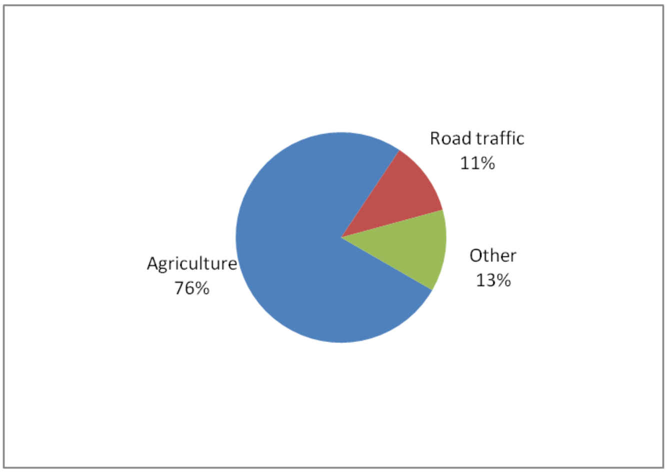


Figure 3.7 Distribution of N_2O emissions by source in 2007

3.1.1.4 Perfluorocarbons (PFCs)

The emissions of the perfluorocarbons, i.e. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) from the aluminum industry were 238 and 43 Gg CO_2-eq respectively in 2007.

Total PFC emissions decreased by 33% in 1990 – 2007. The emissions decreased steeply from 1990 to 1996 but increased again in 1997 and 1998 owing to an enlargement of the existing aluminum plant in 1997 and the establishment of a second new aluminum plant in 1998 (see Figure 3.8). After the start-ups of the new production facilities the emissions showed a steady downward trend until 2005. This reduction was achieved through improved technology and process control and led to a 98% decrease in PFCs emitted per ton of aluminum produced during the period 1990 to 2005. The new aluminum plant was enlarged in 2006 resulting in significant increase in PFC emissions. A third aluminum plant was established in 2007. The start-up phase of aluminum production in new plants or when plants are expanded usually brings increased PFC emissions per ton of aluminum. As the operation of a smelter reaches stability after the start-up the emissions gradually decrease.

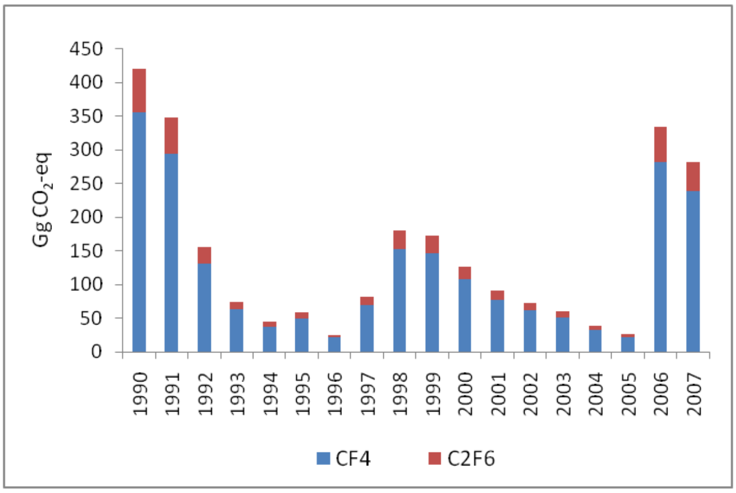


Figure 3.8 Emissions of PFCs from 1990 to 2007, Gg CO_2-equivalent

3.1.1.5 Hydrofluorocarbons (HFCs)

The total actual emissions of HFCs, used as substitutes for ozone depleting substances, amounted to 59.4 Gg CO_2-eq in 2007. The emissions have increased steadily after the import of HFCs started in 1992 (see Figure 3.9). Refrigeration contributes by far the largest part of HFCs emissions and air conditioning systems in cars are also minor source that is gradually increasing. In 2007 the actual emissions of HFCs were about 1% of national total greenhouse gas emissions (without LULUCF).

HFCs are used as substitutes for the ozone depleting substances (CFCs and HCFCs) which are being phased out by the Montreal Protocol. In Iceland the F-gases have been regulated since1998, and HFC is banned for certain uses. HFCs are imported in bulk for use in stationary and mobile air-conditioning systems, and occur also in imported equipment e.g. refrigerators, cars and metered dose inhalers. HFC is banned in other aerosols, solvents and fire extinguishers. The HFCs used in significant quantities in Iceland are HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a and HFC-152a. Annual imports since 1998 have stayed between 30 and 81 Gg CO_2-eq. It is assumed that the import of cars with MAC (mobile air-conditioning systems) started in 1995. Since then there has been a rapid increase in private cars with MAC. From the year 2005 about 30-40% of all private cars have MAC, all busses and about 60% of larger trucks. The use of HFCs in some applications, specifically rigid foam (typically closed-cell foam), refrigeration and fire suppression, can lead to the development of long-lived banks of HFC. The total HFC import in 2007 was 90 Gg CO_2-eq and HFC stored in banks was 383 Gg CO_2-eq

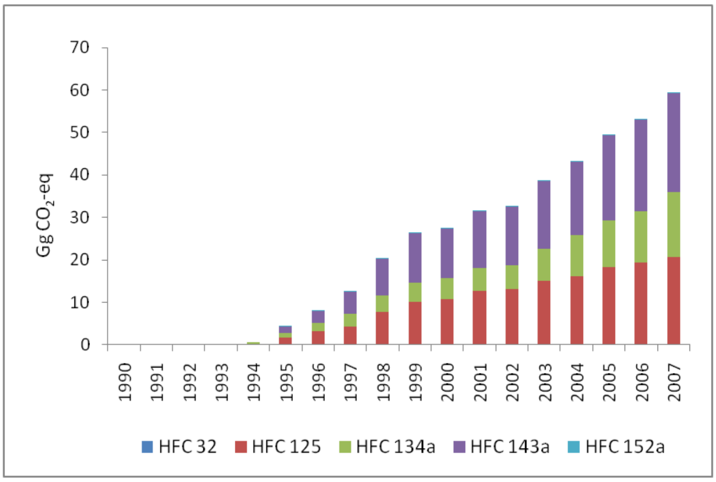


Figure 3.9 Actual emissions of HFCs by 1990 – 2007, Gg CO_2-eq

3.1.1.6 Sulphur hexafluoride (SF_6)

Total emissions of sulphur hexafluoride in 2007 were 10 Gg CO_2-eq. Annual emissions since 1990 have been in the range 1 to 11 Gg CO_2-eq, with peaks occuring during construction of power plants and expansion of older systems. The average emissions in 1990 -2007 were 3 Gg CO_2-eq.

Sulphur hexafluoride (SF_6) is mainly used for insulation and current interruptions in equipment used in the transmission and distribution of electricity. It is also used to a minor extent in research particle accelerators in universities. There is no production of SF_6 in

Iceland. Information on SF_6, which dates back to 1974 shows that installed accumulated amount of SF_6 in electrical equipment, is approximately 17,200 kg.

3.1.2 Emission trends by source

The largest contributor of greenhouse gas emissions (without LULUCF) in Iceland is the energy sector, followed by industrial processes, agriculture, waste and solvent and other product use. The distribution of the total greenhouse gas emissions by sector in 2007 is shown in Figure 3.10. Changes in emissions relative to 1990 levels are shown in Figure 3.11.

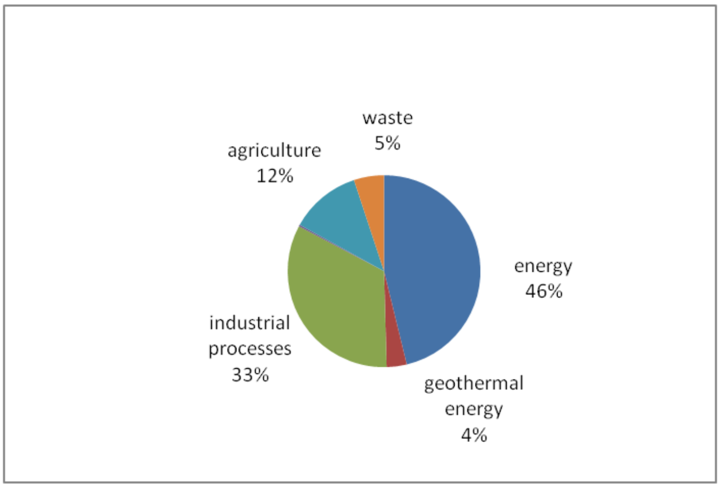


Figure 3.10 Emissions of greenhouse gases by UNFCCC sector in 2007

Emissions from the energy sector account for 50% (fuel combustion 46% and geothermal energy 4%) of the national total emissions, industrial processes account for 33% and agriculture for 12%. The waste sector accounts for 5% and solvent and other product use for 0.3%. The contribution of the energy sector to the national total decreased from 52% in 1990 to 50% in 2007 and the contribution of industrial processes increased at the same time from 25% to 33%.

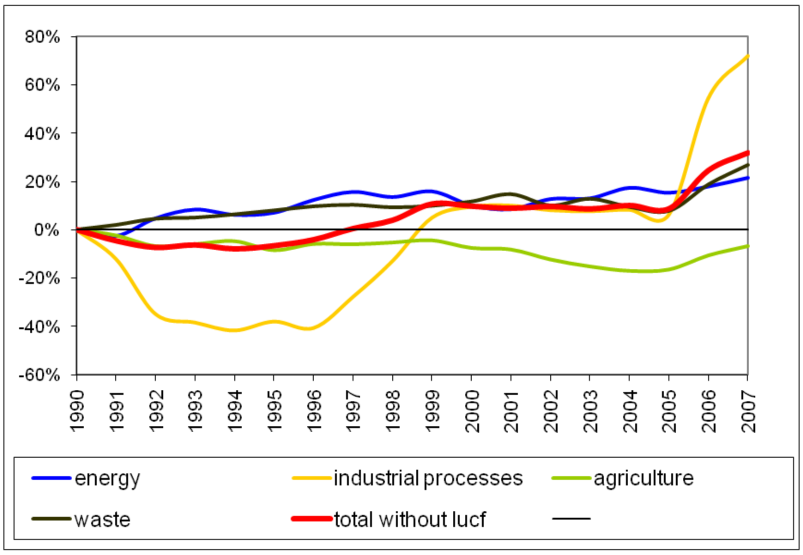


Figure 3.11 Percentage changes in emissions of total greenhouse gas emissions by UNFCCC source categories during the period 1990 – 2007, compared to 1990

3.1.2.1 Energy

The energy sector in Iceland is unique in many ways. In 2007 the per capita energy use was more than 650 GJ, which is high in comparison with other industrialized countries. Energy intensive primary metal production and fisheries are major pillars of the economy and the cool climate and sparse population calls for high energy use for space heating and transport. The proportion of domestic renewable energy of primary energy use is 80%, which is a much higher share than in most other countries. The largest part of the electricity generated (77%) is used for metal production. Geothermal energy sources are used for space heating and electricity production. About 30% of electricity produced in Iceland is from geothermal sources and 70% from hydroelectric power stations.

Emissions from the energy sector are primarily from transport, followed by other sectors (fisheries) and the manufacturing industries and construction as can be seen in Figure 3.12. More than 80% of emissions from the energy sector derive from mobile sources (transport, mobile machinery and fishing vessels). The energy industries accounted for only 1.4% of the emissions from the energy sector in 2007.

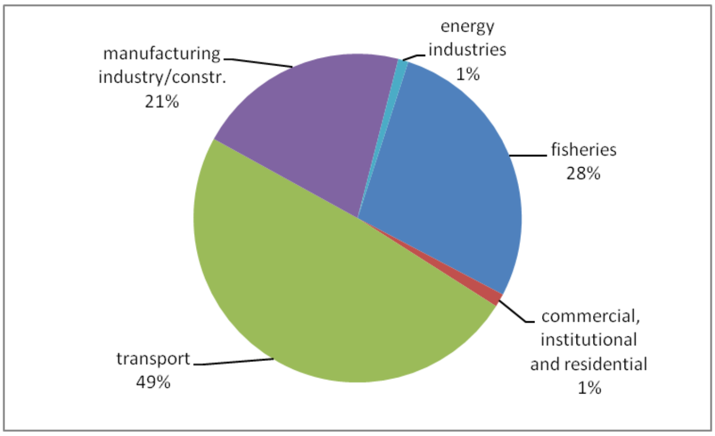


Figure 3.12 Greenhouse gas emissions from fuel combustion in the energy sector 2007, distributed by source categories

Between 1990 and 2007 the vehicle fleet in Iceland increased by 79%. The number of kilometers driven per car has also increased and an economic upswing in the years leading up to 2007 stimulated appetite for larger passenger cars. This led to an increase of 75% in emissions from road vehicles in 2007 compared with 1990 levels. Decrease in navigation and aviation compensated somewhat for rising emissions in the transport sector.

Emissions of greenhouse gases from fisheries increased from 1990 to 1996 because a substantial portion of the fishing fleet was operating in unusually distant fishing grounds. From 1996, the emissions decreased again reaching 1990 levels in 2001. Emissions increased again by 10% between 2001 and 2002, but had reached 1990 levels again in 2003. In 2007 the emissions were 15% below the emissions in 1990. Annual changes in emissions reflect the inherent nature of fishing industries.

Electricity production using geothermal energy increased by more than 12-fold in 1990 – 2007, with 3579 GWh generated in 2007. The greenhouse gas emissions in 2007 amounted to 152 Gg CO_2-eq, an increase since 1990 of 85 Gg CO_2-eq. Average per unit emissions in 2007 were 43 g CO_2-eq/kWh. Emissions from the geothermal power plants, per kWh, are less than 5% of what is obtained in coal fired power plants. Average per unit emissions for electricity production in Iceland is 15 g CO_2-eq/kWh.

3.1.2.2 Industrial processes

Industrial processes are second in terms of scale of greenhouse gas emissions in Iceland accounting for 33% of the total in 2007. The greenhouse gases emitted from industrial processes are primarily CO_2 and the sector is the sole contributor to emissions of PFCs. Consumption of HFCs and SF_6 within the sector leads to emissions of these gases. Production of nonferrous metals, aluminum and ferrosilicon, is the predominant source of greenhouse gas emissions within the sector accounting for 91% of the total in 2007. Production of minerals accounted for 4% of the emissions, mainly from cement production, and the remainder is due to consumption of HFCs and SF_6.

Trends in emission from major industrial processes in 1990 – 2007 are shown in Figure 3.14. The emissions decreased between 1990 and 1996 because of improvements made in technology and process control at the single aluminum smelter in operation at that time leading to steep reductions in emissions of PFCs (see also Figure 3.2). During the late nineties the nonferrous metals industry expanded in Iceland. The production capacity of the aluminum plant was increased in 1997 and the ferrosilicon plant was enlarged in 1999. A second aluminum plant was built and started operation in 1998. This aluminum plant was expanded in 2006 and a third aluminum plant went into operation in 2007. Exports of ferrosilicon increased by 83% and exports of aluminum more than quadrupled from 1996 to 2007. The increased production has led to the observed growth in emissions from industrial processes depicted in Figure 3.14.

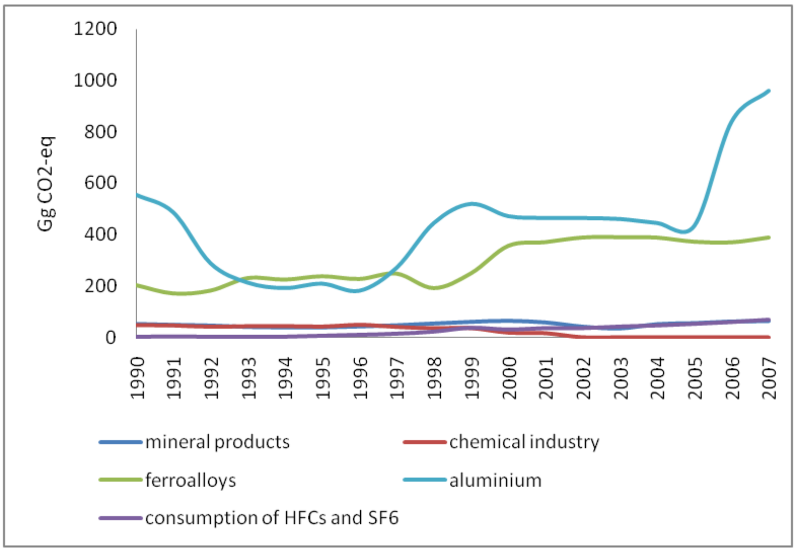


Figure 3.14 Total greenhouse gas emissions in the industrial process sector during the period from 1990 – 2007, Gg CO_2-eq.

The most significant part of the greenhouse gas emissions from industrial processes, i.e. 65% can be attributed to primary aluminum production. These emissions are primarily CO_2, released in the electrolysis process by oxidation of the carbon anodes. The use of carbon anodes is inherent in the Hall-Héroult process that is employed for producing alumina. The CO_2 released is about 1.5 tons for each ton of aluminum produced. Possibilities of reducing these releases per ton of aluminum are limited beyond applying the prebake technology and process control classified as best available techniques, which are currently used in the aluminum smelters in Iceland.

PFC emissions are also significant in the aluminum industry. The PFCs, tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) are formed during so called anode effects, caused by disturbances in the electrolysis process. A major effort made in Iceland after 1990 to lower the frequency and length of the anode effects resulted in 94% reduction of emissions of PFCs from 1990 to 1995. The emissions, per ton of aluminum, were reduced from 4.78 tons CO_2-eq in 1990 to 0.10 CO_2-eq in 2005. When new aluminum plants or new sections of existing plants are taken into use the emissions of PFCs usually increase before the operation of the new electrolytic cells becomes stable. This has also been the case during the expansion of the industry in Iceland and can be clearly seen in Figure 3.2, which shows a peak in PFC emissions in 1998 followed by a steady decrease until the start-up of new production capacity in 2006.

Production of ferrosilicon is the second major source of emissions from industrial processes, accounting for 25% of the emissions in 2007. Production of ferrosilicon leads to emissions of CO_2 from the use of coal and coke as reducing agents and oxidation of carbon electrodes. In 1998 a power shortage caused a temporary closure of the ferroalloy plant, resulting in exceptionally low emissions that year (see figure 3.14). The ferrosilicon plant was expanded in 1999 and the CO_2 emissions increased accordingly.

Cement production is the dominant contributor to greenhouse gas emissions in the category “production of minerals“. Cement is produced in one plant in Iceland, emitting CO_2 derived from carbon in the shell sand used as the raw material in the process. Emissions from the cement industry peaked in 2000 but declined thereafter until 2003, partly because of cement imports. From 2004 the emissions increased again because of increased activity related to the construction of a new hydropower plant.

Production of fertilizers, which used to be the main contributor to the process emissions from the chemical industry, was closed down in 2001. No chemical industry has been in operation in Iceland after closure of a diatomite processing plant in North-Iceland in 2004.

3.1.2.3 Agriculture

Greenhouse gas emissions from agriculture in Iceland consist of methane and nitrous oxide. The two largest sources, CH_4 emissions from enteric fermentation and N_2O emissions from agricultural soils, are almost equal in terms of CO_2-eq. About 9% of the emissions are from manure management. Greenhouse gas emissions from the agricultural sector accounted for 12% of the overall greenhouse gas emissions in 2007.

The emissions over the period 1990 - 2007 were relatively stable at levels just over 500 Gg CO_2-eq/yr, as can be seen in Figure 3.15.Decreasing number of livestock led to decline in emissions prior to 2006, but emissions increased again in 2006 and 2007 because of increased use of synthetic fertilizers.

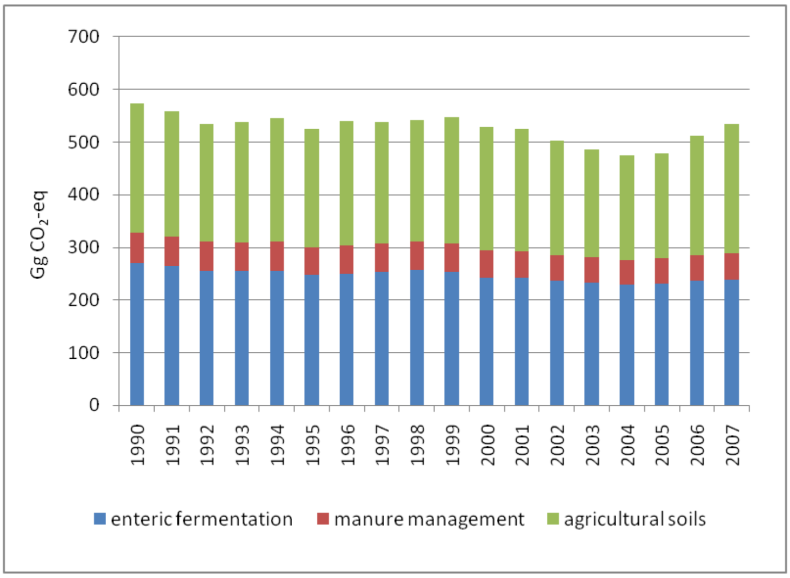


Figure 3.15 Total greenhouse gas emissions from agriculture 1990 – 2007, Gg CO_2-eq

3.1.2.4 Waste

Greenhouse gas emissions attributed to waste amounted to 5% of Iceland's total emissions (without LULUCF) in 2007. These emissions were mainly from landfills (89%) and wastewater handling (10%). Trends in the emissions are shown in Figure 3.16. The emissions from landfills increased from 1990 to 2001, followed by a small decrease until 2005. The emissions increased again in 2006 and 2007. The general increase in emissions from landfills occurred because of more waste, 28% increase in 1990 – 2007, and a larger share of waste taken to managed waste disposal sites. The full effect of increased waste on emissions was partly counteracted by installation of a methane recovery system in 1997 at the largest landfill serving the capital area. The amount of methane recovered increased progressively until 2006 and 2007 when the collection system partly failed because of technical problems.

Emissions from waste incineration have decreased consistently since 1990 because the total amount of waste being incinerated in Iceland has decreased. A higher percentage of the waste has concurrently been incinerated with energy recovery.

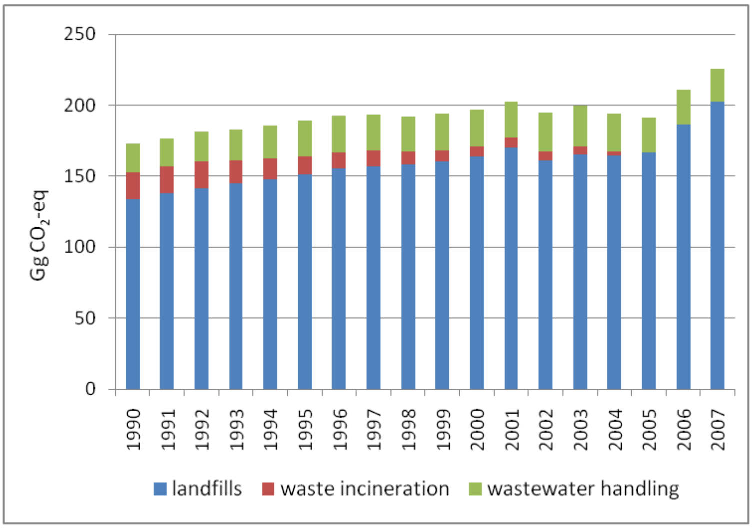


Figure 3.16 Emissions of greenhouse gases in the waste sector 1990 – 2007, Gg CO_2-eq

3.2 Greenhouse gas inventory system

Under Article 5.1 of the Kyoto Protocol, Annex I Parties must have a national system for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol by 1 January 2007. The national system includes all the institutional, legal and procedural arrangements for estimating greenhouse gas emissions and removals and for reporting and archiving inventory information.

3.2.1 Institutional arrangements

A new act on the emission of greenhouse gases was passed by the Icelandic legislature, Althing, in March 2007. The purpose of the act is to create conditions for Icelandic authorities to comply with international obligations in limiting emissions of greenhouse gases. The act establishes the national system for the estimation of greenhouse gas emissions by sources and removals by sinks, a national registry, emission permits and the duty of companies to report relevant information to the authorities. The act specifies that the Environment Agency of Iceland (EA) is the responsible authority for the national accounting as well as the inventory of emissions and removals of greenhouse gases according to Iceland's international obligations. The EA shall, in accordance with the legislation, produce instructions on the preparation of data and other information for the national inventory. Formal agreements have been made between the EA and the necessary collaborating agencies involved in the preparation of the inventory to cover responsibilities such as data collection and methodologies, data delivery timelines and uncertainty estimates. This involves the National Energy Authority and the Agricultural University of Iceland (AUI). In addition, the Agricultural University has made formal agreements with its major data providers, the Soil Conservation Service of Iceland and the Icelandic Forest Service.

The Environment Agency of Iceland carries the overall responsibility for the national inventory and finalizing the inventory reports. The Agency reports to the Ministry for the Environment, which reports to the Convention. The flow of information and allocation of responsibilities is illustrated in Figure 3.1.

The contact person at the Environment Agency of Iceland is:

Birna S Hallsdóttir
Environment Agency of Iceland
Suðurlandsbraut 24
IS-108 Reykjavík
Iceland

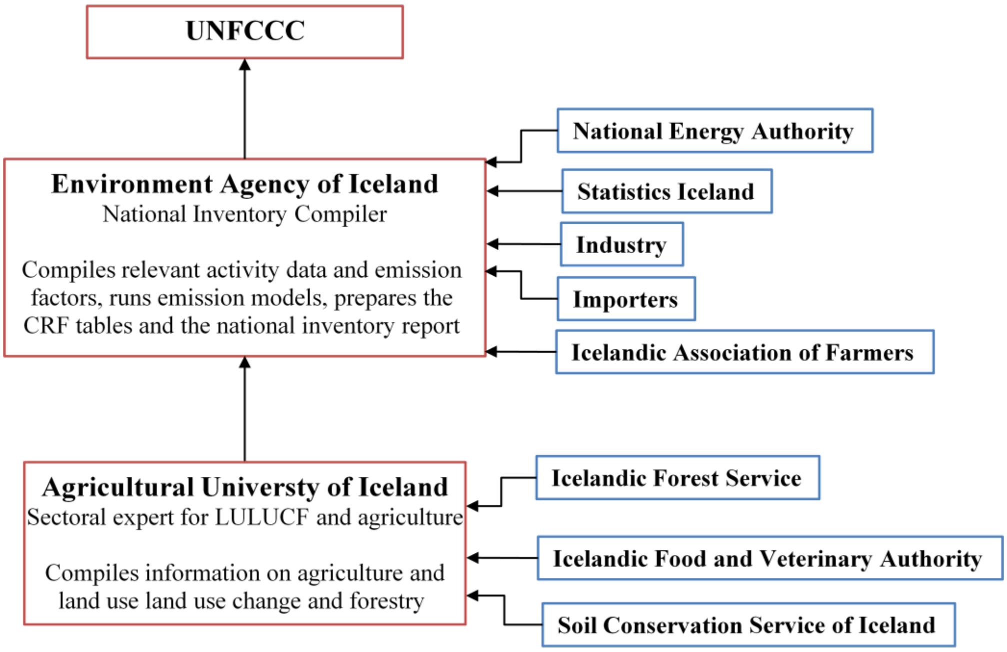


Figure 3.17 National system for the greenhouse gas inventory

3.2.2 Inventory process

The Environment Agency of Iceland collects the bulk of data necessary to run the general emission model, i.e. activity data and emission factors. Activity data is collected from various institutions and companies, as well as by EA directly. The National Energy Authority (NEA) collects annual information on fuel sales from the oil companies. This information was provided on an informal basis until 2008. In 2007, new legislation, Act No. 48/2007 went into force, enabling the NEA to obtain sales statistics from the oil companies. The Icelandic

Association of Farmers (IAF), on the behalf of the Ministry of Agriculture and Fisheries, is responsible for assessing the size of the animal population each year. On request from the EA, the IAF also accounts for young animals that are mostly excluded from national statistics on animal population. Statistics Iceland provides information on population, GDP, production of asphalt, imports of solvents and other products, the import of fertilizers and on the import and export of fuels. The EA collects various additional data directly. Annually a questionnaire on imports, use of feedstock, and production and process specific information is sent out to industrial producers, falling under Act 65/2007. Also Green Accounts from the industry are used. Importers of HFCs submit reports on their annual imports by type of HFCs to the EA. EA also estimates activity data with regard to waste. Emission factors are taken mainly from the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC Good Practice Guidance and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, since limited information is available from measurements of emissions in Iceland.

3.2.3 Quality management

The objective of QA/QC activities on national greenhouse gas inventories is to improve transparency, consistency, comparability, completeness, accuracy, confidence and timeliness in national inventories. A QA/QC plan for the annual greenhouse gas inventory of Iceland has been prepared. The document describes the quality assurance and quality control program. It includes the quality objectives and an inventory quality assurance and quality control plan. It also describes the responsibilities and the time schedule for the performance of QA/QC procedures. The QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Source category specific QC measures have been developed for several key source categories. A quality manual as stated in the ISO 9001 is under preparation.

A Coordinating Team was formally established in 2008, with representatives from the Environment Agency of Iceland, the Agricultural University and the Ministry for the Environment. The team has the role to officially review the emission inventory before submission to UNFCCC, as well as formulating proposals on further development and improvement of the national inventory system.

QA/QC procedures are documented for referral and reviewing. Results and reports of these procedures are documented and stored.

3.2.3.1 The annual inventory cycle

The annual inventory cycle describes individual activities performed each year in preparation for next submission of the emission estimates.

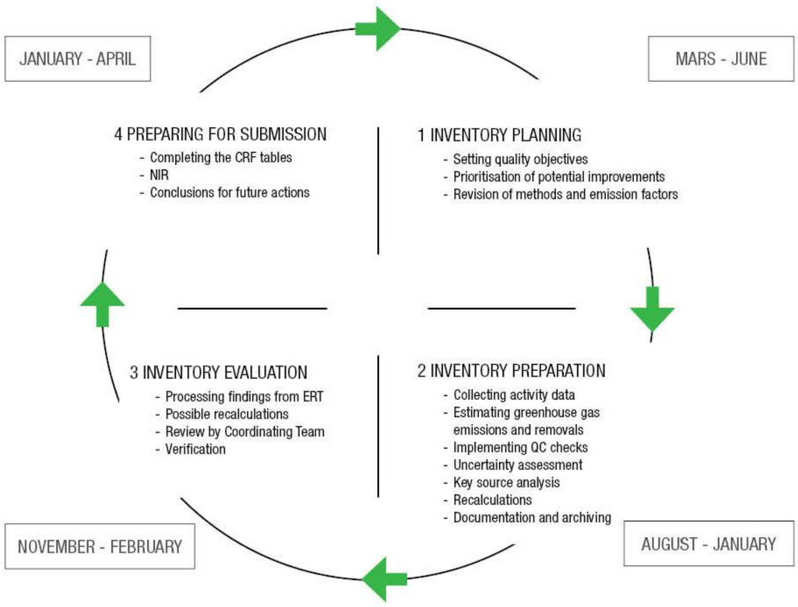


Figure 3.18 The annual inventory cycle

A new annual cycle begins with an initial planning of activities for the inventory cycle by the Coordinating Team, taking into account the recommendations from the UNFCCC review. The initial planning is followed by a period assigned for compilation of the national inventory and improvement of the National System.

After compilation of activity data, emission estimates and uncertainties are calculated and quality checks are performed to validate results. Emission data is received from the sectoral expert for LULUCF, i.e. the AUI. All emission estimates are imported into the CRF Reporter software.

A series of internal review activities are carried out annually to detect and rectify any anomalies in the estimates, e.g. time series variations, with priority given on emissions from key source categories and for those source categories where data and methodological changes have recently occurred. These reviews are performed according to the quality control procedures in chapter 8 of the IPCC, Good Practice Guidance (2000).

After final review of the greenhouse gas inventory by the Coordinating Team, the inventory and the NIR are submitted to UNFCCC by the Environment Agency.

3.2.3.2 Document and data storage

All National System documents are stored electronically on the EA's computer network. This includes quality system documents, reports, original data from data providers, the CRF Reporter database files, data submitted to the UNFCCC and spreadsheets of the emission inventory. After each submission to UNFCCC a complete copy is archived. This ensures easy access for expert review teams to old data and documents which give correct context for the data. For easy access, hard-copies are made and updated as needed. Backups of the National System documents are taken during regular backups of network drives on EA's computer network.

3.2.4 Methodologies and data sources

The estimation methods of all greenhouse gases are harmonized with the IPCC Guidelines for National Greenhouse Gas Inventories and are in accordance with IPCC's Good Practice Guidance. The general emission model is based on the equation:

Emission (E) = Activity level (A) · Emission Factor (EF)

The model includes the greenhouse gases and in addition the precursors and indirect greenhouse gases NOx, SO_2, NMVOC and CO, as well as some other pollutants (POPs).

3.2.5 Key source categories

According to the IPCC definition, a key source category is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both. In the Icelandic Emission Inventory key source categories are identified by means of a Tier 1 method. The key source analysis now includes LULUCF sources.

IPCC SOURCE CATEGORIES	Direct GHG	Key source		
		Level '90	Level '07	Trend
ENERGY SECTOR				
1.AA.2: Manufacturing Industry And Construction	CO_2	ν	ν	ν
1.AA.3b: Road Transport	CO_2	ν	ν	ν
1.AA.3b: Road Transport	N_2O		ν*	ν
1.AA.3 (A,D): Transport Other Than Road Transport	CO_2	ν	ν	ν
1.AA.4(A,B): Residential, Commercial, Institutional	CO_2	ν*		ν
1.AA.4c: Fishing	CO_2	ν	ν	ν
1.B.2d Geothermal Energy Utilisation	CO_2	ν	ν	ν
INDUSTRIAL PROCESSES				
2.A: Mineral Industry	CO_2	ν	ν	
2.B: Chemical Industry	N_2O	ν		
2.C.2: Ferroalloys Production	CO_2	ν	ν	ν
2.C.3: Aluminium Production	CO_2	ν	ν	ν
2.C.3: Aluminium Production	PFC	ν	ν	ν
2.F Emissions From Substitutes For Ozone Depleting Substances	HFC		ν	ν
AGRICULTURE				
4.A.1 Enteric Fermentation, Cattle	CH_4	ν	ν	ν
4.A.3 Enteric Fermentation, Sheep	CH_4	ν	ν	ν
4.B Manure Management	N_2O	ν*		
4.D.1 Direct N_2O Emissions From Agricultural Soils	N_2O	ν	ν	
4.D.2 Indirect N_2O Emissions From Nitrogen Used In Agriculture	N_2O	ν	ν*	
LULUCF				
5.A Forest Land	CO_2		ν	ν
5.C.2.3 Wetlands Converted To Grassland	CO_2	ν	ν	ν
5.C.2.5 Other Land Converted To Grassland	CO_2	ν	ν	ν
WASTE				
6.A Solid Waste Disposal Sites	CH_4	ν	ν	ν
6.C Waste Incineration	CO_2			ν

*key source excluding LULUCF

Table 3.2 Key source categories for 2007

3.3 National registry

Currently the Icelandic Registry is not live although green light has been given for entering Go Live for ITL. As Iceland is part of the EU ETS a CITL connection is planned in the near future. In February 2010 the registry will go live as non-operational registry during the period prior to the connection to the CITL, since CITL can not recognize transactions made only within the ITL.

3.3.1 Implementing and running the registry system

The Environment Agency of Iceland is responsible for the implementation and operation of Iceland's National Registry under the Kyoto Protocol. The software used for the Icelandic

National Registry is GRETA (Greenhouse gases Registry for Emissions Trading Arrangements) The IT software supplier of GRETA is SFW.

3.3.1.1 Contact details of registry administrators

Institution	Environment Agency of Iceland
Contact	Department for Environmental Quality
Address	Sudurlandsbraut 24, IS-108 Reykjavik, Iceland
Telephone	+354 591 2000
Fax	+354 591 2020
Registry System Administrators	Birna Hallsdottir (birna@ust.is) Sigurdur Finnsson (sigurdurb@ust.is)

3.3.2 Technical description

This technical description of the Icelandic National Registry is presented in accordance with the reporting requirements in Annex II under decision 15/CMP.1.

3.3.3 Consolidated registry systems

The Icelandic National Registry is a standalone registry; it is not operated together in a consolidated form with the registries of other nations.

3.3.4 Compliance with ITL data exchange standards

The GRETA registry software was originally developed for use in the European Union Greenhouse Gas Trading Scheme (EU ETS) which requires the registry to be compliant with the UN Data Exchange Standards (DES) for communication with UN's International Transaction Log (ITL).
The software implements all UN DES. The registry communicates with ITL using XML messages and web-services as specified in the UN DES. These methods are used to perform issuance, conversion, external transfer, cancellation, retirement and reconciliation processes.

3.3.5 Strategies employed to minimize discrepancies

The Icelandic national registry fulfills all required processes to minimize discrepancies in issuance, transactions, cancellation and retirement of ERUs, CERs, AAUs or RMUs. UN DES specifications are followed at every step of the transactions to minimize risks of inconsistent data in the registry database and ITL. Before forwarding requests to ITL the registry validates data entries against a list of checks performed by ITL (see Annex E of UN DES). A transaction is not finalized until the transaction is registered on both registry servers. The transaction is cancelled if ITL sends an error code. The registry administrator has to contact the ITL administrator for instructions if the registry fails to terminate the transaction. It can be necessary to perform manual corrections in the registry database by the registry administrator.

Each unit is marked with unique codes internally in the registry database. This prevents units to be used in more than one transaction until confirmation of successful transaction has been received by ITL and the transaction is completed.

When sending a message, the registry waits for an acknowledgement of the message being received by ITL before completing submission of the message. If no acknowledgement is received after number of retries, the registry terminates the submissions and performs roll-back on any changes possibly made to the involved unit blocks.

Upon receiving the 24 hour clean-up message from ITL, the registry rolls back any pending transactions including units that were involved. This prevents discrepancies of unit blocks between the registry and ITL.

If all automatic roll-back functions of the registry fail to prevent discrepancies with ITL, a number of manual intervention functions exist in the registry software for the administrator to fix the problem. In worst cases a SQL script will be generated to directly fix problems in the registry SQL database.

After any problem, a reconciliation process is run to confirm that both the registry and ITL agree on all relevant data.

3.3.6 Database and registry server specifications

The registry software runs on two separate servers all running as VMware virtual machines on blade servers. The servers run Microsoft Windows 2003.

Server 1: The SQL server

The database server is Microsoft SQL Server 2005 (32-bit) standard edition. The SQL server runs on a separate virtual server.

Server 2: The business logic layer and web access for registry system administrators

A single virtual server runs both the business logic layer (a web service) which handles requests to and from the database server and the registry system administrator access (web interface). The server runs .NET 1.1 runtime and IIS 6.

3.3.7 Disaster prevention and recovery

The registry server is located at a dedicated IT hosting company in Iceland named Skyrr. The server is stored in a fire-proof, temperature controlled room with sensitive fire-detection systems. Access to the server room is only allowed by authorized people and all access is logged.

A daily full backup is taken of the servers with a retention period of 5 weeks.

To mitigate possible data loss in a disaster scenario, backups are sent to an off-site data center (located 12 km. away from the main server room). Critical software patches are applied when they become available. In general 2 working days are needed to get the registry up and running in case of failure.

3.3.8 Testing of the Icelandic national registry

The current version of the GRETA registry system software has already proved its functionality against CITL (EU´s Community Independent Transaction Log). Testing of GRETA against CITL has been done in co-operation of the members of the GRETA working group (GRETA WG) and the current developers of the software.
GRETA WG performs thorough testing of the GRETA registry software in cooperation with the GRETA developers.

3.3.9 Security of the Icelandic National Registry

Administrators and users are granted access through a web interface with usernames and passwords. Digital certificates are used to increase the strength of user authentication.
Access permissions are defined for each user which determines his access to the registry system. This prevents any unauthorized access to restricted procedures. Audit logs are used to track actions.

No direct manipulations of the database are possible through the web-services. Changing the database through the web user-interface is only possible by running predefined procedures. This decreases greatly the risk of intentional or unintentional attacks on the integrity of the database through the web interface.

To minimize risks of incorrect actions due to user errors, the registry uses the following checks before submitting user input for processing:

- Validates all user input before processing.
- Users are asked for confirmation of their input.
- Internal approval process is implemented for secondary approval before submitting details to ITL.

3.3.10 Public information accessible through the web page

The registry software will at least allow public access to reports as required under 5/CMP.1, 13/CMP.1 and 14/CMP.1. These reports will be easily accessible through the web-based home page of the registry system.

3.3.11 Webpage of the registry system

The Icelandic national registry system will be accessible through the web address:

http://co2.ust.is

4 Policies and measures

4.1 Iceland's commitments and climate change strategy

Iceland deposited its instruments of ratification of the Kyoto Protocol on May 23, 2002. Iceland's obligations according to the Kyoto Protocol are as follows:

• For the first commitment period, from 2008 to 2012, greenhouse gas emissions shall not increase more than 10% from the level of emissions in 1990.

• For the first commitment period, from 2008 to 2012, the mean annual carbon dioxide emissions falling under decision 14/CP.7 on the "Impact of single project on emissions in the commitment period" shall not exceed 1,600,000 tons.

In February 2007, the Icelandic government adopted a new Climate Change Strategy, the third of its kind. It is conceived as a framework for action and government involvement in climate change issues. The Strategy will be reviewed regularly in view of new scientific knowledge, developments in international co-operation to combat climate change, and governmental emphases at any given time.

The Strategy sets forth a long-term vision for the reduction of net emissions of greenhouse gases by 50-75% until the year 2050, using 1990 emissions figures as a baseline. Emphasis is placed on reducing net emissions by the most economical means possible and in a way that provides additional benefits, by actions such as including the introduction of new low- and zero-carbon technology, economic instruments, carbon sequestration in vegetation and soil, and financing of climate-friendly measures in other countries.

The Strategy sets forth the Icelandic government's five principal objectives with respect to climate change, which aim toward the realization of the above-described long-term vision:

- 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 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.

The Strategy contains provisions for measures that will be adopted in order to achieve these objectives, grouped by sectors. On the basis of the Strategy, two expert work groups were appointed to support the further development of climate policy. One group had the role of compiling and summarizing the best available scientific knowledge of the likely impact of climate change on Iceland and to present proposals on adaptation efforts. The other work group was given the task of assessing the effectiveness and economic efficiency of measures to mitigate climate change. The Strategy contains statistical indicators that will be updated in the future. These indicators should provide clues to how successfully the Strategy is being enforced and how much progress is being made in reducing greenhouse gas emissions and increasing carbon sequestration.

The Strategy is available on the web:
http://eng.umhverfisraduneyti.is/media/PDF_skrar/Stefnumorkun_i_loftslagsmalum_enlokagerd.pdf

4.2 The policy development process

The 2007 climate change strategy was formulated by an interministerial committee headed by the Ministry for the Environment and consisting of representatives of the Ministries of Agriculture, Finance, Fisheries, Foreign Affairs, Industry and Commerce, Transport and Communications, and the Prime Minister's Office. Currently, a committee consisting of the same ministries (excluding the Ministry of Foreign Affairs), and also led by the Ministry for the Environment, is working on an Action Plan based on the Strategy and guided by the results of the Expert Committee on measures to reduce net emissions. The Federation of Icelandic Municipalities is also represented in this committee. A draft Action Plan was released in early December 2009, and key stakeholders were asked for a feedback on the draft. The 2007 Strategy and the Action Plan are drafted in a consultative manner with stakeholders and civil society, including environmental organizations.

Iceland's current strategy for sustainable development, "Welfare for the Future", was approved by the government in July 2002. It provides a framework for sustainable development for the next two decades, setting up seventeen key long-term objectives, planned short-term measures to implement those objectives, and indicators to measure success. One key objective is mitigating climate change, and another is to increase further the share of renewable energy in the energy mix. The strategy is reviewed every four years, with the indicators and the short-term measures to be updated. In November 2005, Iceland's fourth Environmental Assembly, a national gathering of institutes, academics and stakeholders in the field of the environment and sustainable development, reviewed the strategy and subsequently a new plan for priorities in the period 2006-2009 was adopted. The sixth Environmental Assembly in 2009 again reviewed a draft plan for priorities 2010-2013, which is pending approval by the government.

Iceland has two administrative levels, and local authorities work alongside the central government in implementing many of the climate-related policies. In some fields, like waste management, the local governments have a key role. In recent years Icelandic municipalities have done considerable work in forming their own sustainable development policy under the label of Local Agenda 21. The City of Reykjavík, the largest municipality in Iceland, adopted a Climate Change and Air Quality Policy that includes the goal of reducing net greenhouse gas emissions by 35% until 2020, and 73% until 2050, compared to 2007 levels.

4.3 Key measures in emission reduction

As almost all stationary energy in Iceland is produced from renewable sources, measures to reduce emissions are largely focused on mobile sources: Transport and the fishing fleet. There is also an effort to keep industrial emissions as low as technically possible. Carbon sequestration in the land use, land use change and forestry (LULUCF) sector is also a priority, given Iceland's large potential for afforestation and revegetation.

The most effective measures taken so far have been in reducing fluorocarbon emissions from aluminum production and in increased carbon sequestration through revegetation and afforestation. Various other measures have been adopted as well, and though these have yielded less measurable success so far, it is expected that some of them — such as the recently imposed carbon tax and reductions in fees and taxes on climate-friendly motor vehicles — will generate results later on.

Below is a more detailed discussion about measures in individual sectors.

4.3.1 The energy sector

Almost all stationary energy is produced from renewable sources, and about 80% of the total primary energy supply. Most energy-related GHG emissions come from mobile sources (transport on land and fishing vessels), where cuts in emissions are generally considered more difficult to achieve than from stationary energy sources. Iceland's 2002 strategy for sustainable development, *Welfare for the future*, states the goal of phasing out fossil fuels almost completely within a few decades. Measures related to energy are therefore discussed mostly in the subsequent sections on transportation and fisheries.

Geothermal energy production is not completely climate-neutral, as it causes dissolved CO_2 in geothermal fluid to be released more rapidly than would occur naturally. Such emissions are measured and accounted for in Iceland, and are about 4% of total GHG emissions. These emissions are still miniscule compared to emissions that would occur if heating and electricity production which is now from geothermal was produced by fossil fuels. An experimental project (CarbFix) is under way at the Hellisheiði geothermal plant, injecting CO_2 captured in geothermal steam back into the basaltic rock underground. The aim of the Carbfix Project is to study the feasibility of sequestering the greenhouse-gas carbon dioxide into basaltic bedrock and store it there permanently as a mineral. The project's implications for the fight against global warming may be considerable, since basaltic bedrock susceptive of CO_2 injections are widely found on the planet and CO_2 capture-and-storage and mineralization in basaltic rock is not confined to geothermal emissions or areas.

4.3.2 The transportation sector

Transportation is a big and growing source of greenhouse gas emissions in Iceland. Road vehicles were responsible for 27% of total CO_2 emissions in 2007, compared to 24% in 1990.

A new oil charge system took effect on 1 July 2005. The pertinent legislation changed the taxation structure for diesel fuel, thus simplifying the use of diesel automobiles by charging fees in the same manner as is done for gasoline. This change was expected to result in a gradual increase in the number of smaller diesel vehicles in use, thus reducing greenhouse gas emissions resulting from motor vehicle traffic. For vehicles weighing 10 tons or more, a per-kilometer fee is still charged in addition to the oil charge. The abolition of the weight tax and the adoption of an oil fee instead of the weight tax have resulted in a reduction in fees charged for busses and long-distance coaches, making public transportation more affordable.

Vehicles that generate virtually no pollution and are powered by unconventional energy sources, such as electricity or hydrogen, have been exempt from excise tax. This exemption includes all motor vehicles that are imported to or manufactured in Iceland and are powered solely by pollution-free energy sources, such as electricity or hydrogen. It does not include vehicles that are powered by both polluting and non-polluting energy sources, such as automobiles with hybrid engines. Vehicles that are powered by electricity and are imported or built for experimental purposes are also exempt from excise tax.

Automobiles that are equipped with engines utilizing methane or electricity to a substantial degree instead of gasoline or diesel fuel bear an excise tax that is ISK 240,000 less than that on conventional vehicles. As a result of the reduced excise tax, hybrid automobiles could become more economical than conventional vehicles in some instances.

It is now permissible to cancel or refund value-added tax on hydrogen-powered vehicles and on specialized spare parts that are imported for research purposes. It is also permissible to cancel import duties and/or excise tax on spare parts. This authorization applies only to hydrogen-powered automobiles that are virtually pollution-free. It is also authorized to refund 2/3 of the value-added tax on new group transport vehicles equipped with engines that meet the quality standards for fuel utilization and environmental impact (EUROIII).

Despite these efforts to favor low-emission cars, emission from road transport has continued to grow. The purchase of new cars took a sharp downturn with the economic crisis in the fall of 2008, and has stayed low since. The number of registered new cars was 12.308 in 2008 and 2.830 in 2009.

The Public Roads Administration has, in collaboration with the City of Reykjavík, worked on coordinating traffic lights in the Reykjavík area, which should reduce emissions.

In the past few years, a great deal of road construction has been done in order to shorten driving routes, by road improvements and tunnels. Work is also being done on proposals for changes in road placement in several populated areas, and this could affect driving times.

4.3.3 The fisheries sector

The fisheries sector is one of the biggest sectors in terms of GHG emissions in Iceland. The use of fossil fuels for fishing vessels was responsible for 17% of total CO_2 emissions in the year 2007. The emissions decreased by about 14% from 1990.

There has been significant renewal of the fishing fleet. In general, new ships are more efficient than comparable older ships in terms of fuel consumption; therefore, newer ships can represent substantial benefits for fisheries when fuel prices are high.

Various fisheries companies have examined the possibility of equipping their ships with Icelandic-designed energy-saving devices based on information technology. The government has supported experimental projects in this field. The Marine Research Institute has also set up an energy-saving system in the research vessel Árni Fridriksson, and the Ministry of Justice has concluded a contractual agreement related to the installation of such a system in the Coast Guard's new cruiser.

Increased provision of land-based electricity in harbors, that allows ships to keep engines turned off, is believed to save emissions by almost 16,000 tons of CO2 annually.

HFCs are used in cooling systems in fishing ships; their use began when they were substituted for HCFCs, which were considered undesirable because of their ozone-depleting properties. It was later revealed that HFCs could be negative in relation to greenhouse gas emissions. It is possible to use ammonia-based or other climate-friendly (and ozone-friendly) cooling system, but some of them carry greater health risks. Work is ongoing to phase HFCs out, but it will take some time to exchange them with climate-neutral cooling agents.

The processing of fish and seafood on land is a relatively small source of greenhouse gas emissions in Iceland, with the exception of the fishmeal industry, which uses oil along with electricity generated from renewable energy sources. There has been a steady trend towards lowering emissions in the fishmeal industry, largely because of investment by the industry itself in better and cleaner technology. The Icelandic fishmeal industry is one of the few that employs electric (climate-neutral) heating instead of oil heating. Typical oil use for plants using electric heating is 25 kg oil/ton of processed raw material compared with the use of 40 kg oil/ton for conventional plants.

4.3.4 Industrial processes

Industrial processes in energy-intensive industries accounted for 36% of total CO_2 emissions in Iceland in the year 2007, compared to 18% in 1990. Reduction in perfluorocarbons (PFC) emissions from aluminum production is the greatest success story so far in reducing GHG emissions in Iceland. The 2002 climate change strategy set the goal of PFC emissions from aluminum smelters at 0.14 tons of CO_2 equivalents. This target has been achieved in the three aluminum smelters in operation in Iceland, with some temporary exceptions. A provision to this effect is included in the operating permit for the Alcan smelter and will be included in the Nordurál and Fjardarál operating permits. The aluminum plants have achieved their goal by improving technology in continuing production, and by introducing Best Available Technology in new production.

PFC emissions dropped by over 300,000 tons from 1990 to 2004, despite the fact that aluminum production increased during that period. In Iceland's report on Demonstrable Progress in the implementation of the Kyoto Protocol, the assessment of the success rate of measures adopted attempts to present a quantitative evaluation of the success of the measures employed. That report does not assume that PFC emissions per ton of aluminum produced would have remained the same after 1990 without the adoption of measures to protect the climate, but by assuming such premises, it would be possible to calculate still greater savings. Instead, an examination is made of the difference between the average PFC emissions per ton of aluminum produced in the world and the emissions demanded in Iceland's Climate Change Strategy, and which have been actually achieved by the smelters. According to such a comparison, the calculated success of measures adopted were approximately 65,000 tons of CO_2 equivalents in 2005.

It is also possible to estimate the mitigation impact of decreased emissions by the aluminum industry by comparing the required PFC limit of 0.14 t CO_2-eq/t aluminum with the world median emissions of PFCs for the point fed prebake technology (PFPB), which is best available technology, or the global mean average for aluminum production. The International Aluminum Institute's *Results of the 2008 Anode Effects Survey* reports global mean emissions of PFCs to be 0.7 t CO_2-eq/t aluminum and world median emissions of PFCs (not including China) for the PFPB technology as 0.27 t CO_2-eq/t aluminum. The calculation of the impact of strict regulation of these emissions yields an estimated mitigation benefit of 0.13 t CO_2-eq/t aluminum when compared with worldwide users of the PFPB technology or 0,56 t CO_2-eq/t aluminum when compared with the global average. For the total annual production of aluminum in Iceland, 780 000 tons, the benefits of using the limit of 0.14 t CO_2-eq/t aluminum are about 101 000 tons CO_2-eq/year when compared with the world median for PFPB smelters and about 437 000 tons CO_2-eq/year when compared with the world total average.

4.3.5 The waste sector

GHG emissions from the waste sector were 5% of total GHG emissions in 2007, the same percentage as in 1990. Most of these emissions are methane from landfills.

The total amount of waste has been increasing in recent years, although a reduction has occurred since the economic downturn in fall 2008. Despite the increase in waste, GHG emissions from the sector have declined due to increased recycling and technological advances in the handling of waste. The most important measure is the collection of methane from the largest landfill in the country, serving all of the greater Reykjavík area, which started in 1997. Icelandic Waste Management Law and regulations on waste treatment transpose the following targets into Icelandic law: i) to reduce the total weight of organic household waste to be landfilled by 25 per cent by January 2009, by 50 per cent by June 2013, and by 65 per cent by June 2020; ii) to reduce the total weight of other organic waste, such as biodegradable organic waste to be landfilled, by 25 per cent by no later than January 2009, by 50 per cent by no later than June 2013 and by 65 per cent by no later than June 2020. A reduction in the landfilling of organic waste is intended to result in a reduction in methane emissions.

The waste management firm Sorpa, owned by Reykjavik city and six other municipalities, collects methane from the Reykjavik-area landfill. Some 50 vehicles are run on methane from the landfill, but it is estimated that the gas from the landfill could power at least 4.000 cars annually. The remainder of the methane is burned for electricity production. These measures reduce emissions by 30,000 CO2 equivalents per year.

4.3.6 The agriculture sector

Agriculture accounted for 12% of total GHG emissions in 2007, compared to 17% in 1990. Studies indicate that it is difficult to reduce emissions from agriculture, which is mainly methane from livestock and manure and N2O from fertilizer. Possibilities of improved manure management are being studied as perhaps the most promising method to reduce agricultural emissions.

Related to agriculture is the issue of emissions from drained wetlands. Research indicates that drained wetlands are a significant source of CO_2-emissions. These emissions can be attributed largely to human influence, from the draining of wetlands undertaken almost entirely before 1990. Some of the land is currently used for crop cultivation or animal grazing, but other is of marginal use. The discovery of this apparently significant emission source indicates that the reclamation of wetlands can help stop the emission of CO_2, and even in some cases sequester carbon in vegetation and soil. Increased reclamation of wetlands is listed as a priority measure for the mitigation of climate change in the 2007 climate change strategy, regardless of whether it can result in credits in the Kyoto Protocol GHG accounting or not. Iceland has submitted a proposal in the current negotiations in the AWG-KP that wetland degradation and reclamation be included as an elective activity under Article 3.4 of the Kyoto Protocol, as an incentive to conserve and reclaim wetlands.

4.4 Carbon sequestration

Revegetation and reforestation is a high priority in Iceland, and there is significant potential to enhance carbon sequestration beyond the present level, due to the high proportion of devegetated and deforested land. In 2007 carbon sequestration was 279 Gg CO_2-equivalents for activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol.

In 1996 the Icelandic government announced its decision to dedicate ISK 450 million for a four-year program of revegetation and tree planting to increase the sequestration of carbon dioxide in the biomass. This program was implemented in 1997-2000. The stated goal was an increase of 22,000 tons in carbon sequestration. Assessment of the results of the program indicates that the total additional sequestration was 27,000 tons. Efforts to increase the annual carbon sequestration rate resulting from reforestation and revegetation programs have continued since. A strategic plan for soil conservation and revegetation, adopted by the Icelandic Parliament in the spring of 2002, lists carbon sequestration as one of the four main objectives of the strategy. The strategic plan covers the period of 2003 to 2014. The parliament has also adopted action plans for the forestry sector, where attention is given to carbon sequestration.

4.5 Research and development

The 2007 Climate Change Strategy stresses the importance of research, extending not only to scientific knowledge of the nature and extent of climate changes and the various effects of those changes, but also to research and development in the field of new, climate-friendly technology, economic and social research into the most effective and economical responses to climate changes, and studies of possible ways to co-ordinate the battle against climate change with the move toward greater economic and social welfare.

A report by the Ministry for the Environment to the Science and Technology Policy Council in 2006 stated that Iceland was in many respects an interesting venue for research into climate changes and their effects, as well as the possible measures to mitigate them. This stems in part from the country’s geographical position — at the boundary of the Arctic region and in the path of the Gulf Stream — and it also results from the significant emissions from damaged vegetated lands and the corresponding potential for sequestration of carbon from the atmosphere. In addition, Iceland is an interesting subject of research because of renewable energy resources and progressive technology that can aid in both utilizing those resources and reducing greenhouse gas emissions in general.

The report mentioned several subjects that would be especially interesting to study and monitor:

- The effects of climate change on Iceland;
- The natural emission of greenhouse gases and the sequestration of CO2;
- Emissions caused by human activities — improvements in greenhouse gas inventory;

- Measures to combat climate change — assessment of mitigation potentials and economic efficiency of measures;
- Climate-friendly technology — innovation and promotion.

Implementation of policies related to research and development is a joint responsibility of all ministries. Discussion on research and development is provided in more detail in Chapter 7.

4.6 Information and public awareness

Increased emphasis on information and public awareness is one of the seven main components of the 2007 Climate Change Strategy. It states that measures taken to combat climate change "will be of limited value if there is no general awareness of the subject and if the general public is not willing to participate in achieving set targets." It further states: "The government must work with industry and non-governmental organizations in order to mobilize the public so that goals can be achieved."

The government has in the past consulted with industry concerning the implementation of various elements of the Climate Change Strategy of 2002. Chief among those efforts is collaboration with the aluminum industry. Aluminum manufacturers have, in co-operation with the government, made substantial progress in minimizing the emissions of fluorocarbons, with the result that PFC emissions in Icelandic plants are among the lowest in the world. The government has financially supported the work of non-governmental organizations, such as the Landvernd Climate Change project, which has yielded a number of proposals for potential reduction of emissions.

Emissions generated by individuals in Iceland are different than in most other countries and are mostly a result of transport rather than domestic energy use. Private car use is the dominant mode of transport. Efforts have been made to encourage alternative ways of transport, such as walking and bicycling, for example in specific campaigns where workplaces can compete in the number of employees bicycling for work.

The Ministry for the Environment has produced an information brochure on climate change that has been widely distributed to schools.

4.7 Other measures

Iceland is part of the European Union Emission Trading Scheme for carbon dioxide emissions. At present no facilities in Iceland fall under the scheme. This will change in 2012, when aviation will be part of the EU-ETS, and in 2013, when aluminum and ferrosilicon production will be part of it. By then, about 40% of Iceland's emissions may be part of the scheme.

5 Projections and the total effect of measures

5.1 Introduction

Following the adoption of Iceland‘s third climate change strategy, the Minister for the Environment appointed a committee in the spring of 2007 with the mandate to explore the technical possibilities of mitigating greenhouse gas emissions in different sectors of the Icelandic economy. The committee submitted its report to the Environment Minister in May 2009. The report presents a comprehensive summary of mitigation options until 2020, technical feasibility and cost. The report contains a greenhouse gas emissions forecast to 2050 with two alternative scenarios, which was created by the Environment Agency of Iceland (EA).

The magnitude of national emissions of greenhouse gases depends on many different interlinked factors including population and economic growth, energy use, industrial production and the sectoral characteristics of the economy. Industrial activities and fuel use are key parameters relating to emissions in Iceland. Decisions about single industry projects can have major impacts because of the small size of the economy.

The two scenarios from EA projections and key assumptions are presented below. The scenarios are based on different assumptions regarding production of aluminum and ferrosilicon owing to the large impact these industries have on total national emissions. Both scenarios predict that Iceland‘s emissions of greenhouse gases will be within the limits set by the Kyoto protocol for the first commitment period.

5.2 Scenarios and key assumptions

Scenario 1

In scenario 1 it is assumed that future production by energy intensive industries equals production capacity at the end of the year 2008. Total sectoral emissions are shown in Figure x. A peaking in emission is seen in 2008, followed by a decline until 2023, a second slight peaking in 2038 and downward trend thereafter.

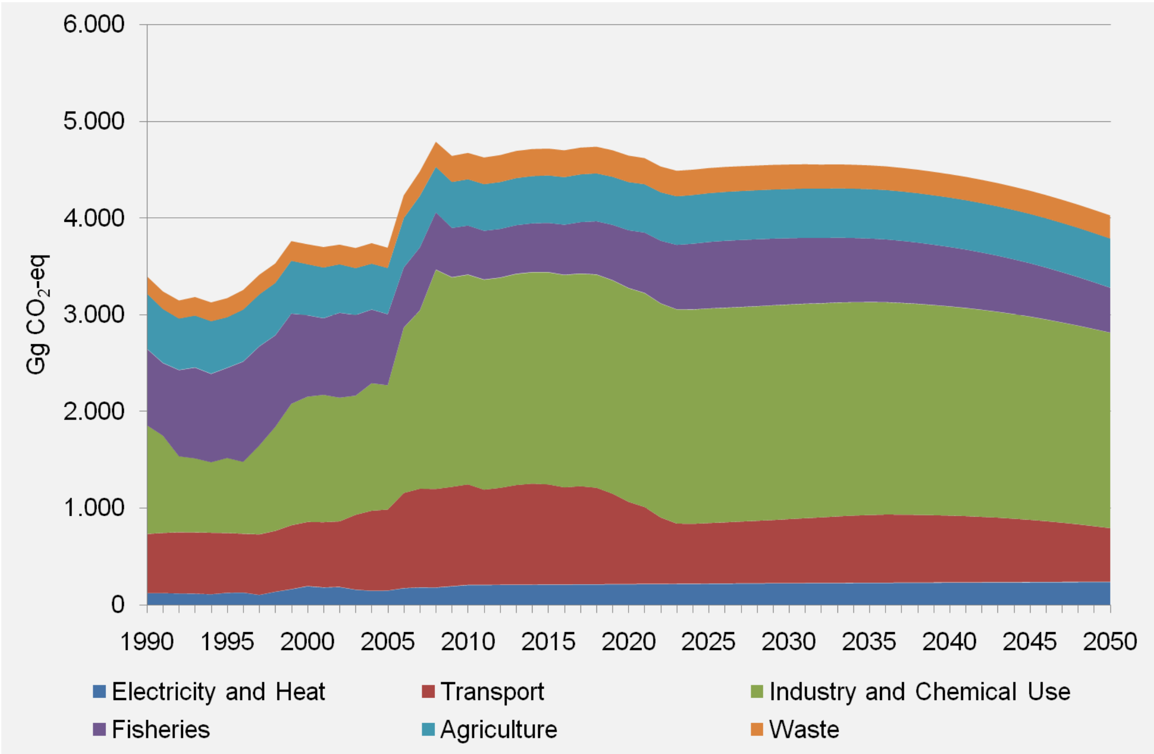


Figure 5.1 Forecast of sectoral emissions of greenhouse gases (Scenario 1)

The scenario predicts that total emissions, excluding LULUCF, during the first commitment period will equal 23388 Gg CO_2-eq, or 4678 Gg CO_2-eq on average per year. Emissions of CO_2 from projects that fulfill the provisions of 14/CP.7 are predicted to amount to 6259 Gg CO_2-eq, or 1252 CO_2-eq on average per year.

Iceland's AAUs for the first commitment period amount to 18,523,847 tons of CO_2 equivalents for the period or 3,704,769 tons CO_2-eq per year on average. The predicted total emissions in 2008 – 2012, 23388 Gg CO_2-eq, are 26% above the AAUs for the commitment period. Emissions of CO_2 from projects that qualify for the provisions of decision 14/CP.7 are however 6259 Gg CO_2, or 26.8% of the predicted total emissions. These projects shall be reported separately according to the decision and carbon dioxide emissions from them not included in national totals to the extent that they would cause the Party to exceed its assigned amount. Separating emissions fulfilling the provisions[1] of decision 14/CP.7 from the predicted total emissions results in total emissions of 17129 CO_2 or 7.5% below the assigned amount. Taking sequestration by afforestation and revegetation into account would further widen the gap by adding to the assigned amount. This scenario predicts therefore that CO_2 emissions that would reported separately according to decision 14/CP.7 would be 23388 – 18523,847 = 4864 Gg CO_2, or 78% of the emissions that qualify for decision 14/CP.7 and only 61% of the emission cap of 8000 Gg CO_2 set by the decision.

[1] See Chapter 2.12

Scenario 2

In scenario 2 it is assumed that production by energy intensive industries will reach full capacity according to permitted levels in 2015. It should be noted that even if environmental permits have been obtained for new projects it does not automatically mean that they will be launched. Sectoral emissions in accordance with assumptions underlying scenario 2 are shown in Figure x. An increase is observed in emissions until 2014 followed by a decline until 2023, a second slight peaking in 2038 and downward trend thereafter.

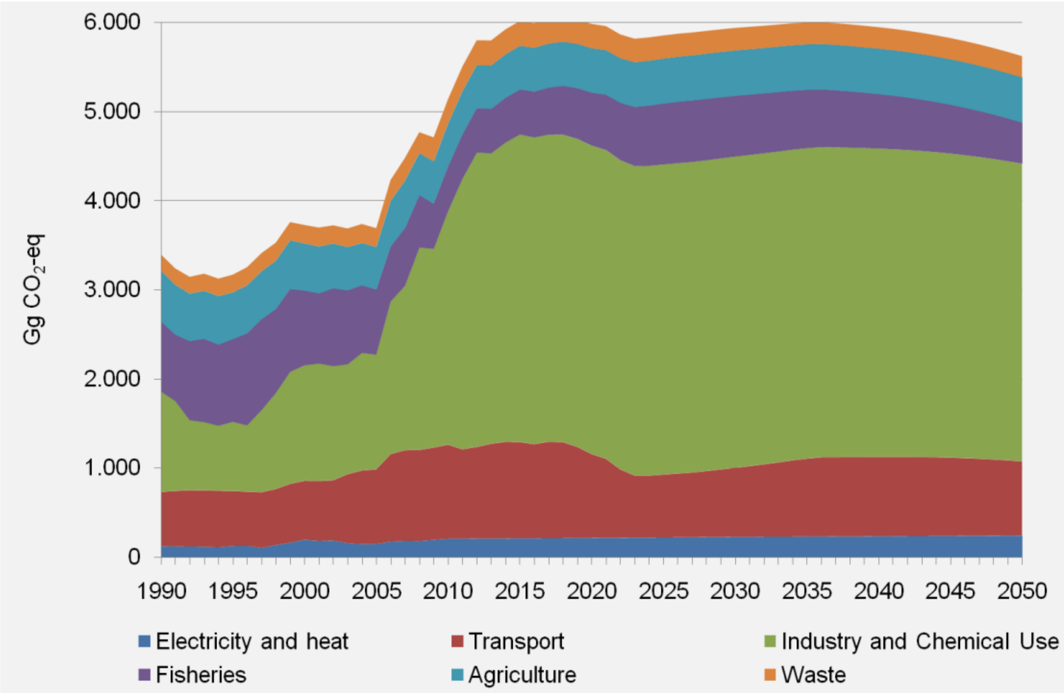


Figure 5.2 Forecast of sectoral emissions of greenhouse gases (Scenario 2)

The scenario predicts that total emissions, excluding LULUCF, during the first commitment period will equal 25936 Gg CO_2-eq, or 5187 Gg CO_2-eq on average per year. Emissions of CO_2 from projects that fulfill the provisions of 14/CP.7 are predicted to amount to 7666 Gg CO_2-eq, or 1533 CO_2-eq on average per year.
The predicted total emissions in 2008 – 2012, 25936 Gg CO_2-eq, are 40% above the AAUs, 18,523,847 tons of CO_2-eq, for the commitment period. Emissions of CO_2 from projects that qualify for the provisions of decision 14/CP.7 are however 7666 Gg CO_2, or 29.6% of the predicted total emissions. These projects shall be reported separately according to the decision and carbon dioxide emissions from them not included in national totals to the extent that they would cause the Party to exceed its assigned amount. Separating emissions fulfilling the provisions of decision 14/CP.7 from the predicted total emissions results in total emissions of 18270 CO_2 or 1.4% below the assigned amount. Taking sequestration by afforestation and revegetation into account would further widen the gap by adding to the assigned amount. This

scenario predicts therefore that CO_2 emissions that would reported separately according to decision 14/CP.7 would be 25936 – 18523,847 = 7412 Gg CO_2, or 96,7% of the emissions that qualify for decision 14/CP.7 and 92,7% of the emission cap of 8000 Gg CO_2 set by the decision.

5.3 Projections and aggregate effects of policies and measures

If emissions are in accord with projections, Iceland will be able to meet its obligations for the first commitment period of the Kyoto Protocol, even with the planned expansion in energy-intensive industries in Scenario 2. The scenarios are calculated excluding estimations on carbon sequestration by afforestation and revegetation.

Fiscal measure that have been taken to influence consumption to lower emissions of greenhouse gases include exemption and reduction of excise tax on non and low emitting vehicles, an oil charge tax to encourage use of small diesel cars. The recently introduced carbon tax covers liquid fossil fuels for vehicles and ships. The tax is based on the carbon content of the fuel. The taxation of the fuel carbon corresponds to half the price for CO_2 allowances in the EU emission trading system. The non-ferrous metal industry will fall under the EU emission trading system from 2013. Benchmarking, gradual lowering of the cap and trading of allowances under the EU-ETS are designed to encourage a shift toward cleaner technologies and lower emissions of greenhouse gases.

The main possibilities in the aluminum industry to reduce process related emissions of greenhouse gases are by minimizing emissions of PFCs. These gases are formed during so called anode effects that occur in the electrolysis process. Much progress was made after 1990 to reduce these emissions in Iceland and formal consultations with the aluminum sector on the issue were initiated by the Ministry for the Environment and the Ministry of Industry. Provisions in the environmental permits for the aluminum sector now stipulate caps on the frequency of anode effects and maximum values for the emissions of PFCs (0.14 tons CO_2-eq/ ton aluminum).

Policy or measure	Objective	GHG	Type of instrument	Status	Implementing entity	Estimated mitigation impact		
						2010	2015	2020
Carbon tax on fossil fuel use	Reduce fossil fuel use	CO_2	Economic	Under implementation	Finance Ministry	na	na	na
Participation in EU-ETS	Encourage industry to cut CO2 emissions	CO_2	Economic (cap-and-trade)	Planned	EU	0	na	na
Limits on PFC emissions in permits for aluminum production	Encourage aluminum plants to cut PFC emissions	PFCs	Regulatory	Implemented	Ministry for the Environment	na	na	na
Afforestation and revegetation	Increase carbon sequestration from the atmosphere	CO_2	Government-funded projects	Under implementation	Ministry for the Environment & Ministry of Fisheries and	280 Gg	na	773 Gg

					Agriculture			
Oil charge tax	Make small diesel cars more competitive	CO_2	Economic	Implemented	Finance Ministry	na	na	na
Exemption and reduction of excise tax on non- and low-polluting vehicles	Encourage buying of low-polluting vehicles	CO_2	Economic	Implemented	Finance Ministry	na	na	na
Capture of methane in landfills	Reduce methane emissions	NH_4	Technical	Under implementation	Municipalities	na	na	na
CarbFix CCS project	Capture carbon from geothermal emissions and store them permanently under ground	CO_2	Technical	Planned	Reykjavík Power Company	na	na	na
Provision of land-based electricity to ships in harbors	Discourage burning of fuels by ship engines	CO_2	Regulatory, technical	Implemented	Ministry for the Environment	18 Gg	18 Gg	18 Gg

Table 5.1 Policies and measures affecting emissions of greenhouse gases

Sale of land-based electricity to ships while in harbor increased from 8 GWh in 1992 to 18.6 GWh in 2006, an increase of 133%. The use of 18.6 GWh of electricity corresponds to savings 5000 tons of oil, which equals approximately 3% of the total use by the fisheries fleet in 2006. Typical fuel use by a trawler in harbor, without land-based electricity, is 1 – 2% of the total fuel use.

In 1996 the Icelandic government announced its decision to dedicate ISK 450 million for a four-year program of revegetation and tree planting to increase the sequestration of carbon dioxide in the biomass. This program was implemented in 1997-2000. The stated goal was an increase of 22,000 tons in carbon sequestration. Assessment of the results of the program indicates that the total additional sequestration was 27,000 tons. Although this four-year program is over, efforts to increase the annual carbon sequestration rate resulting from reforestation and revegetation programs will continue in the future. The measures taken are estimated to increase annual carbon sequestration in the first commitment period by about the same amount as in 2007, i.e. 280 Gg CO_2.

An international team of experts has been preparing the initial tests of one the world's first carbon-dioxide sequestration. The project, CarbFix, is designed to pump CO_2 into a massive basalt formation.

5.4 Methodology

The projections of total greenhouse gas emissions are based on forecasts of emissions from six sectors: Electricity and heat, transport, industry and chemical use, fisheries, agriculture and waste. The projections of greenhouse gas emissions are extensively based on the National Energy Authority´s (NEA) forecast for use of fossil fuels. The projections of greenhouse gas emissions are therefore based on the same assumptions as the NEA forecast regarding basic key elements such as economic and population growth, and GDP. The projections are based on NEA‘s latest forecast for 2008 – 2050, issued in November 2008. Three scenarios, low, medium and high, are presented in the NEA forecast. The severe economic crisis that hit Iceland in the fall of 2008 was not taken into consideration in the preparation of these projections.

Production of non-ferrous metals has a large impact on emissions of greenhouse gases in Iceland. The two scenarios of future emissions are therefore based on different assumptions regarding production volumes of aluminum and ferrosilicon. In scenario 1 it is assumed that the total production will stay the same as in 2008, i.e. annual production of 790.000 tons of aluminum and 120.000 tons of ferrosilicon. In scenario 2 the production volumes are set at maximum levels allowed according to existing environmental permits issued by the Environment Agency, i.e. that 1.356.000 tons of aluminum and 190.000 tons of ferrosilicon will be produced annually.

Emissions of CO_2 are assumed to be 3.4 tons for each ton of ferrosilicon produced. For the aluminum production the emissions are expected to be 1.5 tons CO_2 per ton of aluminum. The projections assume the emissions of PFCs to be 0.14 tons CO_2-eq for each ton of aluminum during normal production. For the first three years in operation after startup of new plants the emissions are assumed to be 0.28 CO_2-eq for each ton of aluminum and 0.2 CO_2-eq for each ton of aluminum after startup of new units during enlargement of existing plants. In the fourth year emissions are expected to reach normal production levels, i.e. 0.14 tons CO_2-eq per ton aluminum.

Since increased production of aluminum and ferrosilicon influences other sectors of the society, NEA’s medium forecast is used for scenario 1 and NEA’s high forecast is used for scenario 2. This implies e.g. higher GDP growth in scenario 2 than in scenario 1, 3.65% and 2.65% respectively. The population growth rate is also expected to be higher in scenario 2. Emissions from cement production and from construction are expected to be higher in scenario 2 compared with scenario 1. The different parameters used in the two scenarios result in higher emission from transport in scenario 2 besides the considerable differences in emission from industry. Other sectors are not influenced.

The number of vehicles in Iceland increased on average by 4.6% annually between 1998 and 2008. Diesel driven vehicles increased at a much faster rate than gasoline driven vehicles, i.e. 11.9% and 3.3% respectively. Gasoline consumption increased during the same period by 1.5% per year only. In the projection of greenhouse gas emissions it is assumed that the use of alternative energy sources increases, following an S curve, as vehicles using these fuels become commercially available. Fuel efficiency is expected to improve, linked to increased fuel prices. The projections assume that 20% of the effect of higher fuel prices will result in increased use of alternative energy.

6 Impacts and adaptation measures

6.1 Impacts on climate

Observed variability

Temperature in Iceland exhibits large inter-decadal variations. The longest continuous temperature record comes from Stykkishólmur on the west coast of Iceland. Statistical treatment of data from this station and of non-continuous measurements at other locations in Iceland, allows this record to be extended back to 1798 (Fig 6.1). This record shows that during the 19th century temperatures were cooler than in the 20th century, and the magnitude of inter-annual variations in temperature was larger. In the 1920s there was a period of rapid warming, similar to what is observed in global averages, but in Iceland the temperature change was greater and more abrupt. From the 1950s temperatures in Iceland had a downward trend with a minimum reached during the Great Salinity Anomaly, when sea ice was prevalent during late winter along the north coast. Conditions were rather cool in the 1970's with 1979 being the coldest year of the 20th century in Iceland. Since the 1980's, Iceland has experienced considerable warming, and early in the 21st century temperatures reached values comparable to those observed in the 1930s. From 1975 to 2008 the warming rate in Iceland was 0.35°C per decade, which is substantially greater than the globally averaged warming trend (~0.2°C per decade). However, the long term warming rate in Iceland is similar to the global one, suggesting that the recent warming is a combination of local variability and large scale background warming.

In Reykjavík the 2009 was the fourteenth consecutive year with temperatures above the 1961 - 1990 average and the 9th consecutive year warmer than the 1931 - 1960 average.

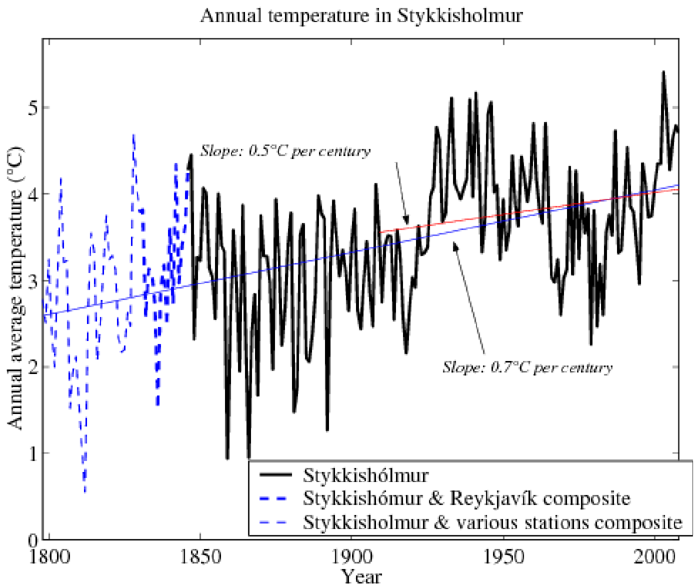


Figure 6.1: Mean annual temperature at Stykkishólmur 1798 - 2008. Solid line shows measurements in Stykkishólmur, thick dashed line shows Reykjavík-Stykkishólmur composite and thin dashed line shows composite of measurements at Stykkisholmur and various other stations. The earlier data (dashed line) is less reliable. Also shown are trend lines for the entire period (slope 0.7°C/century) and for the 1908-2008 period (slope 0.5°C/century)

Decadal variations in precipitation are also significant in Iceland. Continuous precipitation records extend back to the late 19th century, but precipitation has been measured at several stations since the 1920s. The station network, however, had insufficient coverage in the highlands in Iceland where precipitation is greater than in lowland areas. Recently a precipitation record for the whole of Iceland during the latter half of the 20th century has been established using a high resolution statistical dynamical model for orographic precipitation and atmospheric reanalysis. Using the two weather stations with the longest continuous precipitation record, the precipitation variability in Iceland since 1874 has been estimated (Fig 6.2). This record shows significant decadal variations in precipitation, and a tendency for higher amounts of precipitation during warmer periods. The long term station records indicate that precipitation tends to increase by 4% to 8% for each degree of warming.

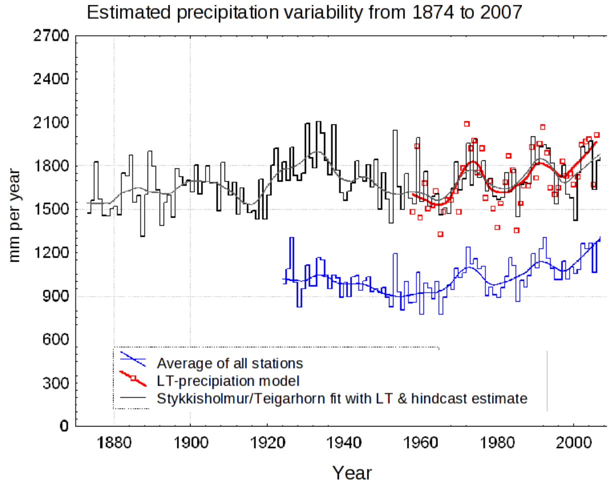


Figure 6.2: Precipitation variability in Iceland from 1874. Step like curves and squares indicate annual data smooth curves show filtered data. The blue curve shows the results from averaging all station data. The red curve shows the results obtained from a statistical-dynamical precipitation model that also includes the precipitation that falls on the highlands. The black curve shows the results of estimating the precipitation in Iceland by fitting the two stations with longest continuous records to the model estimates.

Climate projections

Based on the results of the Climate models used in the IPCC AR4 report (2007), this warming is projected to continue in the 21st century (Fig 6.3). The warming rate differs between the IPCC SRES scenarios, in the warmest scenario (A2) the warming rate is 0.28°C per decade yielding 2.4 degrees of warming to the end of the 21st century; in the coolest scenario (B1) the warming rate is 0.16°C per decade yielding a warming of 1.4°C at the end of the century. The intermediate scenario (A1B) yields a warming rate of 0.23°C per decade and a warming of 2.0 °C at the end of the century. In all cases there is a significant spread in the model results.

The warming in Iceland exhibited in the IPCC climate models are somewhat lower than the warming rates realized in Iceland in recent decades. This fits with the view that the recent warming is in part a local natural temperature change, superimposed on a large scale global warming signal.

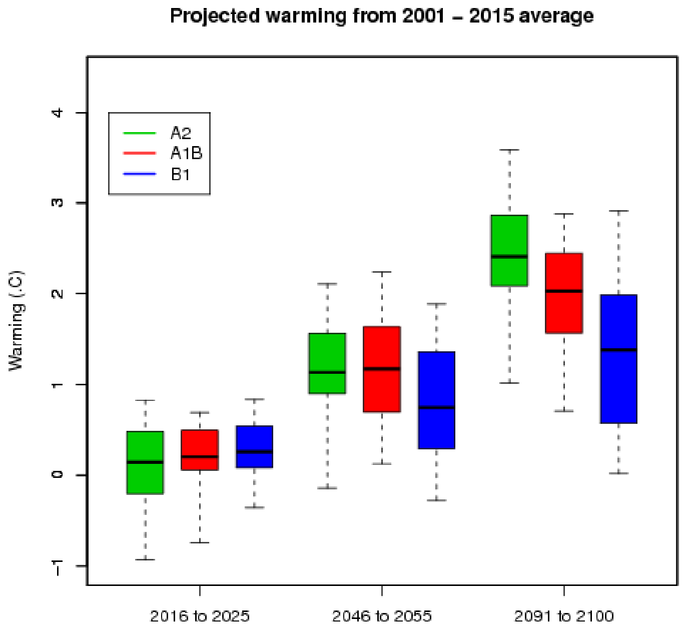


Figure 6.3: Estimated warming in Iceland for three periods in the 21st century. Shown are results based on IPCC models for three SRES scenarios. In each case 50% of results lie within each box, and 90% within the range spanned by the lines. The thick horizontal line in each box is the average of all models.

Projected changes in precipitation were estimated using the same climate models (Fig 6.4). Precipitation is projected to increase on average by 5%. In general, precipitation is more variable in the climate models, and the spread in the results is consequently large. Nevertheless, in general, precipitation increases roughly in proportion with the warming (Fig 6.5).

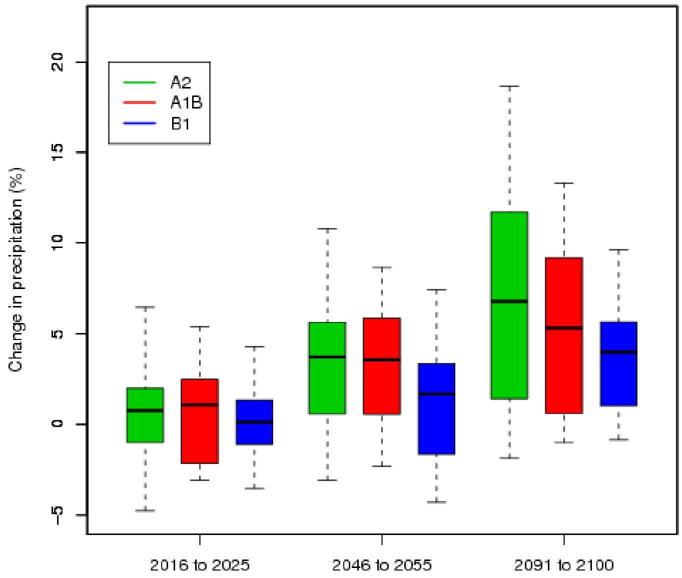


Figure 6.4: Estimated precipitation change in Iceland for three periods in the 21st century. Shown are results based on IPCC models for three SRES scenarios. In each case 50% of results lie within each box, and 90% within the range spanned by the lines. The thick horizontal line in each box is the average of all models.

Comparison between the warming and the increase in precipitation reveals that the precipitation increases by about 2.5% for each degree of warming (Fig. 6.5). Note that this percentage increase is slightly lower than that seen in observations from the 20th century. This is possibly a reflection of model biases.

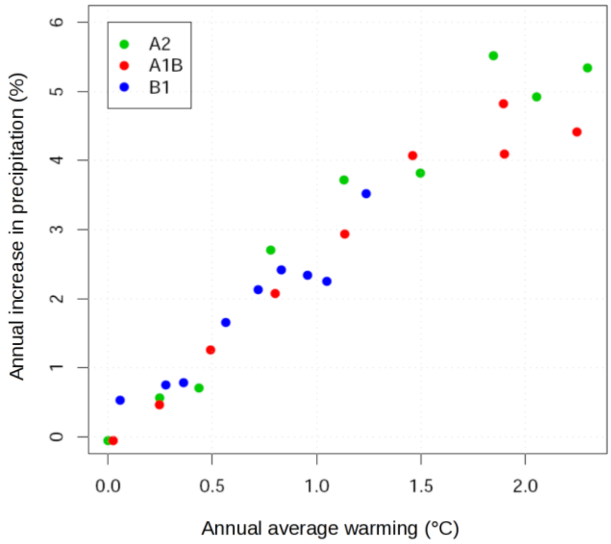


Figure 6.5: Change in temperature vs change in precipitation in the 21st century in Iceland. Shown are 10 year averages of temperature change and precipitation change from 2016-2025, 2026-2035 etc.

The projected warming in Iceland is likely to result in a reduction in the number of frost days and more frequent heat waves. Based on 20th century records the duration of snow cover in the lowlands in Iceland is reduced by 3 - 4 weeks for each degree of warming.

Climate model projections do not show a significant change in wind near Iceland. There are some indications that average wind speed may be reduced along the south coast, but increased along the north coast, but the agreement among models is to poor for definite conclusions to be reached.

6.2 Impacts on oceanic currents

The climate of Europe and the North Atlantic is much milder than it is at comparable latitudes in Asia, Canada and Alaska. This is due to the heat transport from the south with air and water masses. A key process in this respect is the so-called Meridional Overturning Circulation (MOC) in the North Atlantic. It is based on the sinking of seawater, mainly due to cooling and ice formation, at certain locations at high latitudes. After sinking this water is called deep water and it subsequently flows to lower latitudes. In the North Atlantic huge amounts of deep water is formed, e.g. in the Arctic Ocean, the Greenland Sea, the Iceland Sea and the Labrador Sea. The deep water that is formed north of the Greenland-Scotland Ridge flows over the ridge on both sides of Iceland and also through the Faroe-Shetland Channel.

Many numerical models predict that the production of deep water will be reduced as a result of increasing greenhouse gas emissions. This happens when more fresh water is introduced to the Nordic Seas because of melting of glaciers and thawing of permafrost that will make the surface layer fresher and therefore reduce the likelihood of convection. This in turn would lead to reduced deep water flow over the Greenland-Scotland ridge and a compensating reduction of flow of warm currents into the Nordic Seas thus inducing a cooling in the area. Ice core data from the Greenland Ice Sheet seem to indicate that this can happen rather quickly or within decades. Research projects measuring changes in the deep water fluxes over the ridges have succeeded in obtaining a time series of the flux of Atlantic water as well as of the deep water. With the time series available now it is however not possible to conclude that the flow of deep water is decreasing. In the fourth assessment report of the IPCC (2007) it was concluded that while it was "very likely that the Atlantic Ocean Meridional Overturning Circulation (MOC) will slow down during the course of the 21st century", it was also "very unlikely that the MOC will undergo a large abrupt transition during the course of the 21st century". The slowdown of the MOC may reduce the warming rate near Iceland but is not likely to halt the warming or reverse it. The results shown in Figure 5.3 already include models results where the MOC slowed down.

6.3 Impacts on marine ecosystems and fish stocks

To project the effects of climate change on the marine ecosystem is a challenging task. Available evidence suggests that, as a general rule, primary and secondary production and thereby the carrying capacity of the Icelandic marine ecosystem is enhanced in warm periods, while lower temperatures have the reverse effect. Within limits, this is a reasonable assumption since the northern and eastern parts of the Icelandic marine ecosystem border the Polar Front. In cold years the Polar Front can be located close to the coast northwest to northeast Iceland. During warm periods it occurs far offshore, when levels of biological production are enhanced through nutrient renewal and associated mixing processes, resulting from an increased flow of Atlantic water onto the north and east Icelandic plateau.

Over the last few years the salinity and temperature levels of Atlantic water south and west off Iceland have increased. At the same time, there have been indications of increased flow of Atlantic water onto the mixed water areas over the shelf north and east of Iceland in spring and, in particular, in late summer and autumn. This may be the start of a period of increased presence of Atlantic water, resulting in higher temperatures and increased vertical mixing over the north Icelandic shelf. The time series is still too short though to enable firm conclusions. However, there are many other parameters which can affect how an ecosystem and its components, especially those at the upper trophic levels, will react to changes in temperature, salinity, and levels of primary and secondary production. Two of the most important are stock sizes and fisheries, which are themselves connected.

It is unlikely that the response of commercial fish stocks to a warming of the marine environment around Iceland, similar to that of the 1920s and 1930s, will be the same in scope, magnitude, and speed as occurred then, mainly because most spawning fish are now fewer, younger and smaller than at that time. Nevertheless, a moderate warming is likely to improve survival of larvae and juveniles of most species and thereby contribute to increased abundance of commercial stocks in general. The magnitude of these changes will, however, be no less dependent on the success of future fisheries management aiming at recovery of all commercial species to former stock levels sizes in near future.

The Marine Research Institute and the University of Iceland conduct studies on sea water carbonate chemistry and the air-sea flux of carbon dioxide. Research on seasonal biogeochemical processes enables evaluation of the magnitude of the ocean carbon dioxide sink and its relation to oceanographic conditions. The North Atlantic Ocean is overall a strong sink for carbon dioxide but it is, however, evident that the conditions are both regionally variable and changing in response to rising atmospheric carbon dioxide.

There are long term records, time series since 1983, from seasonal observations of ocean carbon dioxide at two oceanographically different sites near Iceland. These are invaluable for assessing long term trends. They reveal a high rate of ocean acidification in the Iceland Sea at 68°N. The surface pH falls 50% faster than is observed in the sub-tropical Atlantic. The rapid rate of change is because the Iceland Sea is a strong sink for carbon dioxide but the sea water is cold and relatively poorly buffered. The sea water calcium carbonate saturation state is low in these waters and it falls with the lowering pH. The saturation horizon which lies at about 1700 m is shoaling which results in large areas of sea floor becoming exposed to waters that have become undersaturated with respect to aragonite (calcium carbonate). The biological effects and ecosystem consequences of the carbonate chemistry changes are of concern and are studied through participation in the European Project on Ocean Acidification (EPOCA).

6.4 Impacts on glaciers

Glaciers are a distinctive feature of Iceland, covering about 11% of the total land area. The largest glacier is Vatnajökull in southeast Iceland with an area of 8,200 km^2. Climate changes are likely to have a substantial effect on glaciers and lead to major runoff changes in Iceland. Changes in glacier runoff are one of the most important consequences of future climate changes in Iceland. The expected runoff increase may, for example, have practical implications for the design and operation of hydroelectric power plants.

Rapid retreat of glaciers does not only influence glacier runoff but leads to changes in fluvial erosion from currently glaciated areas, changes in the courses of glacier rivers, which may affect roads and other communication lines. A recent example of this is the change in drainage from Skeiðarárjökull, but due to thinning and retreat of the glacier the outlet of the river Skeiðará moved west along the glacier and the river merged into another river, Gígjukvísl. As a consequence little water now flows under the bridge over Skeiðará, Iceland's longest bridge. In addition, glacier melting is of international interest due to the contribution of glaciers and small ice caps to rising sea level. Regular monitoring shows that today, all non-surging glaciers in Iceland are retreating (Fig 5.6).

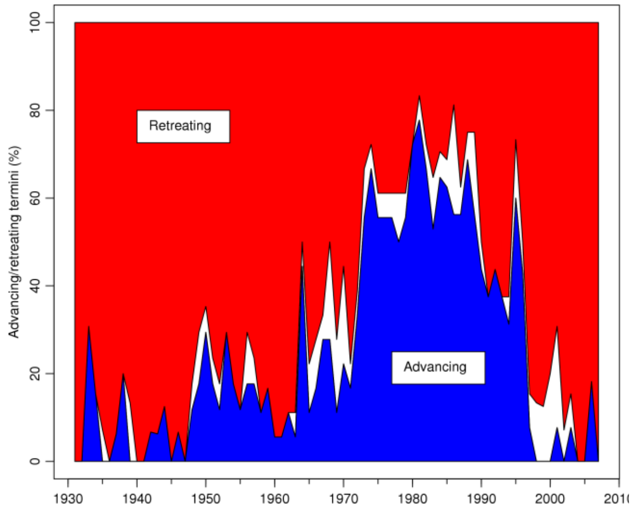


Figure 6.6: The fraction of monitored non-surging glacier termini in Iceland from 1930/31 to 2006/07 that are either advancing or retreating. Over most of the period the figure is based on measurements at 15 to 19 locations.

Recent airborne lidar measurements of glacier topography show significant amount of thinning, in recent years. The picturesque Snæfellsjökull ice cap is the only ice cap that can be seen from Reykjavík. In the 1864 novel Journey to the Center of the Earth, by Jules Verne, the ice cap serves as the entrance to a passage that led to the center of the earth. It has persisted for many centuries, at least since Iceland was settled in the ninth century AD, but recent measurements show that the ice cap, which has an average thickness of less than 50 m, thinned by approximately 13 m in the last decade. At the current rate of thinning it will disappear within the century. Snæfellsjökull is not alone in this regard; other monitored ice caps are also thinning. The larger Hofsjökull ice cap thinned by a similar amount in the last decade (Fig 5.7).

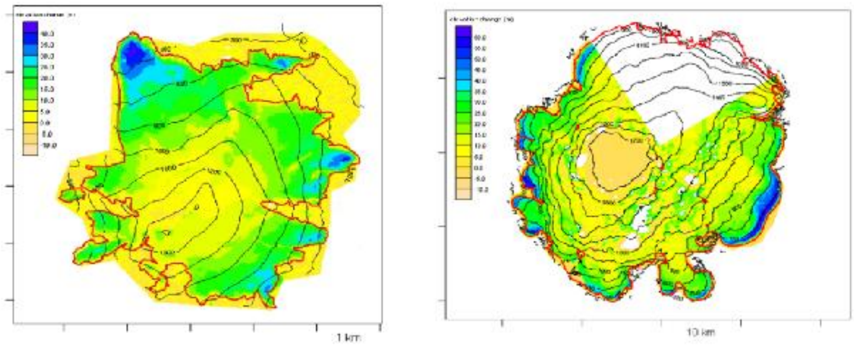


Figure 6.7: Recent thinning of Icelandic glaciers. The left panel shows the thinning of Snæfellsjökull from 1999 to 2008, and the right panel shows results for Hofsjökull in 2008. Older maps for Hofsjökull were based on measurements done in 1983, 1997 and 2001 and the map shows the thinning to 2008, with corrections applied for the different ages of the older map. Over a part of the Hofsjökull ice cap the older data are too unreliable for the thinning to be estimated. On average both icecaps thinned by about 13 m from 1999 to 2008.

The thinning of large glaciers, such as the Vatnajökull ice cap, one of Europe's largest ice masses, reduces the load on the Earth's crust which rebounds. Consequently large parts of Iceland are now experiencing uplift. The uplift does not, however, reach to the urban south west part of Iceland, where subsidence is occurring (Fig 5.8).

The uplift along the south coast may reduce the impacts of rising global sea levels during the 21st century. If subsidence continues in the south west part of Iceland, it will exacerbate the impact of rising sea levels. Measurements in Reykjavik show that sea level rose by 5.5 mm/year from 1997 - 2007. Once these results have been adjusted to account for local subsidence, sea level in Reykjavik during this period rose by about 3.4 mm/year, which is close to the global sea level rise.

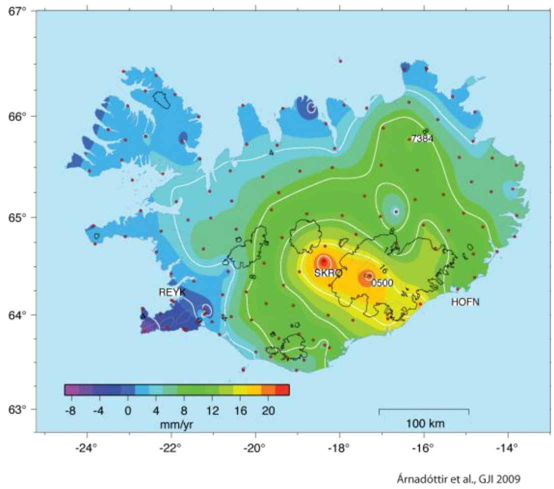


Figure 6.8: Vertical movement of land in Iceland. Much of the interior and the south eastern coast are experiencing uplift due to glacier thinning.

Modeling of the Langjökull and Hofsjökull ice caps and the southern part of the Vatnajökull ice cap in Iceland reveals that these glaciers may essentially disappear over the next 100–200 years (Fig 5.9).

Runoff from these glaciers is projected to increase by about 30% with respect to present runoff by 2030 (Fig 5.10). The peak runoff is expected to occur in the latter part of the 21st century.

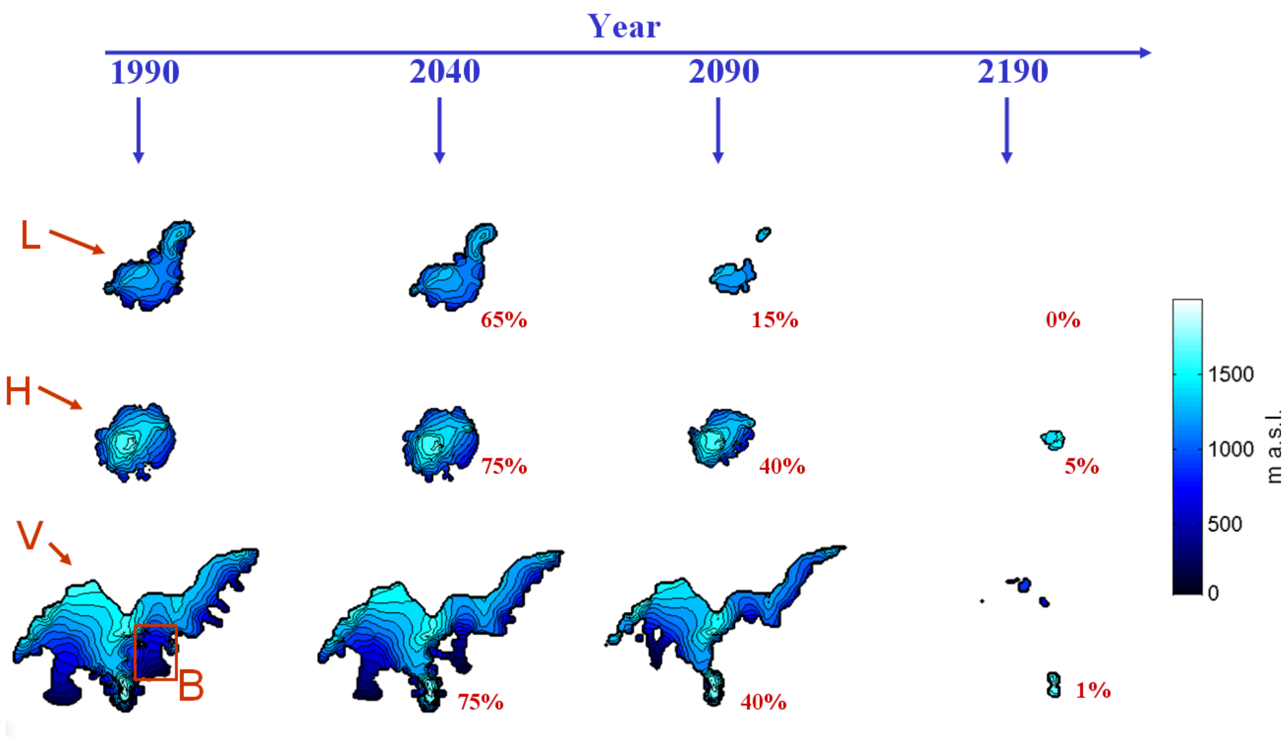


Figure 6.9: Response of Langjökull (L), Hofsjökull (H) and Southern Vatnajökull (V) to a climate warming scenario. The outlet glacier Breiðármerkurjökull on the south flank of Vatnajökull is indicated with a rectangle marked B in the left most map of Vatnajökull. The inset numbers are projected volumes relative to the initial stable glacier geometries in 1990. Note that Vatnajökull is only modeled south of the main east-west ice divide.

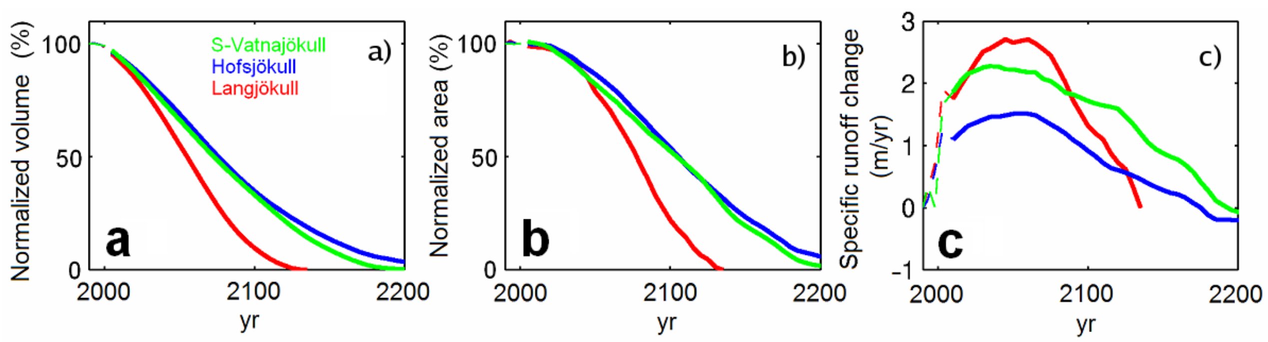


Figure 6.10: a) Volume and b) area reduction, normalized to present day values, and c) area averaged runoff change. The runoff consists both of glacier melting and precipitation. The enhanced glacier melting is the dominant contribution to the runoff change to begin with.

Although glaciers and ice caps in Iceland constitute only a small part of the total volume of ice stored in glaciers and small ice caps globally, studies of their sensitivity to climate changes have a general significance because these glaciers are among the best monitored glaciers in the world. Field data from glaciated regions in the world are scarce due to their remote locations and difficult and expensive logistics associated with glaciological field work. Results of monitoring and research of Icelandic glaciers are therefore valuable within the global context, in addition to their importance for evaluating local hydrological consequences of changes in glaciated areas in Iceland.

6.5 Impacts on forests, land management and agriculture

In 2008 an expert panel appointed by the Ministry for the Environment published a scientific report on global warming in Iceland. It summarized the present knowledge on how nature and society have responded to past climate fluctuations and predicted how future climate change is likely to impact both nature and society. Climatic factors, such as temperature, precipitation, wind and seasonality, greatly influence plants and vegetation cover and therefore have a direct impact on agriculture and forests.

Mean annual temperature has risen by ca. 1.2 °C compared to what it was on average during the 1961-1990 period, These and other accompanying changes have already had a substantial impact on agriculture and forest growth in Iceland. Long-term studies have shown that a rise in spring temperature by 1°C increases hay production by 11%. Frost heaving frequently damaged hayfields in many parts of Iceland, especially during the cold period in the 1960s-80s, reducing the potential hay production by 20-30% when it happened. This problem has now largely disappeared in the warmer winter climate of the 2000's. The warming has therefore already had large impact on traditional agriculture in Iceland.

Barley production has increased much in Iceland during the past two decades, both because of research and development within the country and changing climate. Barley needs ca. 1200 day degrees during the growing season to be usable as animal fodder and 1300-1500 d.d. to fully develop. Barley production increases by ca. 1 t/ha for each 1 °C increase in temperature when grown between these limits. Much larger part of Iceland is now found within these limits than 20-30 years ago. The change in climate has also made it possible to grow new crops, such as winter wheat, that is now grown in the country's warmest areas in southern Iceland.

An analysis of the possible impact of climate change on agriculture, forestry and land use was made in 2004. It used a scenario derived from a Nordic study on climate change in the North Atlantic region, assuming that in the year 2050 the mean temperature would have increased by 1.5 °C in the summertime and 3.0 °C over wintertime, and that precipitation would increase by 7.5% in summer and 15% in winter. The following paragraphs are mostly based on this analysis and describe the changes that were predicted to occur, given these assumptions.

The production of hey per unit area could significantly increase, up to 64%. This would partly be due to a direct effect of increasing concentrations of carbon dioxide (CO_2) in the atmosphere on production, but mostly due to longer growing seasons, higher temperatures and less damage by winter frosts. The effects of climate change would be greatest on cereals. The harvest of barley could increase where presently grown and basically all Icelandic lowlands would become suitable for successful barley production. An increase of average summer temperatures by 1.5 °C would also open up the possibility of successfully growing many new crops on wider acreage, including oats and wheat, even rye. Harvest of potatoes, turnips, carrots and other vegetables grown outdoors in Iceland today, would increase. Increased cloud cover and summer precipitation could, however, lead to less inputs of solar light. This could increase the cost of lighting in greenhouses. Pests and plant diseases would also become more of a problem for outdoor crops in warmer and more humid climate than currently, and the use of pesticides could possibly increase. This could challenge the image of the Icelandic agricultural produce as unpolluted high-quality foodstuffs. Climate change will make the cultivation of many areas more feasible and new species like barley previously difficult to grow more profitable. This might cause a shift in utilization of cultivated land and/or increase pressure on cultivating new areas.

Impacts of warmer climate on animal husbandry would mostly be positive. In addition to increased production of crops for fodder, wild grazing plants should also benefit from higher summer temperatures and increased precipitation. If this would result in an increase in animal numbers, that will increase the GHG emissions from the agricultural sector. The time available for grazing would increase and the need for sheltering livestock during winters would decrease. Winter grazing is more damaging to vegetation than summer grazing, and this could therefore have some potential negative effects if not managed in a sustainable way. A recent study (2006) showed indeed that natural grassland production in N and S Iceland has been increasing during the past decade. It was, however, difficult to determine the main cause for this change; it could both be change in climate and/or a change in grazing pressure.

An increase in summer temperatures and the length of the growing season will doubtlessly increase annual growth rates and coverage of both natural and managed forests in Iceland. It was recently shown that the downy birch treelines are generally moving upwards in Iceland and its growth rate close to the treelines has increased manifold since in the 1970s. An experimental study in southern Iceland showed that growth rates of black cottonwood were increased by 9-15% by 1.2 °C rise in mean growing season air temperature, where trees growing in infertile soils were benefitted relatively more. An increase in winter temperature could, however, do more damage than good, especially for exotic tree species used in managed forests and as ornamental garden plants originating from cold and continental climate. Those are generally not well adapted to mild, oceanic, winter climate. Further winter warming could thus lead to untimely start of tree growth in late winters or early springs, with increased danger for frost damage. On the other hand severe frost periods in the spring will decrease drastically because of higher ocean temperature in the Arctic ocean north of Iceland. During the past two decades, an increasing number of new pests have emerged that can cause damage to trees. This has been linked to the climate warming that has taken place during the same period, but other factors may also be partly responsible. Further warming is expected to increase the vigor and number of new pests. Special concern is paid to the natural woodlands of downy birch. Severe, repeated defoliation by both native and alien insects have occurred to a large extent in the 2000s, leading to permanent erasure of the woodlands in a few cases. The overall effect on forest propagation and production is, however, expected to be positive, which again might enhance the afforestation of new areas and utilization of forests as a natural resource.

6.6 Impacts on terrestrial ecosystems

Iceland's natural terrestrial ecosystems can be roughly divided into four main categories; wetlands, woodlands, grasslands, and barren or sparsely vegetated areas. Effects of warmer climate on most terrestrial ecosystems in Iceland are not expected to differ from those earlier described for forests. As for the managed ecosystems, the warmer climate is likely to extend the length of the growing season and increase plant production. Higher winter temperature is also likely to stimulate decomposition of litter and soil organic matter and thereby mineralization of nutrients, with more available for plant growth. These changes will have effects on the function, structure and distribution of terrestrial ecosystems. Similar changes are expected in Iceland as in other parts of the high-boreal, sub-arctic and arctic areas, as described e.g. in the ACIA 2005 report and in the IPCC's 4th Assessment Report from 2007.

Many areas in Iceland have suffered from extensive historic vegetation change and soil erosion due to, among other factors, heavy livestock grazing and periods of cold climate. The grazing pressure on many areas has decreased and one effect of the warmer climate is to enhance reestablishment of former vegetation and productivity of many of these areas. It has been concluded that vegetation of sparsely vegetated or barren areas should mostly benefit from warmer climate; at least if changes in precipitation patterns don't counteract its effects. Increased precipitation could lead to increased water erosion of barren soils.

The prediction of higher production of Icelandic plant communities in future climate was, however, only partly confirmed by the ITEX-project (International Tundra Experiment). It experimentally simulated during 3-5 years a climate warming of 1-2 °C in two widespread, but contrasting plant communities. A dwarf-shrub heath showed up to 100% increase in height growth, while biomass production in a moss heath was not affected. It was concluded that the sensitivity of Icelandic tundra communities to climate warming varies greatly depending on initial conditions in terms of species diversity, dominant species, soil and climatic conditions as well as land-use history. If, however, some large-scale changes occur in land cover, it would affect distribution and diversity of both flora and fauna, and some rare species might become endangered while other might benefit. Other possible negative impacts of climate change on terrestrial ecosystems include increasing risks of plant diseases and insect pests.

One rare plant community, highland permafrost string bogs (palsamires), is already under threat from the recent climate warming. The string bogs and their discontinuous permafrost areas might even disappear with further warming. Then their function as important habitats for plants and as breeding ground for birds would disappear as well. The permafrost string bogs hold much soil organic matter that currently is unavailable to decomposition. The thawing of these soils could therefore result in more emissions of GHGs.

Decomposition of organic matter and the subsequent CO_2 emission rate is primarily temperature controlled, where oxygen can access it. Warmer winters will increase decomposition of organic matter in terrestrial ecosystems, both litter and soil organic matter, and presumably increase the annual release of all GHGs (CO_2, CH_4 and N_2O). How this will affect the annual ecosystem GHG balance depends, however, on how fast and how much the summer carbon uptake (productivity) will be increased due to more plant cover, longer growing seasons, warmer temperatures, and increased nutrient availability in each ecosystem type.

Arctic Fox is the only native land mammal in Iceland. In a recent study (2009) it was shown that its growth and population size has varied with past climate fluctuations, mainly through effects on its food availability. Three bird species have become extinct in Iceland since 1844 but during the same period 14 new bird species have colonized and become regular breeding birds. The climate warming during this period could possibly have influenced one extinction; the Little Auk, which is an arctic seabird. Some of the colonizations could also possibly be linked to warmer climate, especially winter climate. Establishment of new habitats, such as coniferous forests and urban gardens, has also been an important contributing factor. There have been large-scale changes in many seabird colonies in Iceland during the past decade. The reason is not well understood, but seems to be linked to changes in population sizes of their feedstock fish, such as sand eel.

There have been some studies that have shown that biogeochemistry of rivers has changed during recent years. The amount of dissolved organic carbon has e.g. increased with increased annual temperature. Salmon has also shown more growth and higher production per unit area in NE Iceland during the past 20 years, which has been related to warmer climate. There are some indications that the Arctic Char, which is a sub-arctic freshwater fish, has been becoming less frequent in shallow lakes in Iceland during the past years. This has been linked to its low optimum temperature, but other factors may also be important.

6.7 Impacts on society

It is uncertain what impacts climate change will have on society in Iceland. Any impacts on the fishing industry though, are likely to have some impacts on the society especially in some of the smaller communities in Iceland. From an economic point of view, climate change may impact the fishing industry in at least two ways; by altering the availability of fish stocks and by changing the market price of fish products. Although both may be initiated by climate change, the issue of fish stock availability is a more direct consequence of climate change. The possible impact of climate change on fish stock availability may occur through changes in the size of commercial fish stocks, changes in their geographical distribution, and changes in their catch-ability. These changes, if they occur, will affect the availability of fish stocks for commercial harvesting. The impact is however uncertain. It may be negative, and so reduce the maximum sustainable economic yield from the fish stocks, or positive, and so increase the maximum sustainable economic yield from the fish stocks. Also, the impact may vary between fish stocks and regions. Irrespectively, it is very likely that climate change will, at least temporarily, cause instability or fluctuations in harvesting possibilities while ecosystems adjusts to new conditions. The adjustment period may be long, and may even continue after the period of climate change has ended. The same applies to changes in economic value.

If the change in the fishing industry is gradual and the economic impacts relatively small it is unlikely that the accompanying social and political impacts will be noticeable at a national level. In the long run, social and political impacts will undoubtedly occur, but whether these will be large enough to be distinguished from the impact of other changes is uncertain. Regionally, however, the situation may be very different. In some parts of Iceland the economic and social role of the fishing industry is far above the national average. In these areas, the economic, social, and political impact of an expansion or contraction in the fishing industry will be much greater than for Iceland as a whole and in some areas undoubtedly quite dramatic.

The main conclusion to be drawn is that the changes in fish stock availability that seem most likely to be induced by climate change over the next 50 to 100 years are unlikely to have a significant long-term impact on GDP in Iceland and, consequently, on social and political conditions in Iceland. Also, it appears that any impact, small as it may be, is more likely to be positive than negative. If on the other hand, climate change results in sudden rather than gradual changes in fish stock availability, the short-term impact on GDP and economic growth rates may be quite significant. Over the long term, the impact on GDP of a sudden change in fish stocks will be indistinguishable from the effects of more gradual changes.

The impact that climate change could have on human health is likely to be less in Iceland than in many other countries. Direct and indirect impacts on human health in Iceland are possible in relationship to changes in the frequency or intensity of natural disasters or extreme weather events. In small remote locations this is further accentuated by a challenged capacity to respond to these events because of the isolated nature of communities. The variability of such events is not however expected to increase with climate changes in the future. Changes in temperature have the potential to influence health in both negative and positive ways. Considering the low mean annual temperature in Iceland, the likelihood of heat events having large impacts on public health is low. Fewer colder days associated with winter warming may in fact have several positive health impacts.

Climate change is likely to have profound effects on biota which can in turn, affect human health in northern communities and elsewhere in the world. Infectious diseases of plants, animals and humans are also affected by climatic changes. Due to the indirect nature of these influences, predictions of their likelihood are not possible; however. The potential impacts on human health related to these changes clearly warrant further research and monitoring attention.

The potential effects of climate change include increased magnitude and variability in precipitation, and increased melting of glaciers. These changes may temporarily increase the potential for hydropower production in the country. They may also increase the frequency and severity of river and coastal flooding and erosion.

6.8 Adaptation measures

Climate change impacts on infra-structure sectors are the subject of ongoing studies. While the results of these studies show that significant impacts can be expected plans for adaptation to climate change are in most cases not well developed. The most notable exception is the National Power Company (Landsvirkjun) but the likely impacts of expected climate change are taken fully into account in their operational strategies and investment planning.

Following recommendations from a 1992 report on expected sea level rise, consideration has been made for this in the design of new harbors in Iceland. However, recent studies indicate that sea level rise may far exceed earlier expectations.

7 Financial assistance and transfer of technology

7.1 Official Development assistance

Development co-operation a key pillar in Iceland’s foreign policy and represents Iceland’s fulfillment of its political and moral obligations as a responsible member of the international community.
Following a steady increase in allocations to official development assistance (ODA) during the last decade, ODA contributions in 2008 reached a record 0.48% of GNI. This was significantly higher than the target of 0.31% for 2008, which is mainly attributed to the contraction of GNI and higher ODA volume to offset for the depreciation of the Icelandic króna against the US Dollar. The ODA volume in 2009 is estimated to remain similar in Icelandic króna, followed by a significantly lower budget appropriation for 2010.

In spite of the current crisis, development co-operation remains at the forefront of Icelandic foreign policy and the Government is committed to the attainment of the Millennium Development Goals and other internationally agreed development goals.

7.2 Icelandic Policy on Development Co-operation

Iceland’s policy on development co-operation is founded on the basic values of Icelandic society; respect for democracy and human rights, gender equality and human dignity and a society characterized by tolerance, justice and solidarity. The policy document for the period

2005-2009 has been revised during the past year. The previous document was based on four pillars of development, which have now been streamlined in accordance with trends in international development co-operation. This is *inter alia* in line with the Paris Declaration on Aid Effectiveness (2005) and the Accra Agenda for Action (2008).
On 1 October 2008, a new Act on International Development Co-operation entered into force, providing the framework for Iceland’s development efforts. The Act is a comprehensive legislation encompassing all aspects of Iceland’s ODA. The Act stipulates that every two years, the Minister for Foreign Affairs shall submit before the parliament a proposal for a resolution for a Programme on International Development Co-operation for the subsequent four years. The new Act also enhances policy coherence, coordination and accountability, increases flexibility for aid modalities, strengthens parliamentary oversight and emphasizes results and predictability.

Iceland’s development co-operation continues to focus on sustainable development, poverty reduction, capacity building, gender equality, and advancement of democracy, through the promotion of the Millennium Development Goals. A special focus is on the Least Developed Countries through bilateral and multilateral co-operation.

The Government of Iceland has committed itself to contribute to the sustainable utilization of natural resources through international co-operation, and ratification of international agreements. From the outset, this has figured prominently in Icelandic development co-operation. The fisheries sector continues to be a strong element of Iceland’s bilateral activities. The Icelandic International Development Agency (ICEIDA) has supported research, training and capacity building in the sector, based on Icelandic expertise in this field. Sustainable fisheries based on sound scientific advice can contribute significantly to the resilience of coastal communities in developing countries and the adaptation to climate change where changing conditions in the ocean are threatening the ecosystem. Iceland will also continue its support for geothermal projects in developing countries with geothermal resources, which can be utilized to decrease their dependency on fossil fuels for economic development.

The Government of Iceland has supported developing countries in the area of sustainable utilization of natural resources through its administration of two United Nations University Training Programmes, the Geothermal and the Fisheries Training Programmes. The Geothermal Training Programme has operated over thirty years, building up expertise in the utilization of geothermal energy, by training more than 400 experts from over 40 countries. The Fisheries Training Programme that was established in 1997 has offered specialized training courses to almost 200 fellows from over 30 countries in various subjects relating to fisheries. Both Programmes provide their graduating fellows with the opportunity to enter MSc and PhD programmes with Icelandic universities.

A Land Restoration Training Programme was established in Iceland in 2007, in co-operation with the Agricultural University of Iceland and the Soil Conservation Service of Iceland. The aim of the project is to assist developing countries in increasing their capacity for holding and reversing land erosion, which will improve conditions for agriculture and husbandry.

Furthermore, it will increase natural carbon sequestration in the affected regions. The Programme became a part of the UNU network in 2010.

A pilot project relating to gender equality and women's empowerment was initiated in 2009, based on the same principles as the above mentioned training programmes. The project will focus on gender equality in general but also on gender and the environment and gender and climate, contributing to capacity building in that field.

Collaboration with international organizations on sustainable development will be increased and ways will be explored to co-operate with small island developing states (SIDS), where the development of fisheries, energy and gender equality are important economic factors.

Priority areas for Icelandic development co-operation that are especially relevant for the purposes of mitigating and adapting to climate change are:

- Increase its focus on sustainable development, emphasizing the sustainable utilization of natural resources.
- Strengthen the United Nations University Fisheries Training Programme and Geothermal Training Programme by enabling the programmes to admit more students and set up training courses in developing countries.
- The establishment of the Land Restoration Training Programme that specializes in restoration of degraded land and sustainable land management, aiming at assisting developing countries in capacity development within this field.
- The establishment of the Gender Equality Training Programme that inter alia offers courses on gender and climate.
- Energy a point of focus in ICEIDA ´s bilateral development co-operation.
- Strengthen collaboration with international institutions in the field of fisheries, renewable energy and gender equality.
- Support to small island developing states.
- Special emphasis on support to the Least Developed Countries.

7.3 Implementation of Iceland's Development Co-operation

The Ministry for Foreign Affairs is responsible for overall coordination of Iceland's official development co-operation. The implementation of Iceland's development co-operation is conducted under the auspices of the Ministry, which is responsible for multilateral development co-operation, support to peace building and post-conflict reconstruction, and emergency and humanitarian aid. Bi-lateral development co-operation is implemented by the ICEIDA in four partner countries (three as from 2011). Icelandic civil society organizations involved in development co-operation have grown in strength and increasingly participate in humanitarian efforts and development co-operation projects. In addition, the Icelandic private sector has to some extent turned the attention to the issues of the developing countries.

The aim of Iceland's participation in international development co-operation is to provide assistance to developing countries in an efficient and reliable manner, either through bilateral or multilateral channels. Emphasis is put on active participation in co-operation within international organizations, building institutional capacity for aid administration and enhancing professional and sound working methods, taking into account the experience and expertise of other countries and international organizations

Multilateral Development Co-operation

In light of the above, the principal emphasis will be placed on participation in the work of selected United Nations Funds and Programmes, and the World Bank and its agencies. Iceland's permanent missions to international organizations play a significant role in Iceland's development efforts. These include the Permanent Mission to the Agencies of the United Nations in New York, Geneva, Paris and the Organization for Economic Co-operation and Development (OECD), the World Trade Organization in Geneva, and the Organization on Security and Co-operation in Europe in Vienna.

Bilateral Development Co-operation

This support is based on bilateral development co-operation agreements between the Government of Iceland and the governments of partner countries. ICEIDA channels its support to a small number of low income countries in sub-Saharan Africa: Malawi, Mozambique, Namibia and Uganda.. With the exception of Namibia they all fall into the category of the least developed countries (OECD, DAC) and rank among the lowest in the UNDP´s Human Development Index. Co-operation with Namibia will come to an end in December 2010. The choice of partner countries reflects Iceland´s focus on poor people and poverty reduction. Furthermore, the Agency provides support to one project in Nicaragua which aims at increasing the use of geothermal resources in the country.

ICEIDA is delivering its aid mainly through targeted support to sub-national districts and specific sectors. The focus is on primary and adult education, primary health care and water- and sanitation, in addition to the fisheries sector. Focus on the energy sector (particularly geothermal energy) has recently been included in ICEIDA´s agenda. Two cross cutting issues have been identified as most relevant in ICEIDA´s development strategies: gender equality and environment. Both issues must be taken into account at all stages of the funding cycle of programmes/projects.

United Nations University in Iceland

One of Iceland's largest undertakings in multilateral development co-operation is the operation of the UN University Geothermal Training Programme and the UN University Fisheries Training Programme. The training programmes provide experts from the developing countries with an opportunity to engage in specialized studies in Iceland. The training programmes are predominately funded by the Government of Iceland. The policy of the Government is to maintain both programmes structurally and financially strong. In addition, the Land Restoration Training Programme, which is entering its fourth year of operations, became an official UNU training programme in 2010. The Programme is an important contribution to Iceland's climate efforts.

Non-governmental Organizations

Non-governmental organizations (NGOs) are important participants in development co-operation and humanitarian efforts. They contribute as implementing agents in the field as well as through their advocacy work for development issues. In recent years, the number of NGOs participating in this field has grown in Iceland, and many of them are engaged in activities in Africa and elsewhere either through affiliation with international NGOs or through co-operation with local NGOs.

In order to improve transparency and ensure that government support is granted on an equal footing, the Ministry and ICEIDA have issued guidelines on co-operation with NGOs. The guidelines stipulate an application process, a vetting arrangement and eventual contractual requirements, including for development objectives, financial statements and audits.

The Private Sector

Private sector development and increased investment in developing countries play an important role in increased economic growth and thereby the possibility of reducing poverty. The Government of Iceland will continue to facilitate private sector development and public-private partnerships in developing countries.

There are various ways available to reinforce the private sector in the developing countries through development co-operation between public and private entities. The Government of Iceland will examine potential opportunities in this area, e.g. trough consultation with representatives of the business community, NGOs and universities. At the same time, the Government will explore avenues of mobilizing the Icelandic business community in co-operation with international organizations.

Iceland: Official Development Assistance (ODA)

Thous. US$		2005*	2006*	2007	2008*	preliminary 2009
Bilateral Cooperation		**14.776,8**	**23.050,0**	**27.442,6**	**28.861,1**	**17.377,5**
Icelandic International Development Agency (ICEIDA)		**8.885,0**	**14.297,0**	**17.753,5**	**22.251,6**	**13.614,8**
of which:	Malawi	2.211,0	3.730,8	4.382,1	5.128,9	2.923,1
	Mozambique	1.560,5	2.522,6	3.338,5	3.574,4	1.452,6
	Namibia	1.357,2	2.020,9	1.565,4	2.636,5	2.024,3
	Uganda	1.606,7	2.278,9	2.565,2	3.203,1	2.868,4
	Sri Lanka	303,9	1.021,9	1.148,3	2.174,4	482,7
	Nikaragua	133,7	1.128,0	1.053,0	2.227,8	1.407,5
	Other	1.710,4	1.593,8	3.701,0	3.306,5	2.456,3
Post-conflict Peacebuilding		**5.891,8**	**8.753,0**	**9.689,1**	**6.609,5**	**3.762,7**
of which:	ICRU (Afghanistan, Bosnia, Kosovo, Sri lanka)	4.634,8	8.463,0	9.382,9	6.448,3	3.604,6
	Bosnia and Herzegovina					
	Iraq (excl. emergency assistance)	1.097,9				
	Sudan	159,1	143,3			
	International Peacekeeping (7%)		146,0	150,0	161,2	158,1
Multilateral Cooperation		**7.346,1**	**13.809,0**	**12.024,2**	**10.281,0**	**10.364,9**
United Nations		**2.854,4**	**8.781,0**	**5.887,7**	**4.822,9**	**4.792,7**
of which:	UNO				75,9	105,0
	FAO	345,3	455,8	495,2	190,8	90,2
	FAO - Icelandic Specialist		72,0			
	UNDP	388,2	864,3	935,8	699,4	485,8
	UNICEF	572,8	1.232,6	1.360,7	1.074,1	1.369,0
	UNIFEM - Core Contribution	385,0	563,3	740,5	1.152,5	1.121,7
	UNRWA	52,5	100,3	242,1	371,3	419,9
	UNESCO	27,0	27,2	28,1	26,1	63,4
	UNEP "Assessment of Assessment"			95,3		
	OCHA	49,3	54,5	50,0	36,3	179,6
	OCHA - CERF		402,8	593,7	425,8	
	UNFPA	95,5	107,5	309,3	185,1	511,8
	UNHCR	92,3	107,5	390,6		189,1
	WFP - Emergency assistance	469,4	3.646,3	193,7	486,0	218,6
	UNVFVT		28,7	31,2	22,7	0,0
	UNITAR			45,3	46,6	
	WHO	149,6	325,4	229,7	67,0	91,7
	CLCS Trust Funds for Developing Countries	195,7	100,3	96,9		
	IAEA - Technical Cooperation Fund	31,8	33,0	31,2	25,0	32,1
	ILO			18,3	14,2	19,8
	Peacebuilding Fund		1.003,3			
World Bank Group		**3.094,7**	**4.586,5**	**4.357,1**	**3.902,6**	**3.991,5**
of which:	International Development Association (IDA)	2.307,1	2.944,0	3.208,9	2.332,2	2.038,7
	Icelandic Consultant Trust Fund (IFC)	206,8	160,5			
	PROFISH	318,2	336,8	324,9	455,3	588,2
	ESMAP		309,6	215,6	358,8	436,4
	Gender Action Plan				172,6	303,6
	Sudan Trust Fund	159,1	143,3	156,2	92,0	212,5
	Doing Business Reform Unit	103,4	430,0	190,6	210,1	209,9
	Multilateral Debt Relief Initiative (MDRI)		140,5	203,1	149,9	149,2
	Justice and Human Rights Trust Fund		51,6		68,1	52,9
	Avian Flu		70,2	57,8	63,6	

Table 7.1 Iceland's Official Development Assistance (ODA)

8 Research and systematic observation

8.1 General research policy

Emphasis on research and development (R&D) has grown in Iceland in recent years. Funds allocated to research and development were 1% of GDP in 1990 but had reached 2.7% of GDP in 2007 (over 35 billion ISK), making Iceland sixth among OECD countries in R&D spending per GDP that year. The business sector accounts for about 55% of R&D expenditure; the public sector, including higher education institutions, accounts for about 43%.

A new legislation on the organization of science and technology policy and the funding of research and technological development in Iceland, went into force in January 2003, establishing a Science and Technology Policy Council, with the task of formulating public policy on scientific research and technological development. The Council is headed by the Prime Minister, and consists of ministers, scientists and business representatives.

Environmental change is recognized as an important area in R&D. In 1998 the Icelandic Research Council launched a five-year program with a special fund to support projects in environmental research and research on information technology, which concluded in 2004. Several climate-related projects received grants from this fund. Such projects also get support from other funds of the Icelandic Research Council, but Icelandic scientists are also involved in a number of international climate-related projects funded from sources, such as the European Union and the Nordic Council of Ministers. Research on climate and systematic observation is also part of the mandate of some public institutions, such as the Icelandic Meteorological Office (IMO) and the Marine Research Institute (MRI).

One of three research programmes receiving significant grants from the Science and Technology Policy Council in 2009 is concerned with renewable energy and climate mitigation, namely the GEOthermal Research Group - GEORG. The grant supports the formation of a Research Cluster in Geothermal Energy, as significant expertise and experience in sustainable harnessing of geothermal power is concentrated in Iceland. Establishment of such a research cluster is seen as vital for Iceland to sustain the current position in the forefront of the geothermal field and to create stronger base for entrepreneurship and high tech industry in fields associated with the cluster. The STPC stated that an increased knowledge of sustainable energy in Iceland could lead to an energy independent state and therefore serve as a role model for other societies. The contribution of the cluster is summarized in the following four main objectives:

- Make Iceland a leading country in geothermal energy
- Make Iceland energy usage sustainable

- Reduce global carbon dioxide emission by strengthening the geothermal power sector
- Create platform for entrepreneurship and export for Icelandic companies in the field of geothermal energy

8.2 Climatic Research

Most of the climate-related research in Iceland is focused on climate processes and climate system studies and impacts of climate change. Other efforts involve modeling and prediction, and large ongoing projects deal with mitigation measures, but there has been less research on socio-economic analysis.

8.2.1 Climate process and climate system studies

The Icelandic Meteorological Office (IMO) is a governmental institute responsible for producing regular and specific weather forecasts. It conducts monitoring and scientific studies of geohazards and hazard zoning in Iceland. It is involved with several kinds of research within the fields of meteorology, hydrology and geosciences and has a leading role in climate change studies in Iceland both in research and in its role as an advising body to the government. It conducts glaciological measurements and modeling with a special focus on glacio-hydrology.

Although IMO research and evaluation of climate change is mainly centered on the climate of Iceland, the IMO has also been active in many international climate research projects. Studies of the spatial characteristics and long term changes in time series of temperature, precipitation, sea level pressure, river runoff and glacier changes have been conducted by IMO staff and published in international peer-reviewed journals.

Icelandic scientists have for many years contributed considerably to paleoclimatological work with their participation in many ice and sediment core projects. Most of this work has taken place within the University of Iceland. Some examples of research topics within that field and in related fields at the University include:

- A review of the size of Icelandic glaciers for the last 300 years and an estimate of their contribution to higher sea levels,
- Analysis of seafloor sediment cores from the coastal shelf north of Iceland to reconstruct changes in sedimentation, biota and ocean currents,
- Analysis of Tertiary and Quaternary oceanic paleo-fauna in order to chart changes in the system of ocean currents in that period,
- Reconstruction of climate change around the North Atlantic in the last 13,000 years by analysis of sedimentation (carbon content, pollen etc.) in lakes and fjords,

8.2.2 Modeling and prediction

The IMO has taken part in research projects where downscaling is used to generate projections of future climate change. In these studies a numerical weather forecast model or a regional climate model is used to refine for a limited area the projected climate changes from a global climate model. Results from such studies have been used to drive models of glacier retreat and changes in river runoff. The results of this work have been published in reports and peer reviewed articles.

8.2.3 Impacts of climate change

The IMO has led a series of Nordic-Baltic climate impact projects focusing on three main renewable energy resources; hydropower, bio-fuels and wind power. The current one, the Climate and Energy Systems (CES) project follows suit from the earlier Climate and Energy (CE) and the Climate, Water and Energy (CWE) project. These projects were funded by Nordic Energy Research. In these study projects the objective was to make comprehensive assessment of the impact of climate change on Nordic renewable energy resources including hydropower, wind power, biofuels and solar energy. This included assessment of power production and its sensitivity and vulnerability to climate change on both temporal and spatial scales; assessment of the impacts of extremes including floods, droughts, storms, seasonal pattern and variability. The CE project finished with the release of the book "Impacts of Climate Change on Renewable Energy Resources - Their role in the Nordic Energy System" which was published by the Nordic Council of Ministers in 2007. The current CES project has the goal of looking at climate impacts closer in time and to assess the development of the Nordic electricity system for the next 20-30 years. The project started in 2007 and will finish in 2010. It will address how the conditions for production of renewable energy in the Nordic area might change due to global warming. It will focus on the potential production and the future safety of the production systems as well as uncertainties.

All the National Hydro-Meteorological Services (NHMSs) in the region are partners in this cooperation that in many respects constitutes a regional Climate Services Application Program for the Nordic-Baltic region, including Greenland. A future ambition is to develop the network into a formal Regional Climate Service Application Program. The project also intends to contribute to the Nordic Council of Ministers Top-level Research Initiative Programmes 2009–2013, which will focus on impact studies, adaptation to climate change and the interaction of climate change with the cryosphere, among other themes.

Icelandic research institutions, agencies and universities are involved in several projects studying the impact of future global climate change and some of those have already been mentioned in previous sections. A key project was published in 2008 as an expert panel report from the Ministry for the Environment. It summarized the present knowledge in Iceland on how nature and society are affected by climate change. Another important dissemination project was the Arctic Climate Impact Assessment (ACIA), organized by the Arctic Council, the results of which were presented at the ACIA International Scientific Symposium on Climate Change in the Arctic in Reykjavik, Iceland, 9-12 November 2004. The goal of ACIA was to evaluate and synthesize knowledge on climate variability, climate change, increased ultraviolet radiation and their consequences and to provide useful information to the governments, organizations and people of the Arctic on policy options to meet such changes. Icelandic scientists also took an active part in the preparation of the 2007 IPCC's 4th Assessment Report.

Various experimental and monitoring studies have reported on the impacts of climate change on Icelandic ecosystems, flora and fauna. Effects of elevated atmospheric CO_2 concentration, temperature and fertility on productivity of forest trees was studied in a Nordic project during 1995-2000 in cooperation between the Agricultural University of Iceland (AUI) and Icelandic Forest Research (IFR). This effort also involved studies with experimental soil heating and measurements of in ecosystem fluxes. The impacts of elevated CO_2 concentration alone on heath land vegetation has also been studied around natural CO_2 springs in W-Iceland. Icelandic participants in the ITEX-project (International Tundra Experiment) have studied the effects of climate warming of 1-2 °C in two widespread but contrasting plant communities. They are from the University of Iceland (UI), AUI and the Icelandic Institute of Natural History (IINH). Both AUI and IFR have recently been part of a Nordic Centre of Excellence entitled NECC (Nordic Centre for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate System), where the effects of climate variability on ecosystem function of Icelandic wetlands, barren lands and forests were studied.

Scientists at UI and other institutes and universities in Iceland and abroad have been working on number of paleoenvironmental studies, involving e.g. fossils, tephra layers in soils and lake sediments, pollen analysis, and remains of various invertebrates in lake and oceanic sediments, where fluctuations in historic climate, flora and fauna have been investigated.

Many other projects that have the purpose of monitoring the current state of environmental factors, flora and fauna in Iceland and Icelandic waters exist. Even if they are not always primarily intended to study impacts of climate change, they can often be used for that purpose. Such long-term national inventories are e.g. done by the Icelandic Meteorological Institute (IMI; e.g. climate and annual runoff), UI (e.g. glacier size), Marine Research Institute in cooperation with UI (fish stocks and oceanic environment), IINH (distribution of native flora and fauna), AUI (e.g. soil inventory, land-use inventory), IFR (national forest inventory), the Soil Conservation Service of Iceland (SCS; inventory of ecosystem changes in eroded areas), and the Institute of Freshwater Fisheries (freshwater environment and fish stocks). Continuous remote sensing by satellites and aerial photographs may also yield important insights into how climate affects nature and societies. The primary local suppliers of such data are the National Land Survey of Iceland and various private companies.

Besides the various national inventories there are also number of important large-scale research projects at various research institutes and universities. One of those is the

SCANNET, a long-term catchment monitoring study in western Iceland. It is an EU-funded project, consisting of a net of research stations on drylands around the North Atlantic, intended to enhance and coordinate research on ecosystem change because of pollution and land-use change. Other such long term projects include e.g. long-term ecosystem research at Lake Mývatn and Lake Þingvallavatn.

There are also various modeling studies that have tried to directly quantify the potential impact of climate change on the physical environment and ecosystems in Iceland. The largest of those was Climate and Energy (CE), which was a Nordic research project that followed up a previous project, entitled Climate, Water and Energy (CWE). The National Energy Authority (NEA), IMI and UI were the main Icelandic participants. The CE project had the objective of a comprehensive assessment of the impact of climate change on Nordic renewable energy resources including hydropower, wind power, biofuels and solar energy and its results were published in the TemaNord report series in 2007. The NEA, IMI, and others have also worked on a related research project, Weather and energy (2004-2007) that focused specifically on the impact of weather and climate on hydro energy in Iceland.

8.2.4 Socio-economic analysis

Academic research on how climate change could affect socio-economic factors has not been substantial. The 2007 expert panel report addressed these issues in relation to potential natural hazards and an increase in sea level on buildings, transport system and costal infrastructure. It also emphasized the potential impacts on fisheries, agriculture and hydropower. It e.g. noted that changes in shipping routes and distribution of economically important fishing stocks with reduced sea ice cover north of Iceland will further increase the need for strengthening international cooperation, research and development.

8.2.5 Carbon cycle and carbon sequestration studies

The Agricultural University of Iceland (AUI), Icelandic Forest Research (IFR; the research branch of the Iceland Forest Service) and the Soil Conservation Service of Iceland (SCS) have conducted various studies focusing on the carbon cycle of both natural and managed ecosystems, both together and in cooperation with various national and international partners. Part of this research has been on sequestration and loss of CO_2 and other GHGs from soil and vegetation because of land-use change, including afforestation-deforestation, revegetation-devegetation and drainage-wetland restoration. Those studies directly contribute to a national estimate of Iceland's GHG bookkeeping and reporting to UNFCCC. The three institutes form together the sectoral expertise on land-use change in Iceland's GHG bookkeeping and together with the Environment Agency of Iceland (EAI) annually prepare a report on the national GHG dynamics, where national changes in both GHG emissions and net-sequestration are estimated.

The three institutes have also been involved in a number of focused research projects on the effect of afforestation, revegetation, grazing control and wetland drainage on the GHG balance, both on the national and international level. Such studies started in the 1980s, when effects of grazing control and fertilization on C-concentrations of degraded highland soils were studied and the first net C-sequestration rates for forest plantations were measured. In the 1990s the institutes cooperated on a number of Canadian-Icelandic, Nordic and European research projects on various aspects of the terrestrial carbon, water and nutrient cycles that mainly took place in an experimental forest in southern Iceland. Of those, the participation in the European EUROFLUX project is maybe best known, but those results were e.g. published in Nature in the year 2000. It assessed the long-term change in the flux of CO_2 and water in European forests, including the experimental forest in southern Iceland. Those results are freely available in an international research databank (Fluxnet), and have been used in numerous modeling studies on the carbon cycle in forest ecosystems. In the mid 1990s, AUI also engaged in several research projects on the GHG-balance of natural and drained wetlands. CONGAS, was a European project that analyzed the role of wetlands in the balance of CH_4 and CO_2 in the Arctic area, with sample sites from Greenland in the west to central Siberia in the east. The results of the project showed inter alia that Icelandic wetlands emitted considerably less CH_4 than in other sample sites.

During 1997-2000, the carbon sequestration potential of the main revegetation and afforestation options used in Iceland was evaluated by AUI, IFR, IINH and SCS with harvest measurements and soil sampling. This work was a part of a governmental action plan on increased carbon sequestration by afforestation and revegetation. Another project that compared ecosystem C-sequestration rates for three middle-aged forest types in eastern Iceland was conducted as a PhD study at Yale University in the US. Another PhD study from Yale and UI showed how natural and managed forests in western Iceland positively affect the chemical weathering rate in Icelandic soils. This is a biogeochemical process that can sequester $CO_{2,}$ but which is often neglected in carbon balance studies.

Research activity on GHG-issues still increased during the 2000s. National inventories were launched to follow changes in areas and C-stocks of natural and managed forests (IFR), revegetation areas (SCS) and other vegetation and land-use classes (AUI), including wetlands, croplands, grasslands, etc. Researchers involved in these projects are collaborating with colleagues in this field at the Nordic level (SNS research networks) and European level (COST-actions).

New research projects were initiated in the early 2000s, which studied various aspects of the GHG cycle. FJAR-KOL was a three-year project coordinated by AUI that assessed the CO_2 fluxes between the most common vegetation types in Iceland and the atmosphere, combining ground measurements and satellite data. Another AUI led project looked at the CH_4 and CO_2 balance of three wetlands types in western Iceland: untouched, drained and reclaimed. One result of this research was to show that drained wetlands are big emitters of CO_2, while restored wetlands can be net sequesters of CO_2. Another three year project run by AUI investigated the effects of submerging vegetated areas under hydropower reservoirs on the GHG fluxes.

In 2002-2005 IFR led a large national research project, ICEWOODS, where carbon sequestration was estimated for forest stands of different age (10-50 years) by harvest measurements and soil sampling. This work also became a part of a Nordic Centre of Excellence (NECC; Nordic Centre for Studies of Ecosystem Exchange and its Interactions with the Climate System), and then multi-annual flux measurements of CO_2 and H_2O exchange were added to the project in cooperation with Lund University in Sweden. This work showed that forests became net sinks for CO_2 soon after establishment and carbon was accumulated in forest soils, at least during the first 50 years following afforestation. Another study conducted in cooperation between IFR, AUI and UI looked at how forest management, including thinning and fertilization, affected the CO_2 balance of a young forest (Kyoto-forest) in southern Iceland.

A recent study showed that hayfields in eastern Iceland, which had received different fertilization treatments, accumulated carbon in their soils. The GHG-cycle and soil C dynamics of other cultivated hayfields and croplands are also being studied at AUI at present. A national research project, CarbBirch, focuses on how revegetation and establishment of mountain birch woodlands on formerly eroded areas changes the ecosystem C stocks, soil chemistry and biodiversity. It involves 50 sites of different age, from totally eroded surfaces to old-growth mountain birch forests in southern Iceland.

The University of Iceland (UI) and the National Energy Authority (NEA), in cooperation with French researchers, have studied further the role of chemical weathering and river-suspended material in the global carbon cycle. The reaction of Ca derived from silicate weathering with CO_2 in the world's oceans to form carbonate minerals is another critical step in long-term climate moderation. Ca is delivered to the oceans primarily via rivers, where it is transported either as dissolved species or within suspended material. A field study to determine these fluxes was performed on 4 catchments in northeastern Iceland. The results indicate inter alia that chemical weathering in Iceland results in significant sequestration of carbon from the atmosphere. A recent PhD study at UI also reported on the riverine DOC transport at landscape and national scale and linked it to modeled terrestrial productivity from MODIS satellite data. In other publications from UI the total flux of dissolved inorganic carbon by chemical weathering has been estimated to be of similar magnitude as all anthropogenic emissions from Iceland. How much of this flux will be permanently stored in terrestrial and oceanic sinks is, however, difficult to estimate. Currently there is an ongoing study, ForStreams, which investigates e.g. how large proportion of the terrestrial C-sequestration in forests and revegetated areas leaves as dissolved carbon (DOC and IC). This is done by harvest measurements in relatively small catchments and monitoring their dissolved carbon flux in stream water.

While the research discussed in the preceding paragraphs is mainly on natural carbon cycles, it can have policy implications. Restoration of drained wetlands has recently been added as a part of the Icelandic climate mitigation policy. A small program started some years ago aiming to reclaim drained wetlands, but large wetland areas in the lowlands in Iceland were drained with government support in the decades after WW II. The draining had almost come to a stop in 1990, but some of the drained wetlands are used for cultivation or grazing, while others have been abandoned by agriculture. Research on the carbon balance of Icelandic wetlands contributed to increase the government's emphasis on reclaiming wetlands, citing carbon sequestration benefits in addition to biological diversity concerns.

The 2009 report on the technical and economic possibilities of mitigating GHG emissions in different sectors of the Icelandic economy pointed out three feasible ways of human induced C-sequestration (afforestation, revegetation and wetland restoration). It concluded that all are among less expensive mitigation options available for the Icelandic society to reduce its national net-emissions. The reduction potential of these land-use options was estimated to be 15% of the net national GHG-emissions in 2020 (from a business as usual scenario), if continued at similar rate as at present. If combined with other inexpensive methods that can even give a net benefit to the national economy, such as increased use of more efficient vehicles and increased walking and cycling, the net emissions could be reduced by 19% in 2020. If however the afforestation, revegetation and wetland restoration activities were to be increased from their current levels they alone could reduce the net emissions in 2020 by as much as one third.

Carbon sequestration by chemical weathering is a natural phenomenon, not directly affected by anthropogenic factors. Rattan Lal, a world famous soil scientist, published in 2009 a review where he linked Icelandic studies on chemical weathering and studies on sequestration in soils and vegetation by revegetation and afforestation. He concluded that if all natural and anthropogenic CO_2-sinks would be included in Iceland's GHG bookkeeping in the future, it could offset fossil fuel emission by 2025 and beyond, and make Iceland an emission-free country.

The University of Iceland and the National Energy Authority, in cooperation with French researchers, have studied the role of river-suspended material in the global carbon cycle, which have been published in the journal Geology. The reaction of Ca derived from silicate weathering with CO2 in the world's oceans to form carbonate minerals is a critical step in long-term climate moderation. Ca is delivered to the oceans primarily via rivers, where it is transported either as dissolved species or within suspended material. A field study to determine these fluxes was performed on 4 catchments in northeastern Iceland. The results indicate inter alia that chemical weathering in Iceland results in significant sequestration of carbon from the atmosphere.

The MRI is engaging in the EU-funded project Atlantic Network of Interdisciplinary Moorings And Time series for Europe (ANIMATE), that aims to measure the flux of CO2 between the atmosphere and the ocean, and to develop the use of buoys for real-time measurement of environmental factors.

8.3 Systematic observation

The institutions most important for the observation of climate change are the Icelandic Meteorological Office (IMO) and the Marine Research Institute (MRI). Other institutions monitor changes in natural systems that are affected by climate change, notably the Icelandic Institute of Natural History (IINH), which monitors the state of flora and fauna in Iceland and the Science Institute of the University of Iceland which monitors changes in glaciers and land movements.

8.3.1 Atmospheric, hydrological, glacier and earth observing systems

The IMO is responsible for atmospheric climate monitoring and observation. The IMO monitors and archives data from close to 200 stations. These stations are either manual (synoptic, climatological and precipitation stations) or automatic. The number of synoptic stations in operation (about 40) was relatively constant from 1960 to 2000 but with increasing numbers of automatic stations the synoptic network has been scaled down to 33 stations. The observations are distributed internationally on the WMO GTS (Global Telecommunication System). The manual precipitation network has been steadily expanding and now consists of about 70 stations measuring precipitation daily in addition to the synoptic stations. The majority of the precipitation stations report daily to the IMO database. The automation of measurements started in Iceland in 1987, and the number of automatic stations has been rapidly growing since then. The IMO now operates about 70 stations and about 35 in addition to this in cooperation with the National Power Company, The Energy Authority and the Maritime Administration. A repository of data from the about 50 stations operated by the Public Roads Administration is also located at the IMO. A majority of automatic stations observe wind and temperature every 10 minutes, a few once per hour, and most transmit data to the central database every hour. Many stations also include humidity, pressure and precipitation observations, and a few observe additional parameters (shortwave radiation and ground temperatures) or observe at more than one level.

The IMO participates in the Global Atmospheric Observing Systems (GAOS). The IMO has participated in the MATCH ozone-sounding program during the winter months since 1990, and the data are reported to the International Ozone Data base at NILU, Norway. The three GAW stations are: the BAPM at Írafoss and Stórhöfði, where tropospheric ozone, carbon dioxide, methane and isotopes of oxygen and carbon are monitored in cooperation with NOAA. Heavy metals and Persistent Organic Pollutants (POPs) in air and precipitation are monitored and reported to AMAP and OSPAR. In Reykjavik, data on global radiation are collected and reported annually to the World Radiation Data Center in St. Petersburg (WRDC).

The IMO also monitors hydrological conditions in Iceland and runs a network of about 200 gauging stations in Icelandic Rivers. The network provides basic information for knowledge of the hydrology of Iceland. As the importance of monitoring and mediating information has been growing, the network has been updated and transmits data to the IMO centre at least once a day. The gauge network mainly measures water-flow, water-level and ground water, and in some cases other environmental factors.

Furthermore, the IMO runs flow monitoring network to watch, measure and warn against danger from floods originating in sub-glacial volcano and geothermal systems, or melt water, heavy rain and ice blockage of river-flow. The development of the network began in 1996, following explosive flooding in Skeiðará, and has in the last decade been extended to the areas south and north of Vatnajökull, south of Mýrdalsjökull, the South Iceland lowland and to Borgarfjörður. Each monitoring station has electronic registration equipment, pressure sensor to measure the water level, sensors for the conductivity and temperature in the water, solar-panel which provides energy for the station, a telephone and a modem for the transfer of data. When conductivity or the water level reaches a given limit the IMO and the Icelandic Emergency Watch are alerted and a decision on actions can be taken.

The glaciers in Iceland have changed immensely in historic time, in particular in most recent decades, as the decrease amounts to approximately 0,3-0,5% every year. In an expedition twice a year, spring and autumn, scientists of the IMO keep track of the development of Hofsjökull and Drangajökull, measuring precipitation, ablation and ice-slide.

Another glacier measuring project was launched by the IMO jointly with the Institute of Earth Science of the University of Iceland, in 2008, aiming at the high-resolution mapping of the surface of the largest glaciers using laser technology from airplane. The project is endorsed by the Icelandic Polar Year Commission. It set out in September 2008, comprising Hofsjökull, Mýrdalsjökull, Eyjafjallajökull, Eiríksjökull and Snæfellsjökull.

The outlines of Icelandic glaciers have been registered, using maps, aerial photographs and satellite images. The data has been released, e.g. by World Glacier Monitoring Service in Zürich and Global Land Ice Measurements from Space (GLIMS) in Flagstaff, Arizona.

The Icelandic Meteorological Office operates a network of continuous geodetic GPS stations in Iceland to monitor crustal deformation related to plate movements, volcanic unrest and earthquakes. With geodetic quality instruments and specialized software it is possible to achieve the daily position of the stations to within a few millimeters. CGPS stations are therefore an excellent tool to monitor crustal deformation. These stations allow IMO staff to monitor isostatic crustal changes that are occurring as a result of glacier thinning due to climate change.

8.3.2 Ocean climate observing systems

Both the IMO and the Marine Research Institute (MRI) contribute to ocean climate observations. The IMO does not operate any Icelandic drifting or moored buoys, but as members of EGOS (European Group on Ocean Stations), which is an organization operating 50 meteorological drifting buoys and 11 moored buoys in the North-Atlantic at any time, it supports a very important meteorological network. The Marine Research Institute (MRI) is a member of the International Council of Exploration of the Seas (ICES) and through that membership contributes to the GOOS (Global Oceanic Observing System). The MRI maintains a monitoring net of about 70 hydrobiological stations on 10 standard sections (transects) around Iceland. These stations are monitored four times per year for physical and chemical observations (phosphate, nitrate, silicate) and once a year for biological observations (phytoplankton, zooplankton). Some of these stations have been monitored since around 1950. The zooplankton biomass monitoring has demonstrated fluctuations, which to some extent appear to be linked to climate and circulation changes. The MRI has monitored carbon dioxide at selected stations for about 20 years and maintains a grid of about 10 continuous sea surface temperature meters at coastal stations all around the country.

The MRI has been involved in several monitoring projects of ocean currents, in cooperation with European and American scientists. These projects include the Meridional Overturning Exchange with the Nordic seas (MOEN), the Arctic-Subarctic Ocean Flux-array for European climate: West (ASOF-W), West-Nordic Ocean Climate and Thermohaline Overturning at Risk (THOR), which all involve the monitoring of ocean currents strength and other environmental factors. The University of Akureyri is a partner in some of these ocean current researches.

8.4 Research on Mitigation Options and Technology

Several research projects deal with issues related to mitigation options and technology. The most important of these involve renewable energy and alternative fuels, notably hydrogen, and carbon sequestration by afforestation, re-vegetation and wetland reclamation.

8.4.1 The IDDP project

One notable research project on geothermal energy, which could have a potentially great impact on the exploitation of geothermal in Iceland and worldwide, is the Iceland Deep Drilling Project (IDDP). The main purpose of the IDDP project is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. An Icelandic energy consortium was established around the IDDP in the year 2000. A feasibility report was completed in May 2003. To begin with the consortium was composed of three Icelandic energy companies (HS Orka hf (HS), Landsvirkjun (LV), Reykjavik Energy (OR)) and the National Energy Authority of Iceland (OS). Alcoa Inc., the international aluminum company, joined the consortium as funding partner in 2007, and

Statoil ASA, the Norwegian oil company, joined in 2008. LV then drilled the first full scale deep IDDP-1 well in 2009 at Krafla, NE-Iceland, which the consortium intended to deepen to 4.5 km to reach 400-600°C hot supercritical hydrous fluid. However, the drilling operation of IDDP-1 was abruptly terminated by late June at 2104 m depth when drilling penetrated molten rock about 900°C hot. IDDP will flow test this well in 2010 and possibly, in near future, create the world hottest Engineered Geothermal System (EGS), if production of superheated steam from the IDDP-1 proves not to be sustainable. Within the next few years OR and HS intend to drill 4 km deep IDDP wells within their geothermal fields in SW-Iceland, which IDDP intends to deepen to 5 km. In addition to the IDDP consortium, ICDP (International Continental Scientific Drilling Program) and the NSF (United States National Science Foundation) granted financial supports for core drilling within the IDDP wells for scientific studies. Approximately 60 research proposals from the international scientific community are active, ranging from petrology and petrophysics to fluid chemistry, water rock reactions, surface and borehole geophysics and reservoir modeling. The IDDP is a long term research and development project which will take a decade or more to conclude. As yet, IDDP is therefore not an alternative solution to meet energy demand in the near or intermediate future. In the longer term, however, the potential benefits of the IDDP regarding increased use of climate-friendly geothermal energy include: (i) Increased power output per well, perhaps by an order of magnitude, and production of higher-value, high-pressure, high-temperature steam, (ii) Development of an environmentally benign high-enthalpy energy source below currently producing geothermal fields, (iii) Extended lifetime of the exploited geothermal reservoirs and power generation facilities, and (iv) Re-evaluation of the geothermal resource base worldwide.

8.4.2 The CarbFix project

An international team of experts working closely with Reykjavik Energy has been preparing the initial tests of one the world's first carbon-dioxide sequestration plants near the Hellisheiði geothermal plant in Iceland. The CarbFix project, which uses a radically new process, is designed to pump CO2 from the Hellisheiði geothermal power plant, outside Reykjavik, into a massive basalt formation below. Natural chemical reactions within this common volcanic rock should turn the CO2 into a carbonate mineral similar to limestone. The process locks CO2 into a solid—a potential great advantage over the few other current projects, which store CO2 as liquid. The $11 million pilot, which follows several years of experiments and construction, will treat 2,000 tons of CO2 over nine months. This project is a partnership of Columbia University's Earth Institute; Reykjavik Energy; University of Iceland; and the National Center for Scientific Research in Toulouse, France

8.4.3 International hydrogen projects

The Icelandic government has offered political support to those interested in developing alternative fuels specifically electricity and hydrogen as an energy carrier in the transport sector, which would greatly reduce GHG emissions from mobile sources. In 1997 the

Ministry of Industry and Commerce appointed a special committee to explore available options for use of domestic renewable energy. Following this committee's work the government has now decided to offer Iceland as an international platform for hydrogen research and for that has created a specific policy which has 4 key elements.

- Favorable framework for business and research
- International cooperation
- Education and training
- Hydrogen research

As part of this policy the government has taken some large steps in implementing these policy measures. The government was a founding member of the International Partnership for the Hydrogen Economy (IPHE) and Iceland is also active in the European Hydrogen Platform. The government has also taken direct measures with the unique step of eliminating all import duties and VAT on hydrogen vehicles.

Following the work of the committee in 1997 all key stakeholders established a company called VistOrka to be the unifier of the Icelandic interest in hydrogen. VistOrka then joined forces with Daimler Chrysler, Norsk Hydro (now StatOil) and Shell Hydrogen to form Icelandic New Energy which has been the key actor in creating the future hydrogen society. Still stakeholders in VistOrka are very active and currently are working towards establishing a joint Hydrogen Technological Center, which is to provide facilities for researchers, students and others which are currently working on various projects. Iceland is an ideal testing site for electric hydrogen vehicle projects because of the small size of society, the availability of renewable energy and the political commitment of the Icelandic government. These factors have drawn various different academics to do work in Iceland and provide Icelandic researchers and universities with a "life" test bed.

Icelandic New Energy (INE), in cooperation with its foreign partners, runs several research projects aiming to make it technologically possible and economically feasible to use hydrogen as an energy carrier in the transport sector and for fishing vessels. The research program of INE has received enormous international attention. The very ambitious overall goal of the program is to create the world's first hydrogen economy. This would mean that Iceland would become independent of imported oil since domestic, renewable energy sources can be used to produce hydrogen. The research program has several phases. The first phase was the ECTOS project (later HyFLEET:CUTE). The objective of those projects was to implement a demonstration of state-of-the art hydrogen technology by running part of the public transport system in the capital with fuel-cell buses. The only emission from the vehicles is pure water and the whole energy chain is virtually emission free as the energy for the hydrogen productions, electrolyzing water, will be almost free of CO2 emissions because geothermal energy and hydropower will be used. The world's first hydrogen station was part of the program in April 2003, and the 3 fuel cell buses started in commercial use in October 2003. The partners in the project were extremely happy with the success, as the team has driven roughly 150.000 km, pumped over 17 tons of hydrogen and surveys indicate that more than 90% of the public is very positive towards using hydrogen as the future fuel instead of fossil fuels. Currently the second and third phase has been in operation. This is testing of hydrogen out at sea as an auxiliary power for a whale watching boat and also using hydrogen vehicles in public service. Already 22 hydrogen vehicles are now in service in Iceland, the largest European fleet, most of them with fuel cell technology. The use of hydrogen is then expected to rise fairly fast in the next decade as the technology reaches maturity and becomes available on the market. Although INE is a private venture, the projects have received funding from public sources, such as the European Union and the Government of Iceland.

Currently the same team is responsible for investigating the use of electric (battery) vehicle as part of the vehicle fleet. The key issue is to understand the public and economic issues related to the different technologies. The Government of Iceland is convinced that the future will bring in electric mobility and with such measures it should is possible to drastically reduce CO_2 emissions from Iceland.

Finally, a new company Carbon Recycling International CRI has been developing methods to produce green methanol from renewable hydrogen and CO_2 which is obtained from geothermal boreholes using their own catalysis technology. The company plans to build a plant at the Svartsengi geothermal site in Reykjanes south of Reykjavik to produce methanol to be mixed with conventional vehicle fuels. Recently a team at the Innovation Center in Iceland completed a project where this green methanol was utilized in a direct methanol fuel cell to produce electricity – thus completing the new energy cycle.

9 Education, training and public awareness

9.1 General education policy

The educational system in Iceland is administered by the Ministry of Education, Science and Culture. The Ministry prepares educational policy, oversees its implementation, and is responsible for educational matters at all educational levels. Education has traditionally been organized within the public sector, and there are few private institutions in the school system. Almost all private schools receive public funding. The educational system is divided into four levels. Pre-school is the first educational level and is intended for children below the compulsory age for education. Parents are free to decide whether their children attend preschool. Compulsory Level is the second educational level. Children and adolescents aged 6 - 16 must by law attend 10 years of compulsory education. Upper Secondary Level is the third educational level. All those who have completed their compulsory education or equivalent have the right to study at the upper secondary level. This generally incorporates the age group 16 – 20.

The modern Icelandic system of higher education dates back to the foundation of the University of Iceland in 1911. The Ministry has issued National Qualification Framework, which is a systematic description of the structure of education and degrees at higher education that is specifically based on learning outcomes. All accredited higher education institutes in Iceland shall follow this framework.

There are currently seven higher education institutions in Iceland that fall under the auspices of the Ministry of Education, Science and Culture: The University of Iceland and the University of Akureyri are public universities. The Agricultural University of Iceland and Holar University College are public universities that were formerly under the auspices of the Ministry of Agriculture. Reykjavik University, Bifröst University and Iceland Academy of the Arts are private institutions that receive state funding and operate under structural charters approved by the Ministry of Education, Science and Culture. At university level there is a growing emphasis on education and research in the field of natural resources and environmental science.

9.2 Environmental education

The Eco-Schools Programme is an international project that Landvernd, an Icelandic environmental NGO, participates in and manages in Iceland. Eco-Schools is a program for environmental management and certification, designed to implement sustainable development education in schools by encouraging children and youth to take an active role in how their school can be run for the benefit of the environment. Schools that fulfill the necessary criteria are awarded the Green Flag for their work, which they keep for two years.

The preparation for the Eco-Schools Programme started in September 2000 when a special Eco-Schools working group was established. This working group now acts as the Eco-Schools steering committee. It has ten members, including representatives for the Ministry for the Environment, The Environment Agency of Iceland, The Icelandic Institute of Natural History, The National Centre for Educational Materials, and the National Teachers Association. Twelve elementary schools participated in a pilot program, which formally started in mid-2001. In January 2002 the program was opened to all elementary schools in Iceland and later to all schools at all levels from pre-schools to universities. Today, the number of participating schools is 170. Just over 27% of all pre-schools in Iceland participate in the Eco-Schools Programme and roughly 45% of elementary schools have entered the program. Just over half of all participating pre- and elementary schools have been awarded the Green Flag, and close to 40% of all students in these two levels are studying in Eco-Schools in Iceland. There are 34 upper secondary schools in the country of which eight have joined the Eco-Schools Programme. Three of the participating secondary schools have been awarded the Green Flag. Out of seven universities, three have joined the program.

In 2008 the Program’s steering committee decided to open up the program to “other schools”, such as Sunday schools and summer schools, according to the international guidelines of the Eco-Schools Programme. The program is financially supported by the Ministry for the Environment and the Ministry of Education, Science and Culture.

Museums play an important role in education. Museums and exhibitions on natural sciences, culture and industrial structure have been established around the country in recent years, promoting increased public awareness of the relationship between mankind and nature. Regional Environmental Research Institutes have also been established in many places around the country in cooperation between the government and municipalities. These Institutes play a role in education as well as in research. The importance of outdoor education is growing and outdoor education in all subjects is now an integrated part of the education in many primary schools and kindergartens in Iceland. The city of Reykjavík has established the Reykjavík Nature School which offers outdoor education for kindergarten and primary schools, teaching material and teachers training.

9.3 Public access to resources and information

General discussion of environmental issues, including disseminating information to the public through the media, the Internet and YouTube, has increased considerably in recent years. The Ministry for the Environment and the Environment Agency of Iceland have information on climate change on their websites, including information about greenhouse gas emissions in Iceland as well as a general explanation of the causes and consequences of climate change. In 2008 the Ministry for the Environment in cooperation with the Meteorological Institute and The Environment Agency published a brochure with information for the public with information on climate change. The Environmental Education Board, which has representatives from both the environmental and education sector, disseminates information to the public on various environmental issues and arranges seminars and conferences. The Board has also reached an agreement with the University of Iceland to include a special section on the environment on the so-called “Web of Science”. This is a website where the public can ask questions, and scientists and researchers at the University provide the answers. The Ministry for the Environment in cooperation with The Institute for Sustainability Studies at the University of Iceland arranges on a regular bases conferences and seminars on relevant environmental issues. These events are open to the public. The National Environment Assembly is a biannual national conference hosted by the Minister for the Environment, where all stakeholders and the public are invited to discuss the most pressing issues regarding the environment and sustainable development for two days. The participation of youth at the Assembly is a high priority. A special Energy Council has been established in cooperation with the Ministry for Industry, Energy and Tourism and the National Energy Authority. The Council is supported by the Intelligent Energy Europe. The main aim of the Council is to improve knowledge among the public and companies on energy efficiency and possibilities to save energy. The homepage of the Council contains information on various issues related to energy resources, advice on what can be done in everyday household to save energy and calculators that show the use of gasoline in different types of cars.

9.4 Involvement of non-governmental organizations

Non-governmental organizations play an important role in disseminating information to the public. Environmental NGOs run several projects that are instrumental in raising environmental awareness. One project especially relevant to climate change is “Global Action Plan” (GAP). This is an international project that Landvernd, an Icelandic environmental NGO, participates in and manages with financial support from The Ministry for the Environment. GAP is a project where small groups of 5 - 8 people follow a special ten-week programme where five subjects are on the agenda. These subjects are: waste, energy, transport, shopping and water. Each group has a coach who has received special training. Over one thousand families in Iceland have participated in eco-teams for households and the organization aims at introducing eco-teams for workplaces later this year. GAP works closely with municipalities in Iceland and the city of Reykjavik now offers employees to participate in eco-teams during working hours. GAP has worked since 1990 to promote action for sustainability through a process of empowerment, so that people make conscious decisions to change their own behaviour. The goal of the project is to make people aware of how their lifestyle and actions in daily life influence the environment, and how simple changes can make a difference. In cooperation with GAP, Landvernd also offers courses in eco-driving. The aim of the project is to reduce CO_2 emission from vehicles by 5-10%. The eco-driving project is supported by the government of Iceland and several private companies.

Contributors

Arnór Snorrason	Iceland Forest Service
Birna Hallsdóttir	Environment Agency of Iceland
Bjarni D Sigurðsson	Agricultural University of Iceland
Danfríður Skarphéðinsdóttir	Ministry for the Environment
Elín R Sigurðardóttir	Ministry for Foreign Affairs
Halldór Björnsson	Icelandic Met Office
Héðinn Valdimarsson	Marine Research Institute
Hermann Sveinbjörnsson	Ministry for the Environment
Hugi Ólafsson	Ministry for the Environment
Jóhann Sigurjónsson	Marine Research Institute
Jón Ólafsson	Marine Research Institute
Jórunn Harðardóttir	Icelandic Met Office
Kristín Harðardóttir	Environment Agency of Iceland
Orri P Jóhannsson	Icelandic Environment Association
Ragnar Baldursson	Ministry for Foreign Affairs
Sigrún Pálsdóttir	Icelandic Environment Association
Sigurður B Finnsson	Environment Agency of Iceland
Sigurður Guðmundsson	Ministry of Finance
Stefán Einarsson	Ministry for the Environment
Trausti Jónsson	Icelandic Met Office
Þorsteinn I Sigfússon	Innovation Center Iceland
Þórdís Sigurðardóttir	Icelandic International Development Agency
Þórður B Guðjónsson	Ministry for Foreign Affairs