2023

Iceland's First Adaptation Communication

The enclosed document is an excerpt from Iceland's 8th National Communication, including parts of chapter 1 and the whole of chapters 2, 6-9. The document serves as Iceland's first Adaptation Communication with reference to Article 7, paragraphs 10 and 11 of the Paris Agreement and decision 9/CMA.1

Government of Iceland

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Iceland's First Adaptation Communication

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National circumstances

Iceland is a constitutional republic with a multi-party parliamentary system of government. The Constitution was adopted on 17 June 1944, when the Republic was established. Legislative power is vested in Parliament (Althingi) and the president, in that bills of legislation are passed by Parliament and submitted to the president for confirmation. Upon confirmation by the president's signature, the bill in question acquires the force of law. The Government must be supported by a majority of Parliament in order to remain in power. The 63 members of Parliament are elected from six constituencies based on proportional representation, for a term of four years. Over the past thirty years, the participation of women in politics has increased significantly and their share of seats in Parliament has increased from 15% to 47,6%. The president is the head of state and is elected for a term of four years by a direct vote of the electorate.

The population of Iceland was 368.792 on 1 January 2021. (See Figure 2-2.) With only 3 inhabitants per square kilometre, Iceland is one of the least densely populated countries in Europe. In 2000–2015, annual average population growth was 1.1% and the natural increase (births less deaths) 0.8%. Around 63% of the population over 230 thousand) live in the capital city of Reykjavík and its surrounding municipalities. In 1990 this same ratio was 57%, demonstrating higher population growth in the capital area than in smaller communities and rural areas.

The largest town outside the capital area is Akureyri, located in North Iceland, with a population of just over 19 thousand. Most of the remaining inhabitants live in small towns along the coast.

Iceland is in the North Atlantic between Norway, Scotland, and Greenland. (Figure 2-5). 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 kilometres, a coastline of 4,970 kilometres and a 200-nautical-mile exclusive economic zone extending over 758 thousand square kilometres 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 10% of the total land area. The largest glacier, also the largest in Europe, is Vatnajökull in Southeast Iceland with an area of 8,300 km2. 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, they are smelting faster which has resulted in significant changes in the areas closest to the glaciers.

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.

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.

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. The Icelandic economy displays the characteristics of an advanced economy, with high income levels and a relatively large services sector. Its distinguishing features are its large marine and energy sectors based on ample resources, a growing tourism sector, and a high labour participation rate.

Iceland is the 17th largest fishing nation in the world, according to the FAO SOFIA 2022 report. See Figure 1. Nearly all catch from Iceland gets exported. The fishing and fish processing sector are still one of the main economic pillars and the backbone of export activities in Iceland although its relative importance has somewhat diminished as other sectors such as tourism have been growing rapidly in recent years. See Figure 2.11.

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 marine resources. All commercially important species are regulated within the system. In addition to the fisheries management system, there are several other explicit and direct measures to rationalize investments in the fishing sector, to support its aims and reinforce conservation and socio-economic sustainability.

The energy profile is unusual as 85% of primary energy use in 2019 came from renewable resources, hydro and geothermal. This share was even higher in 2020-2021 due to COVID-19 effects on lower transport fuel consumption. The remaining 15% came from imported fossil fuels, which are mainly used in transportation, road and aviation, and the fishing industry.

Tourism has increased rapidly in Iceland in recent years. In 2021 the total number of foreign overnight visitors to Iceland was just under 700 thousand as the impacts of the Covid-19 pandemic decreased somewhat. This was a 44% increase from 2020, when foreign visitors numbered just under half million. In 2019 the total number of foreign visitors was around 2 million.[1]

Around 688,000 tourists came on flights through Keflavík International Airport in 2021, or 98.5% of the total number of visitors. Around 10,000 came with the ferry Norræna through Seyðisfjörður, or around 1.5% of the total. Around 100 came on flights through Reykjavík Airport or Akureyri Airport. It must be assumed that there are variations in counts at Keflavik International Airport, as they cover all departures, including foreign national's resident in Iceland. See Figure 2.20.

Impacts and adaptation measures

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, see Figure . This record shows that during the 19th century, temperatures were cooler than in the 20th century, and that the magnitude of inter-annual variations in temperature were larger. In the 1920s, there was a period of rapid warming, as also 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

[1] https://www.ferdamalastofa.is/en/recearch-and-statistics/numbers-of-foreign-visitors

minimum reached during the years of Great Salinity Anomaly in the late 1960s, when sea ice was prevalent during late winter along the north coast. Conditions were rather cool in the 1970s with 1979 being the coldest year of the 20th century in Iceland. Since the 1980s, Iceland has experienced considerable warming, and in first decade of the 21st century, temperatures reached values comparable to those observed in the 1930s. The warmest year in the series was 2016. While there are pronounced inter-decadal temperature swings in Iceland, the long-term warming rate is similar to the global average, suggesting that the rapid warming in the period 1979 to 2021 is a combination of local variability and large-scale background warming. This remains true both for the annual average and individual seasons.

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, has insufficient coverage in the Icelandic highland where precipitation tends to be greater than in lowland areas. Recently, an estimate for precipitation in all of Iceland during the last decades of the 20th century has been derived using high-resolution atmospheric reanalysis. The results show significant decadal variations in precipitation, and a tendency for higher amounts of precipitation during warmer decades. The long-term station records indicate that precipitation tends to increase by 4% to 8% for each degree of warming. Furthermore, several new studies suggest an increase in precipitation intensity during the warming of recent decades. Variations in ocean currents, impacts on glaciers, agricultural land and fish stock are of great concern.

Financial assistance and transfer of technology

International Development Cooperation is one of the key pillars of Iceland's foreign policy, with the main goal of contributing to the fight against poverty in the world's poorest countries and guided by the Sustainable Development Goals (SDGs).

For nearly four decades, Iceland's official development cooperation has placed focus on the sustainable utilization of natural resources, including fisheries and geothermal and other renewable energy sources. This has been grounded on Iceland's experience and expertise in utilizing its own resources for its social, economic and human development.

In line with best practices in development cooperation and OECD-DAC guidelines, Iceland's development cooperation in bilateral partner countries is based on close cooperation with local communities and their needs and is based on detailed needs assessment. The same preconditions apply to the activities of multilateral partners. However, it is worth noting that Iceland's first OECD-DAC Peer Review (2017) highlighted the need to further mainstreaming environmental activities across its development cooperation portfolio and strengthen the harmonization of climate change, business and development cooperation strategies within Iceland's Ministry for Foreign Affairs in accordance with the Kyoto Protocol. The Ministry for Foreign Affairs is developing an environment and climate change strategy, that will be supported by an action plan that will guide environmental mainstreaming in all development cooperation.

With respect to core funding to multilateral institutions that don't have an explicit climate change mandate, although possible to retrieve information on climate relevant proportions of the projects they support from OECD-DAC, these contributions are not part of the information provided in the total climate related summary in this report. Apart from core funding, reporting on climate specific finance through multilateral institutions is identified based on an application of Rio markers in the same manner as bilateral climate-specific finance. Climate specific projects are those with climate change mitigation and climate change adaption markers, marked as having significant or principal objective in applicable category. Additional are cross– cutting projects which have more than one climate category with marked either significant or principal marker. All funds specified in this report have been disbursed.

Most of Iceland's bilateral environmental contributions are channelled through the GRÓ Centre (before 2020 UN University training programs) based in Iceland. The GRÓ Training Programs provide support to climate change adaptation and mitigation in LDCs, gender mainstreaming, capacity building through the four programs: GRÓ Geothermal Training Program, the GRÓ Fisheries Training Program, the GRÓ Land Restoration Training Program, and the GRÓ Gender Equality Studies and Training Program.

Research and systematic observation

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 modelling and prediction, and large ongoing projects deal with mitigation measures, but there has been less research on socio-economic aspects.

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 modelling with a special focus on glacio-hydrology.

Although IMO research and evaluation of climate change is mainly centred on the climate of Iceland, the IMO has also been active in many inter-national climate research projects. Studies of the spatial characteristics and long-term changes in timeseries 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 to paleoclimatological work with their participation in many ice and sediment core projects.

The IMO has led the scientific committee on climate change and the impacts of climate change in Iceland since 1999. The committee has published 3 reports since then (2000, 2008 and 2018) and the next one is expected to be published in 2023.

Both the Marine and Freshwater Research Institute (MFRI) and the Icelandic Meteorological Office (IMO) contribute to ocean climate observations. The IMO and MFRI have been supporting Meteo France in deploying surface drifters with barometers and SST for weather observations and climate in recent years. The MFRI maintains a monitoring net of about 70 hydrobiological stations on 10 standard sections (transects) around Iceland with most of the sections extending beyond the continental slope. These stations are monitored three to four times per year for measurements of temperature and salinity and once or two times a year for phosphate, nitrate and silicate and once a year for phytoplankton and zooplankton. Some of these stations have been monitored regularly since around 1950. The MFRI has monitored carbonate system parameters on two-time series stations northeast and west of Iceland since 1983. A network of about 10 continuous sea surface temperature meters is maintained at coastal stations all around the country.

Education, training and public awareness

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 organised within the public sector, but there are few private institutions in the school system, all of which receive public funding.

The National Curriculum Guide from 2013[2] applies to all grades and subjects in compulsory schools and further specifies what is to be coordinated in all Icelandic compulsory schools. Based on the objective articles of the preschool, compulsory school, and upper secondary school acts, six fundamental pillars of education have been defined for the competence that pupils should achieve at compulsory school. One of the six pillars is “Education towards sustainability”, which concerns the interplay of the environment, economy, society, and welfare. Sustainability includes respect for the environment, sense of responsibility, health, democratic working methods, and justice, not only at present time but also for future generations. Environmental protection, climate change and biodiversity are examples of tasks to be tackled. Sustainability is considered a prerequisite to understand the importance of one’s own welfare and that of others. Education for sustainability further encompasses that in their studies children and youth come to grips with diverse problems and points of controversy. Teaching and working methods of the school are to be interwoven with the idea that the aim of education is capability for action. This involves training in democratic working methods and that children and youth are trained to be interested in and want to take part in society.

[22] https://www.government.is/topics/education/curriculum/

A fundamental principle of the Icelandic education system is that everyone is to have equal access to education irrespective of sex, economic status, geographic location, religion, disability and cultural or social background. 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 must by law attend 10 years of compulsory education from the age of 6 to 16. Upper Secondary Level is the third educational level which generally incorporates the age group from 16 to 19. Everyone has the legal right to enter school at that school level, irrespective of their results at the end of compulsory schooling. Those that have the right to enrol in upper secondary school also have the right to study until the age of 18.

The Eco-Schools Programme is an international project funded by the government and managed in Iceland by the NGO Landvernd (The Icelandic Environment Association). Eco-Schools is a programme for environmental management and certification which aims at enhancing environmental education and to strengthen environmental policy in schools. It is designed to implement sustainable development education in schools by encouraging children and students to take an active role in how their school can be run for the benefit of the environment. Schools that fulfil the necessary criteria are awarded the Green Flag for their work, which they keep for two years, before they need to renew their permission to flag the Green Flag.

2. National circumstances

2.1 Government structure

Iceland is a constitutional republic with a multi-party parliamentary system of government. The Constitution was adopted on 17 June 1944, when the Republic was established. Legislative power is vested in Parliament (Althingi) and the president, in that bills of legislation are passed by Parliament and submitted to the president for confirmation. Upon confirmation by the president's signature, the bill in question acquires the force of law. The Government must be supported by a majority of Parliament in order to remain in power. The 63 members of Parliament are elected from six constituencies based on proportional representation, for a term of four years. Over the past thirty years, the participation of women in politics has increased significantly and their share of seats in Parliament has increased from 15% to 47,6%. The president is the head of state and is elected for a term of four years by a direct vote of the electorate.

General elections are generally held every four years, but the Constitution allows for early dissolution of Parliament, which triggers early elections.

The most recent election was held on 25th of September 2021. The results of the elections were as follows: The Independence Party obtained 24,4 % of votes and 16 seats, the Progressive Party 17,3 % and 13 seats the Left Green Movement 12,6 % and 8 seats, the Social Democratic Alliance 9,9 % and 6 seats, and the Pirate Party 8,6 % and 6 seats, The People's Party 8,8% and 6 seats, The Liberal Reform Party 8,3% and 5 seats, the Centre Party obtained 5,4 % and 3 seats. Other parties did not received votes above the required minimum of 5%.

The coalition government of the Left-Green Movement, the Independence Party and the Progressive Party which first took office in November 2017 stays in power, with the total of 37 members out of 63 in the Parliament.

The government is headed by a prime minister, and the executive branch is divided among 12 ministers. Iceland's court system is divided into three levels: district courts (currently eight in number), the Court of Appeals, and the Supreme Court. Judicial power lies with the Supreme Court, the Court of Appeals and the district courts, and the judiciary is independent. Significant amendments were made to the Act on the Judiciary in spring 2016 with the establishment of a new Court of Appeals, which started operating on January 1st 2018.

The country is divided into 64 municipalities, (see Figure 2.1) and local authorities are elected every four years. The largest municipality is the capital, Reykjavík, with 133.262 inhabitants but the greater capital area has around 232.280 inhabitants in 6 municipalities. The smallest municipality on the other hand has less than 50 inhabitants.[3]

[3] https://hagstofa.is/

Figure 2.1 Municipalities in Iceland 2021.

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 regards to greenhouse gas emissions. This includes physical planning, waste-management, granting industry licenses and the design and operation of public transport. Municipalities also play an important role in education.

The Ministry of the Environment, Energy and Climate is responsible for the implementation of the UNFCCC and coordinated national climate change policymaking in close cooperation with the Ministry of Food, Agriculture and Fisheries, Ministry of the Interior, Ministry of Finance, Ministry of 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 368.792 on 1 January 2021. See Figure 2.2. With only 3 inhabitants per square kilometre, Iceland is one of the least densely populated countries in Europe. In 2000–2015, annual average population growth was 1.1% and the natural increase (births less deaths) 0.8%. Around 63% of the population over 230 thousand) live in the capital city of Reykjavík and its surrounding municipalities. In 1990 this same ratio was 57%, demonstrating higher population growth in the capital area than in smaller communities and rural areas.

The largest town outside the capital area is Akureyri, located in North Iceland, with a population of just over 19 thousand. Most of the remaining inhabitants live in small towns along the coast.

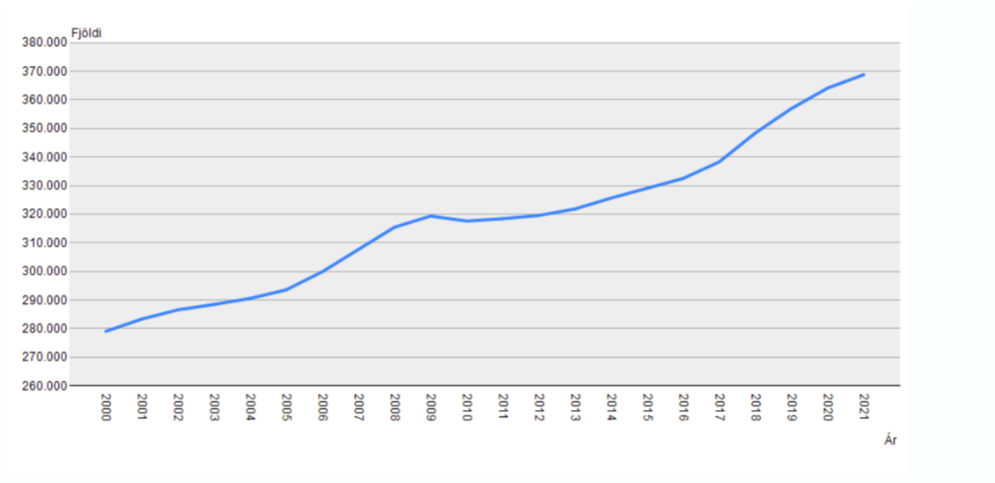


Figure 2.2 Population in Iceland 2000-2021

As in other advanced countries, the population of Iceland is ageing, but at a relatively slower pace than in most OECD countries. In 2021,[4] despite high life expectancy, the ratio of the total population aged over 65 to the population of working age was 14,7%. See Figure 2.3.

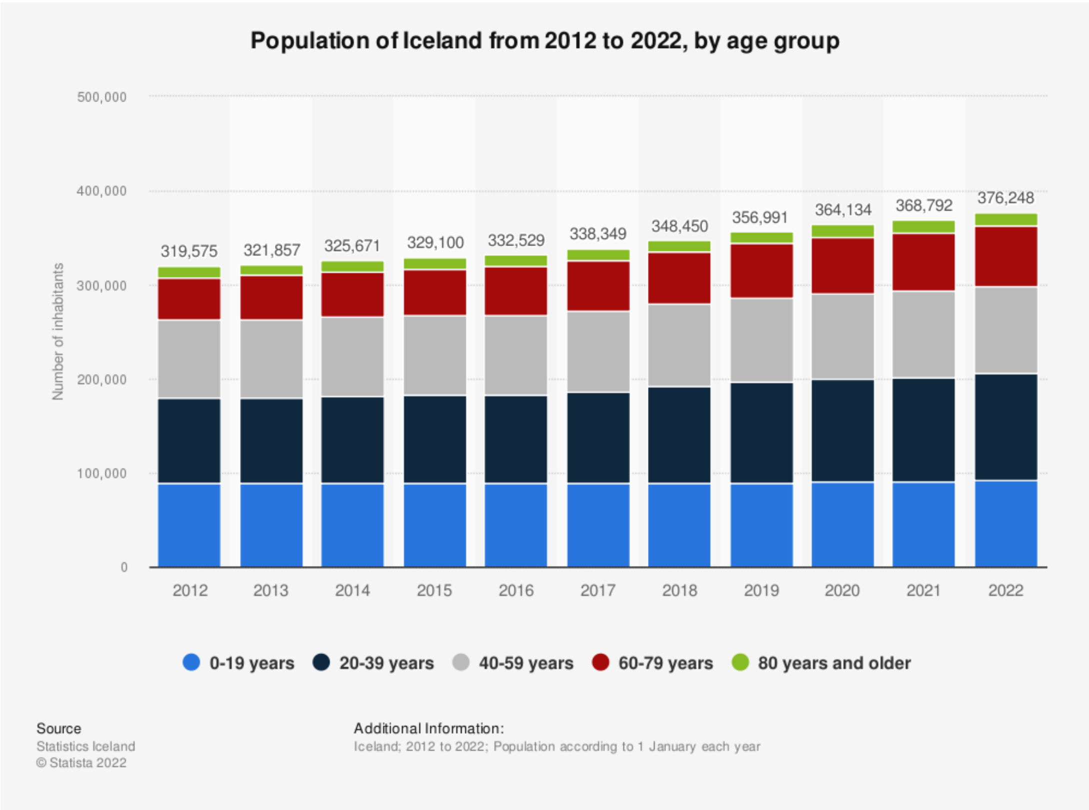


Figure 2.3 Population by age 2021[5]

[4] https://hagstofa.is/utgafur/frettasafn/mannfjoldi/kjarnafjolskyldur-1-januar-2021/

[5] https://www.statista.com/statistics/594621/total-population-in-iceland-by-age/

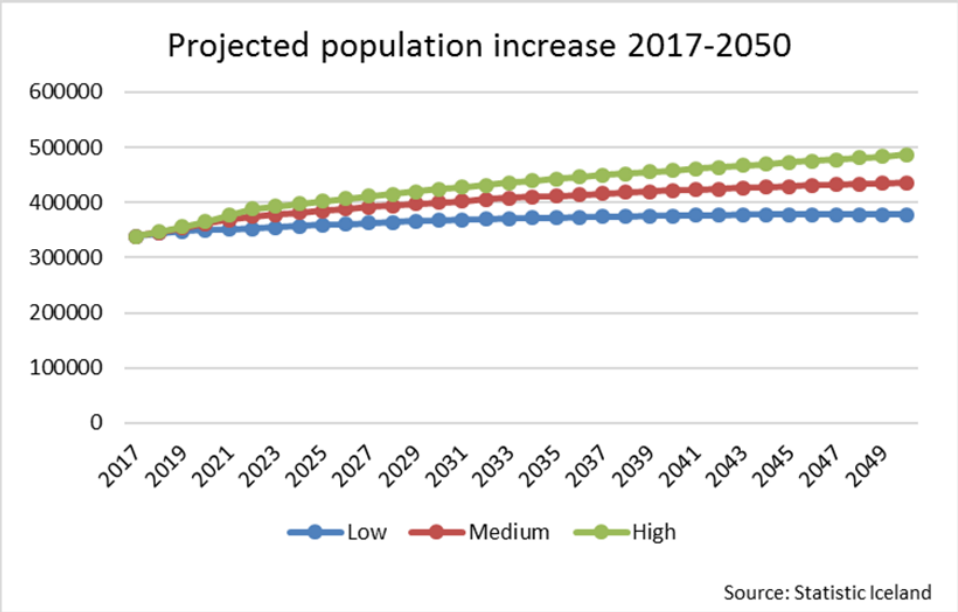


Figure 2.4 Projected population increase in Iceland 2017 – 2050

Figure 2.4 shows three scenarios for population growth until 2050. A low estimate predicts that the population will reach around 380.000 in 2050, the medium estimate predicts the population will reach around 436.000 and the high estimate predicts that the population will reach around 487.000 in 2050.

2.3 Geography

Iceland is in the North Atlantic between Norway, Scotland, and Greenland. (Figure 2.5). 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 kilometres, a coastline of 4,970 kilometres and a 200-nautical-mile exclusive economic zone extending over 758 thousand square kilometres 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.

Figure 2.5 Geographic location of Iceland

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 10% 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, they are smelting faster which has resulted in significant changes in the areas closest to the glaciers.

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.

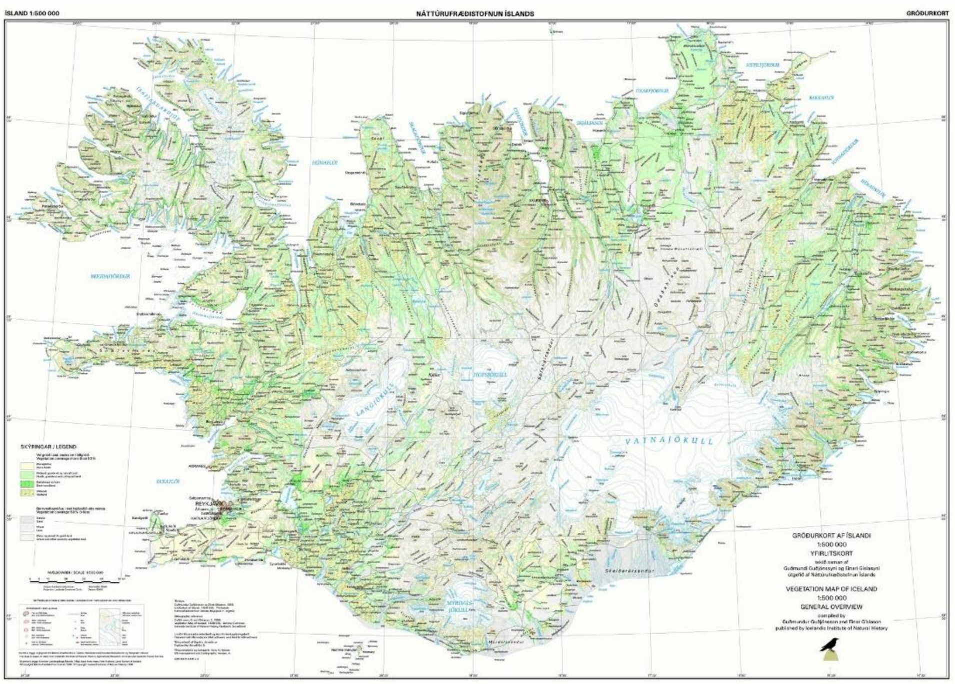


Figure 2.6 Vegetation map of Iceland

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 and land reclamation began more than a century ago with the establishment of the Soil Conservation Service of Iceland in 1907, 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 profile

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.

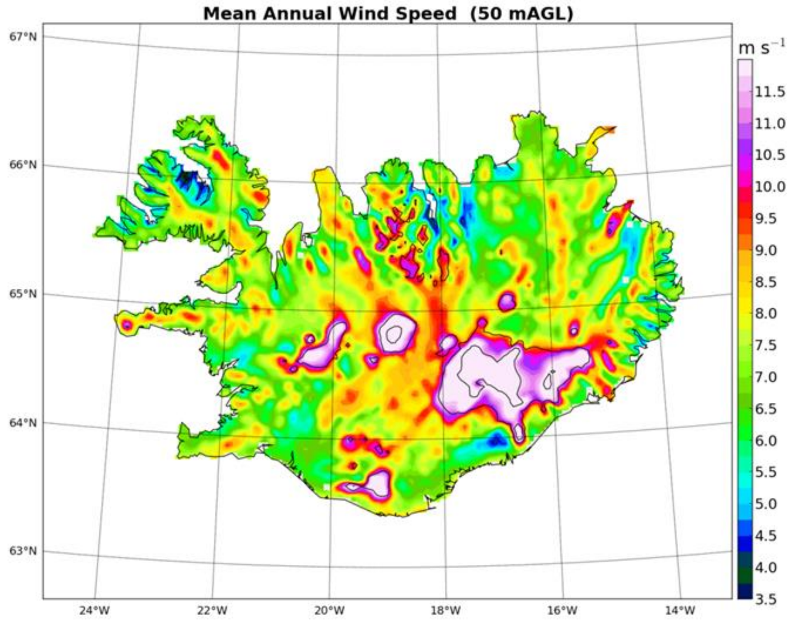


Figure 2.7 Mean annual average wind speed at 50 m above ground level

Figure 2.7 shows annual average wind speed in Iceland. The figure is from a study of the wind energy potential of Iceland made by the Icelandic Met Office. The study shows that Iceland compares with areas such as Scotland and the western coasts of Ireland and Norway, which are ranked within the highest wind power class in Europe. These areas are characterized by average winds above 6 m/s over sheltered terrain and average winds above 8.5 m/s at the coast, measured at 50 m above ground level.

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 The Icelandic economy displays the characteristics of an advanced economy, with high income levels and a relatively large services sector. Its distinguishing features are its large marine and energy sectors based on ample resources, a growing tourism sector, and a high labour participation rate.

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 and economic efficiency due to sustainable quota allocations, a global economic recovery, a rise in exports and a new wave of investment in the aluminium 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.

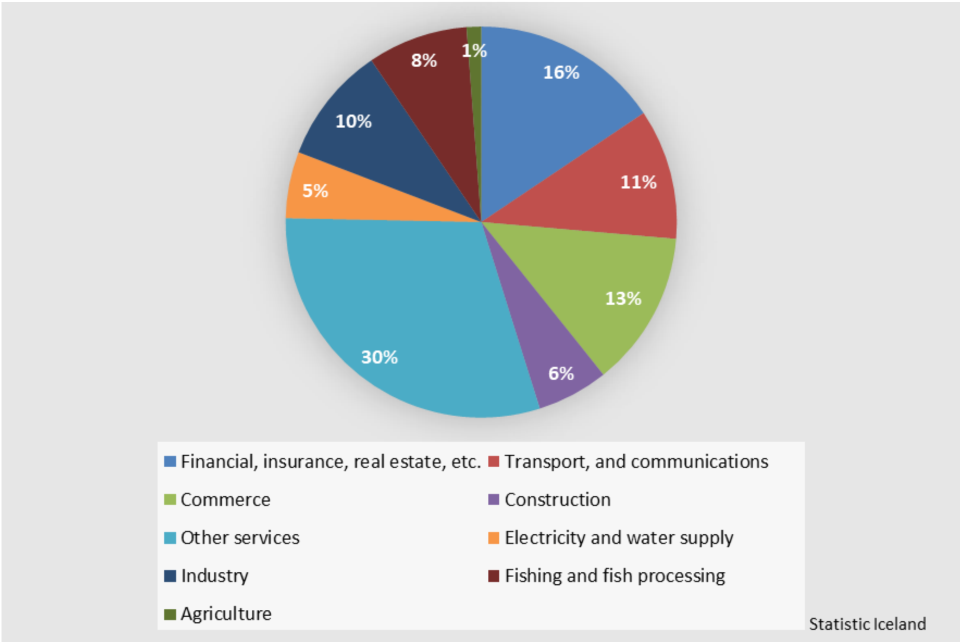


Figure 2.8 Breakdown of GDP in 2015 by sector.

Iceland was severely hit by an economic crisis when its three largest banks collapsed in the fall of 2008. The blow was particularly hard owing to the enormous size of the banking sector in relation to the overall economy as it had grown to be ten times the annual GDP. The crisis 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. The pandemic-related collapse of foreign tourism and international travel during Covid affected Iceland's GDP which was −8,8% per capita in 2020, but bounced back to 2.7% in 2021. See Figure 2.8 for breakdown of GDP in 2015.

The annual national accounts for 2021 show a 4.3% increase in Gross Domestic Product (GDP) in real terms compared with a 7.1% decrease in the previous year. At the same time, gross domestic final expenditure (GDFE), the aggregate of household and government final consumption expenditure and gross fixed capital formation, is estimated to have increased by 7.2% in volume. Household final consumption expenditure (HFCE) increased by 7.6%, gross fixed capital formation (GFCF) by 13.6% and government final consumption expenditure (GFCE) by 1.8%. Due to a greater increase of imports than of exports, the contribution of external trade to economic growth during the period was negative. Even though the decrease in GDP in 2020 has reversed to a considerable extent in 2021, GDP in this year is still 3% lower in volume than in 2019, prior to the COVID-19 pandemic. Due to a greater increase of imports than of exports, the contribution of external trade to economic growth during the period was negative. Even though the decrease in GDP in 2020 has reversed to a considerable extent in 2021, GDP in this year is still 3% lower in volume than in 2019, prior to the COVID-19 pandemic.

Exports are estimated to have increased by 12.3% in volume in 2021 compared with the previous year. The increase in exports of services was 20.3% during the year, while exports of goods increased by 7.6% during the same period. Imports increased by 20.3% in 2021 compared with 2020, imports of goods by 21% and imports of services by 18.6%. Due to a greater increase of imports than the increase of exports, the contribution of external trade as a whole to economic growth during the period was negative. The deficit in the balance of trade in goods and services amounted to 68.8 billion ISK in 2021, compared with a deficit of 22.3 billion ISK in 2020, at current prices.

The value of exported goods from Iceland in 2021 amounted to 762.4 billion ISK fob and the value of imported goods amounted to 994.3 billion ISK cif (926.5 billion ISK fob). Thus, there was a trade deficit, calculated on fob value, of 231.8 ISK billion in 2021 compared with a trade deficit of 145.3 billion ISK in 20201 at current rates of exchange.2. Yet the total value of imports of goods in 2021 was 222.8 billion ISK higher (28.9%) than in 2020.

Figure 2.9 GDP and Gross national income 1998-2016

The unemployment rate has followed the recession in GDP and national income, see Figure 2.10.

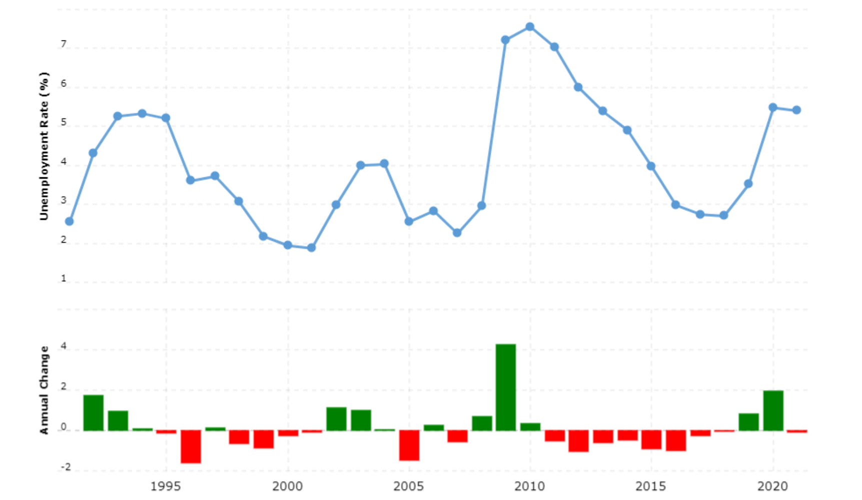


Figure 2.10 Unemployment 1991-2016. [6]

6 https://www.macrotrends.net/countries/ISL/iceland/unemployment-rate'>Iceland Unemployment Rate 1991-2022

2.6 Development of economic sectors

2.6.1 Fisheries

Iceland is the 17th largest fishing nation in the world, according to the FAO SOFIA 2022 report. See Figure 2.11. Nearly all catch from Iceland gets exported. The fishing and fish processing sector are still one of the main economic pillars and the backbone of export activities in Iceland although its relative importance has somewhat diminished as other sectors such as tourism have been growing rapidly in recent years.

Throughout most of the 20th century, the fishing and fish processing sector was of key importance to the Icelandic economy and to a considerable extent, economic growth was generated by this sector. In 2022, the total catch of Icelandic fishing vessels was 1.417 thousand tons which is 259 thousand tons more than in 2021. In 2021 the marine products' exports contributed to nearly 24% of the export value for goods and services and have increased over the course of 2022, mainly owing to the increase in the quota for capelin.

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 marine resources. All commercially important species are regulated within the system. In addition to the fisheries management system, there are several other explicit and direct measures to rationalize investments in the fishing sector, to support its aims and reinforce conservation and socio-economic sustainability.

Between the years 2020 and 2021, export value increased by 7%, excluding aquaculture, and amounted to 296 billion ISK (FOB) up from 275 billion ISK (FOB). The exports of frozen products generated nearly half of the export value, of which the iced and frozen cod were of greatest value, 56,8 billion ISK and 46,8 billion ISK respectively.

In 2021 around 15% of the products' export value was exported to the United Kingdom (44,8 billion ISK) followed by France 42,1 billion, United States (27,8 billion ISK) and Spain (21,6 billion ISK) as the largest markets. Between 2021 and 2020 the exports to the United Kingdom have been declining by 14.800 tons, while at the same time exports to France have increased by 9.000 tons for the same period.

Of the total exports of 644 thousand tons in 2021 about 76,1% were exported to Europe, 10,6% to Asia and 7,5% to North America. In terms, total exports value of 296,2 billion ISK about 73,1% of the export revenues were from the European market and 12,4% of the export revenues from North America. [6]

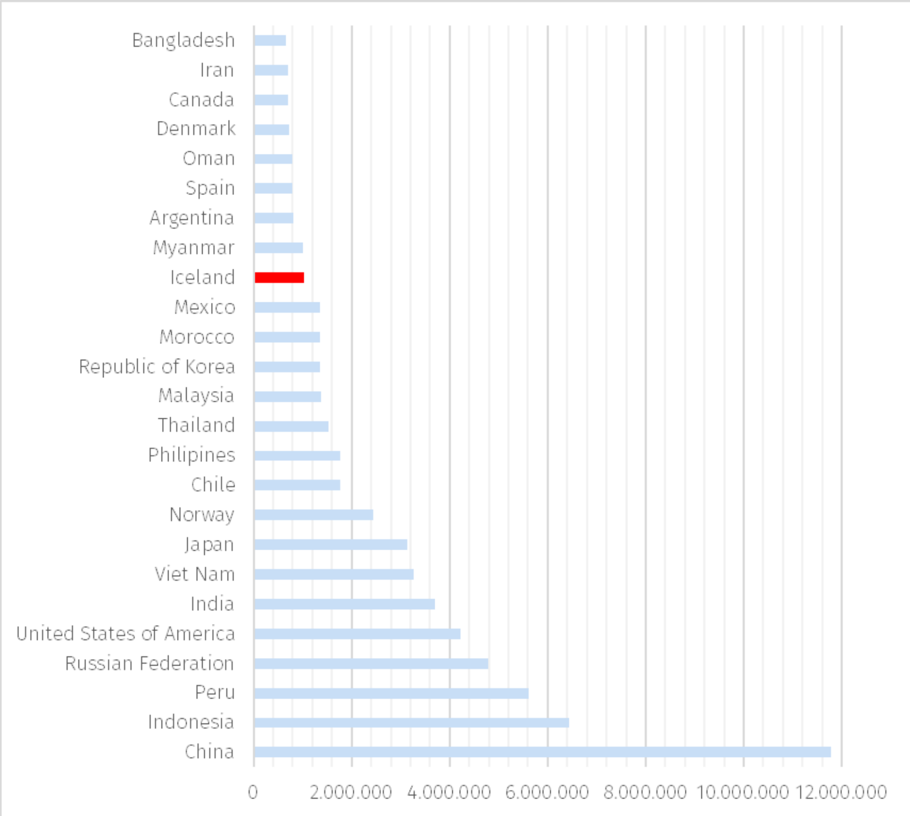


Figure 2.11 Marine Capture production – 20 largest producers 2014[7]

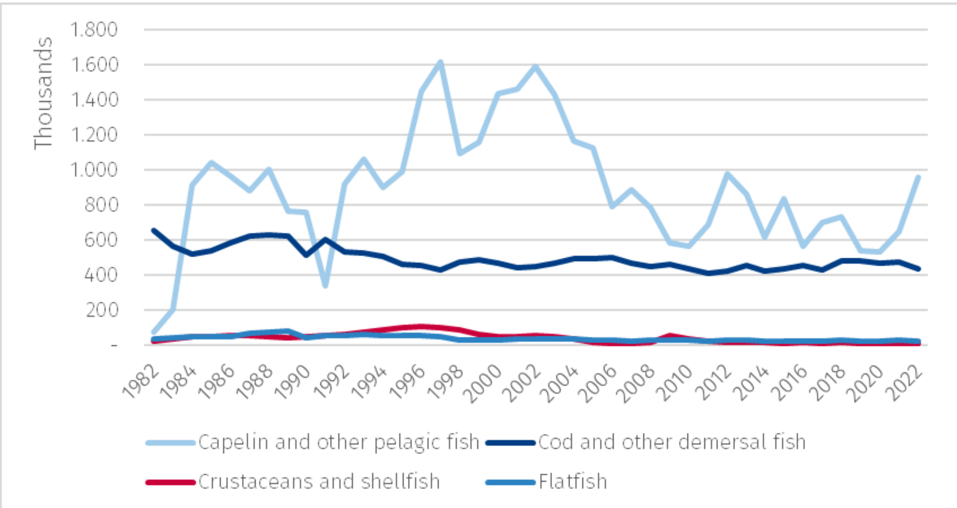


Figure 2.12 Fish catch 1992 – 2012

[7] FAO The State of World Fisheries and Aquaculture (SOFIA) 2022.

Figure 2.12 shows significant fluctuations in the total catch over time. This is mainly due to the fluctuation of the pelagic catch.

2.6.2 Export

In Iceland, the total value of exports of goods in 2021 was ISK 136.2 billion, 21.8% higher than in 2020. Exports of aluminum and aluminum products had the largest share in exported manufacturing products or 37.3% of total exports. Marine products contributed to 38.8% of the total exports and their value was 7.4% higher than in 2020. Fresh fish and frozen fish fillets had the largest share in marine products. Fresh fish was 11.3% of total exports and frozen fish fillets were 9.6% of total exports. The largest trading countries in the export of goods were the Netherlands, Spain, and United Kingdom but 68.8% of all exports went to EEA countries.[8]

Exports of services has increased as the economy has become increasingly service oriented. Tourism has soared over the past few years and has been one of the main drivers of export growth. The total value of exports of services for 2021 was 95.6 billion ISK higher than in 2020, or 25%. The increase in exports of services is mainly due to increase in exports of travel and transportation as the impacts of the Covid-19 pandemic decreased somewhat in 2021. The value of exported travel was estimated 165.4 billion ISK in 2021 and increased by 91% compared with 2020. The value of exported transportation was estimated 120.4 billion ISK in 2021 and increased by 31% compared with 2020.[9]

In Iceland, the total value of imports of goods in 2021 was ISK 222.8 billion, 28.9% higher than in 2020. The increase was mainly in transport equipment and capital goods. The largest import categories were industrial supplies (28.8%) and capital goods (22.2%)[10]. The total value of imports of services for 2021 was 63.5 billion ISK higher, or 21%, than in 2020. The value of imports of travel was 96.3 billion ISK in 2021 and increased by 36% compared with 2020. The value of imports of transportation was 75.1 billion ISK in 2021 and increased by 23% compared with the year before.[11]

2.6.3 Energy profile

The energy profile is unusual, as 85% of primary energy use in 2019 came from renewable resources, hydro and geothermal. This share was even higher in 2020-2021 due to COVID-19 effects on lower transport fuel consumption. The remaining 15% came from imported fossil fuels, which are mainly used in transportation, road and aviation, and the fishing industry.

Iceland has extensive domestic energy sources in the form of hydro and geothermal energy. The development of energy sources in Iceland may be divided into three phases. The first phase covered the electrification of the country, utilization of hydropower and harnessing the most accessible geothermal fields, especially for space heating. In the second phase, steps were taken to harness the resources for the power-intensive industry by building larger hydropower plants. This began in 1966 with the signing of agreements on the building of an aluminium 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 in recent years. Oil has almost disappeared as a source of energy for space heating in Iceland. Domestic energy has replaced oil in industry and other fields where such replacement is feasible and economically viable.

[8] https://tradingeconomics.com/iceland/exports

[9] https://www.statice.is/publications/news-archive/external-trade/trade-in-services-by-classification-and-countries-2021/

[10] https://www.statice.is/publications/news-archive/external-trade/trade-in-goods-final-data-for-the-year-2021/

[11] https://tradingeconomics.com/iceland/imports

Electricity consumption per capita is very high in Iceland compared to other OECD-countries, with 50 MWh/capita in 2020, next comes Norway with 23 MWh/capita (2020) and Canada and Finland with 15-16 MWh/capita (in 2019). See Figure 2.13.

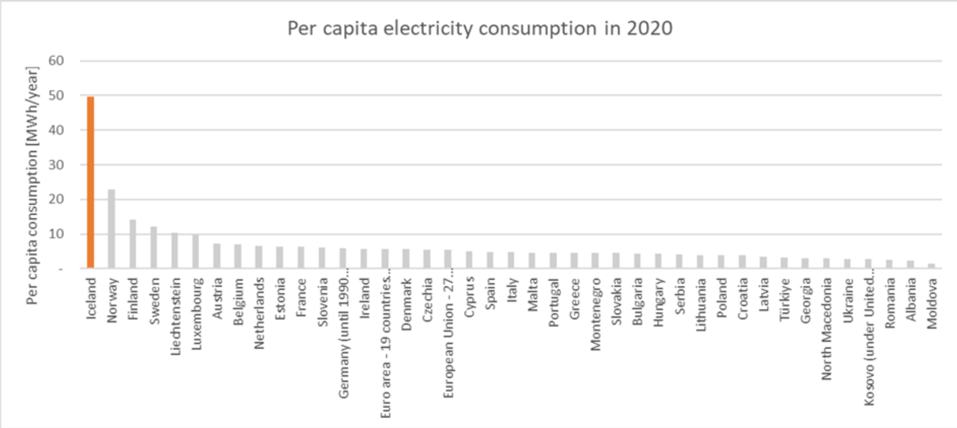


Figure 2.13 Electricity consumption per capita in Europe countries 202020 (Eurostat).

Renewable energy sources, primarily hydroelectric and geothermal, account for 99.9% of electricity production (see electricity produced by source in Figure 2.14), and 99,7% of space heating.

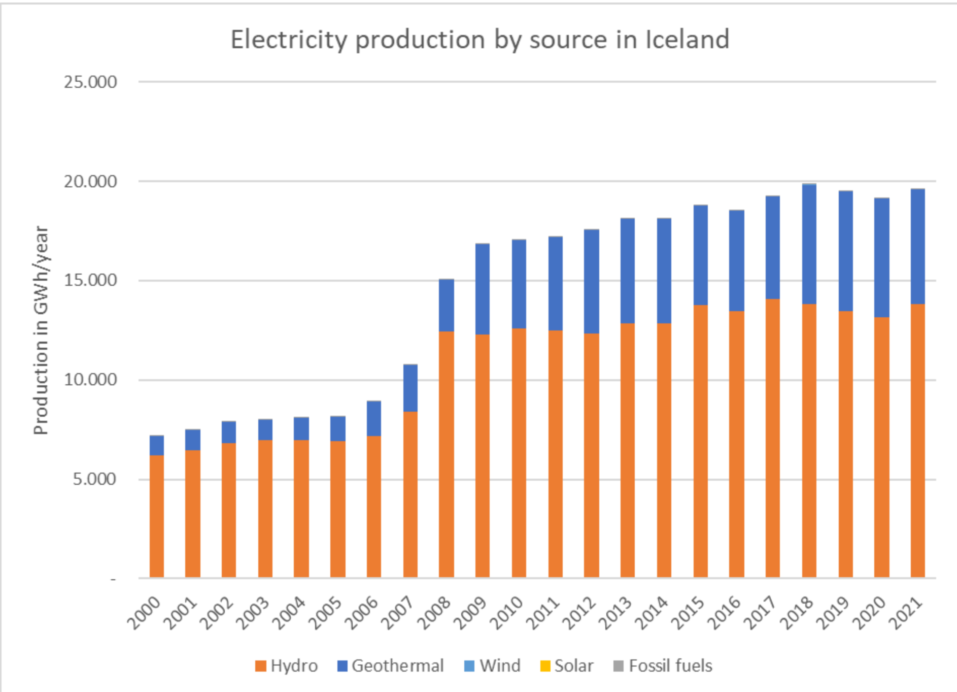


Figure 2.14 Electricity production by sources 2000-2021

The majority of electricity consumption in Iceland has historically been in the energy intensive industry. In 2021 these industries consumed 79%, or 14,994 GWh, of the electricity consumed, see Figure 2.15.

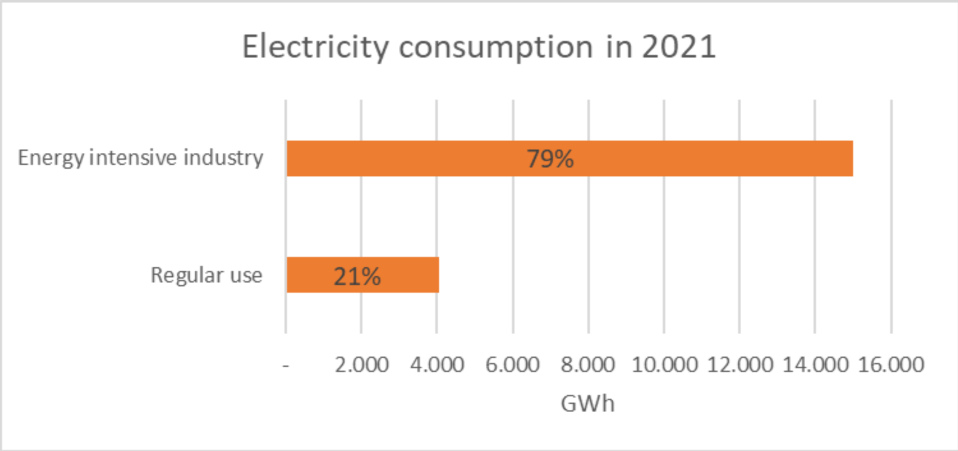


Figure 2.15 Total electricity consumption in Iceland in 2021 was 19,049 GWh

The consumption of energy intensive industries is split between aluminium smelters, which consumed 83% or 12,457 GWh, the ferroalloy industry, aluminium foil industry and data centers, see Figure 2.16.

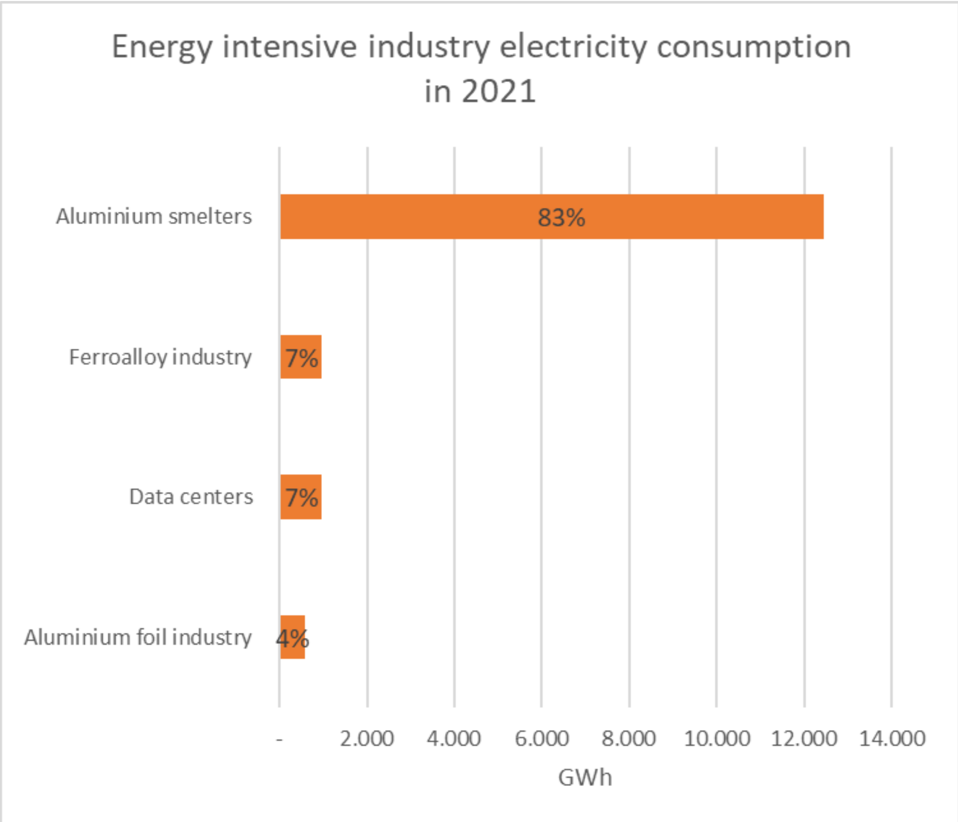


Figure 2.16 Electricity consumption of Energy intensive industries in Iceland in 2021

Figure 2.16, shows the electricity consumption of Energy intensive industries in Iceland in 2021. The total consumption was 14,994 GWh.

The remaining consumption, referred to as regular use in the graphs, includes residential use, utilities, services, fisheries, agriculture, and other industries. The total consumption of these groups was 4,055GWh in 2021, with other industry, service and residential use being the largest consumption groups, consuming around 25% each, see Figure 2.17.

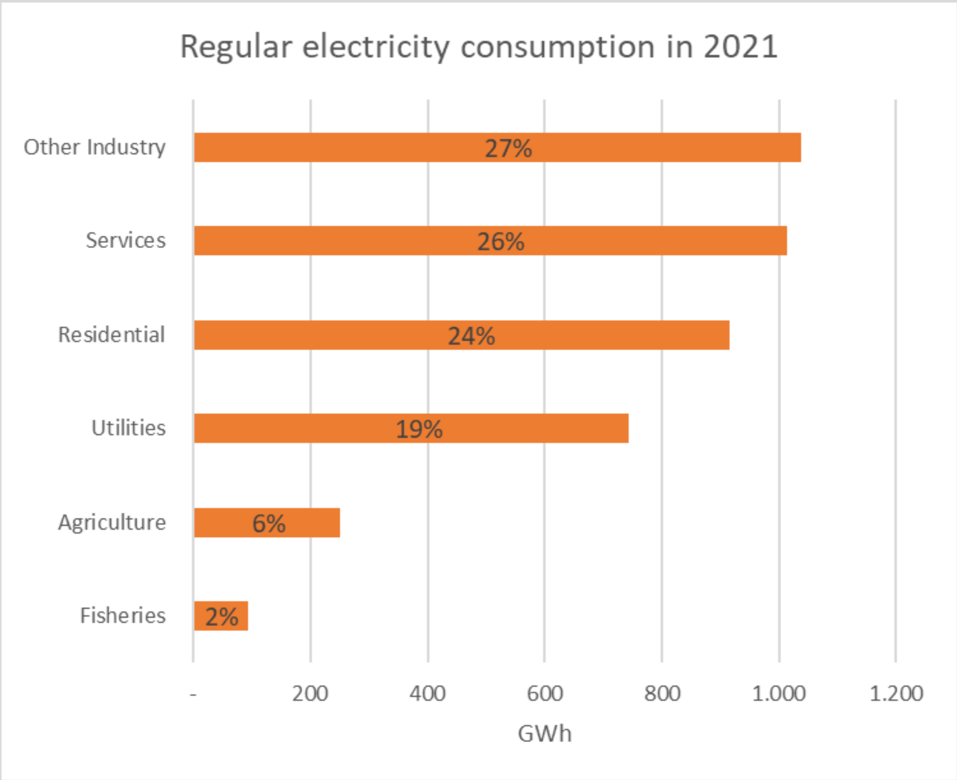


Figure 2.17 Regular electricity consumption in Iceland in 2021.

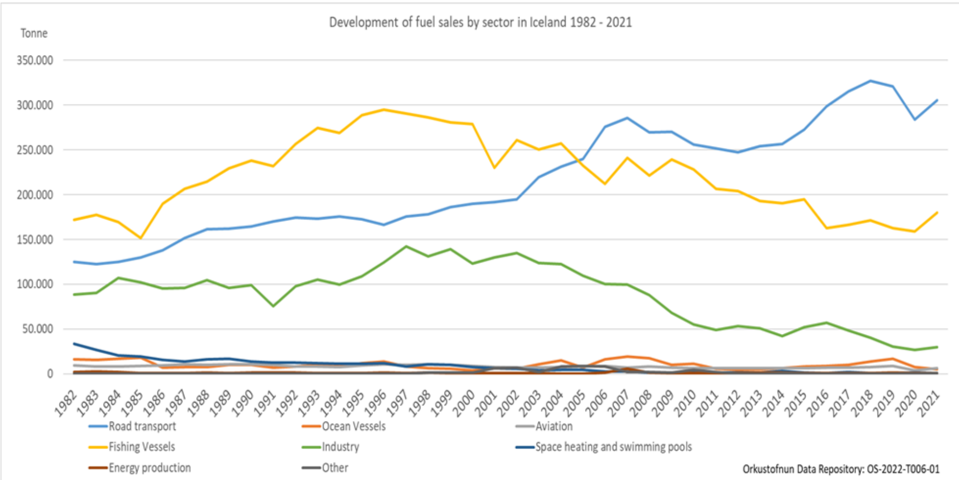


Figure 2.18 Domestic oil consumption in Iceland 1980 –2021.

Geothermal heat and hydropower account for around 85% of the country's primary energy consumption in 2019.

In 2021, the total installed capacity for electricity production was 2,933 MW most of which is hydropower, 71.7%, and geothermal power, 25.8%, see Figure 2-19. Some 92,4% of all homes in Iceland are heated with geothermal energy.

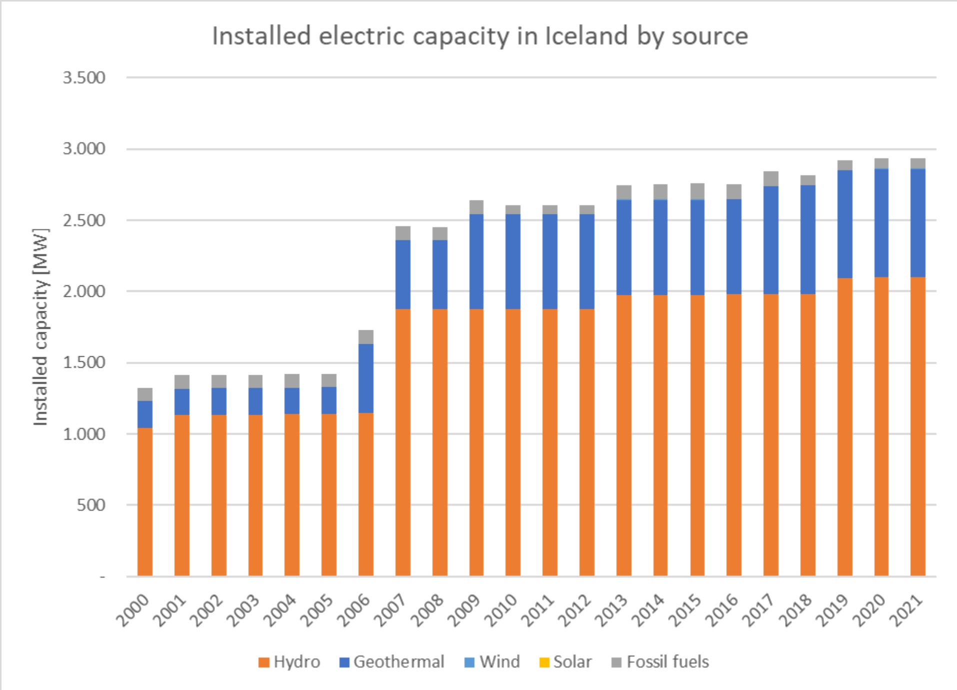


Figure 2.19 Installed electric capacity by source in Iceland.

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 causes air pollution by increasing the natural H_2S emission from the fields. Geothermal power plants associated steam stack exhaust and transmission pipelines for geothermal water create visual impacts in the environment. Noise is associated with boreholes, power generation and water pumps, and pumping water underground at geothermal power plants can lead to earthquakes.

2.6.4 Industry

The production structure of Iceland's manufacturing sector is unique among industrialised countries in many respects. First, the manufacturing sector is dominated by two sub-sectors, food processing and aluminium production, which together account for roughly ¾ of total manufacturing. Second, production of machinery and other investment goods is relatively limited. Food production is directed partly at the domestic market, but a larger share, or 62% (in 2015), focuses on seafood production for export. Other less important sub-sectors are machinery equipment production (12%), building materials production (3%), and pharmaceuticals/chemical products (3%).

2.6.5 Tourism

Tourism has increased rapidly in Iceland in recent years. In 2021 the total number of foreign overnight visitors to Iceland was just under 700 thousand as the impacts of the Covid-19 pandemic decreased somewhat. This was a 44% increase from 2020, when foreign visitors numbered just under half million. In 2019 the total number of foreign visitors was around 2 million.[12]

Around 688,000 tourists came on flights through Keflavík International Airport in 2021, or 98.5% of the total number of visitors. Around 10,000 came with the ferry Norræna through Seyðisfjörður, or around 1.5% of the total. Around 100 came on flights through Reykjavík Airport or Akureyri Airport. It must be assumed that there are variations in counts at Keflavik International Airport, as they cover all departures, including foreign national´s resident in Iceland. See Figure 2.20**.**

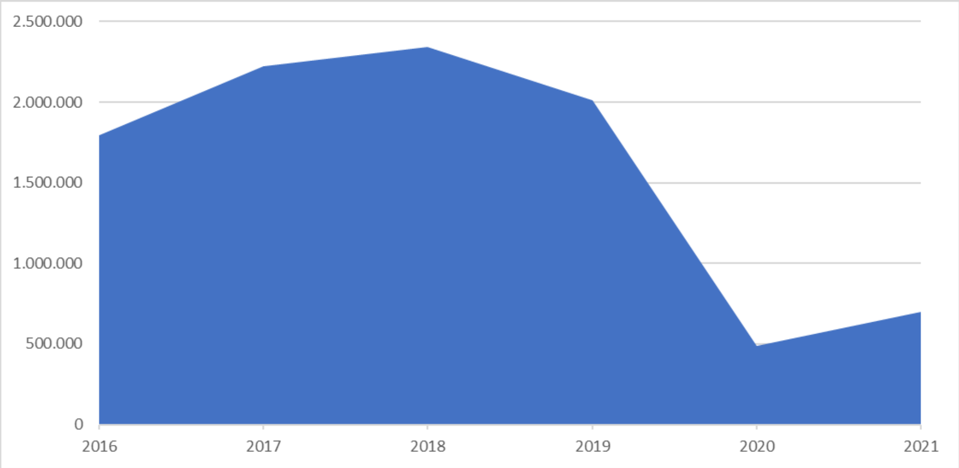


Figure 2.20 Foreign visitors' arrivals by air and sea to Iceland 2016-2021.

In 2020, roughly 12,600 persons were employed in tourism in Iceland. This was a decrease by nearly half compared with 2019 which is the lowest recorded employment figure in tourism since 2013. The number of persons employed in tourism increased by roughly 109% during the period 2012-2018, or by about 13% per year, on average.

In 2020, roughly 5,5% of total working hours are estimated to have been directly related to the production of goods and services for tourism final consumption while tourism direct contribution to GDP is estimated at 3,9%. For comparison, these estimates were, on average, roughly 10.4% for the period 2018-2019.[13]

[12] https://www.ferdamalastofa.is/en/recearch-and-statistics/numbers-of-foreign-visitors

[13] https://statice.is/publications/news-archive/national-accounts/employment-in-tourism-2009-2020/

Figure 2.21 Export of goods and services 2013-2022. [14]

2.6.6 Transport

The domestic transportation network consists of roads and air transportation. Public transportation is mainly in the capital area and few of the bigger towns. Public transportation outside the main urban areas is primitive and has been difficult to operate, due to thin population and widespread private car ownership. In 2016, Iceland had 717 registered vehicles per 1,000 inhabitants, in 2021 this number was up to 750 registered vehicles per 1,000 inhabitants, a total of 329.000 vehicles. Most vehicles still run on gasoline, but the number of vehicles using other types of energy is on the rise. See Figure 2.22.

National roads totalled 12,900 km in 2017, of which 4,920 km are classified as major roads.

[14] https://www.statice.is/statistics/economy/external-trade/trade-in-good-and-services/

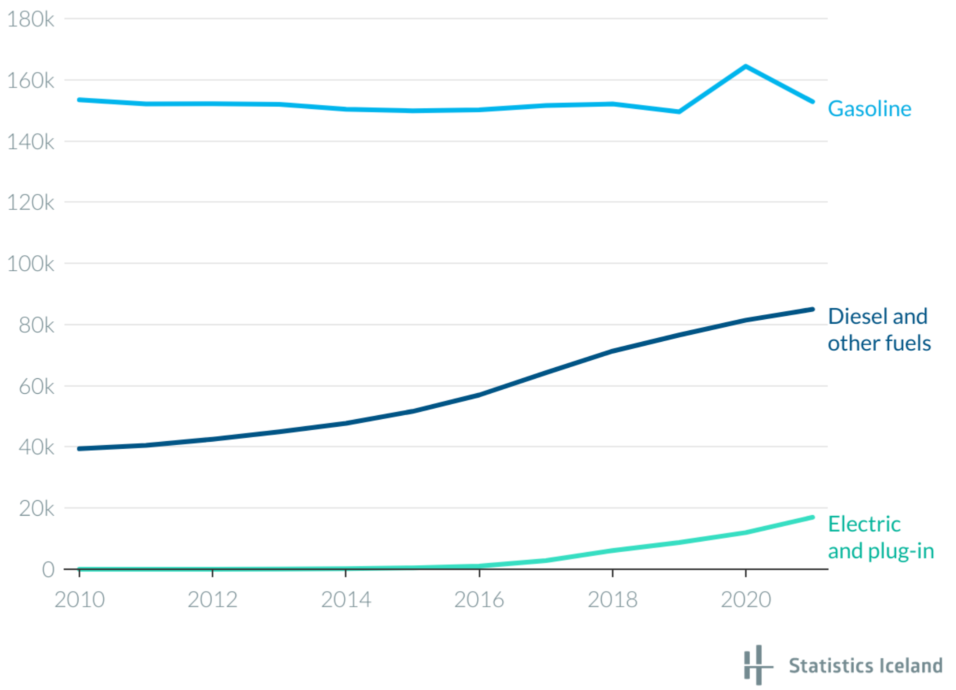


Figure 2.22 Household vehicle ownership by type of energy.

2.6.7 Aviation

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.

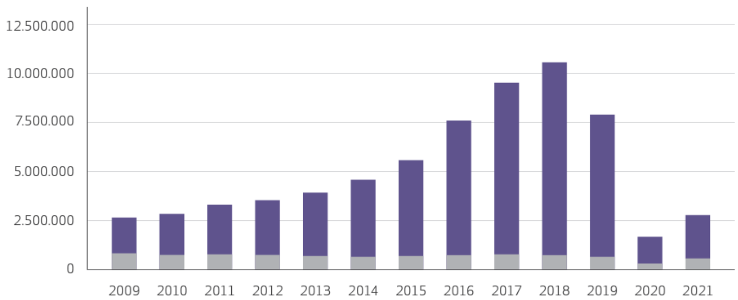


Figure 2.23 International passengers in Icelandic airports with scheduled services 2009-2021

Source: Isavia

In 2021 the total number of international passenger movements through Isavia airports numbered just over 2.7 million in 2021, which is a 60.9% increase from 2020. The number of international passengers using

Icelandic scheduled flight airports increased from just under 1.4 million to just under 2.2 million, i.e. a decrease of some 57.9% between years. There was an increase at most Icelandic airports, i.e. 12.3% in Egilsstaðir Airport, 58.1% at Keflavík Airport, around 98.5% at Reykjavík Airport but a decrease of 21% at Akureyri Airport. In 2016, the total number of international passengers was 6.7 million of which 2.2 million were transit passengers. 99.3% passed through Keflavik International Airport in 2016.

Just over 98,000 aircrafts passed through Icelandic airspace in 2021, an increase of around 30% from 2020. A total of over 131 million kilometres were flown in the Icelandic air traffic control area, or more than 27% more than the previous year. Just over a third of all air traffic over the North Atlantic crosses the Icelandic air traffic control area.[15] By comparison 165.640 aircrafts entered the Reykjavík Oceanic Control Area in 2016.[16]

Iceland has numerous harbours 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.

2.6.8 Construction

In the late 1970s the number of completed residential flats and houses in Iceland lay above 2000 annually. The number decreased steadily until 2001 when construction expanded rapidly with a peak in 2007 with 3300 houses and flats completed. This expansion coincided with major building projects, the Kárahnjúkar hydropower plant and dam and the Alcoa aluminium smelter in eastern Iceland. After the economic crises, the numbers of residential buildings completed each year dropped dramatically, with a rise again in 2012-2019. See figure 2.24.

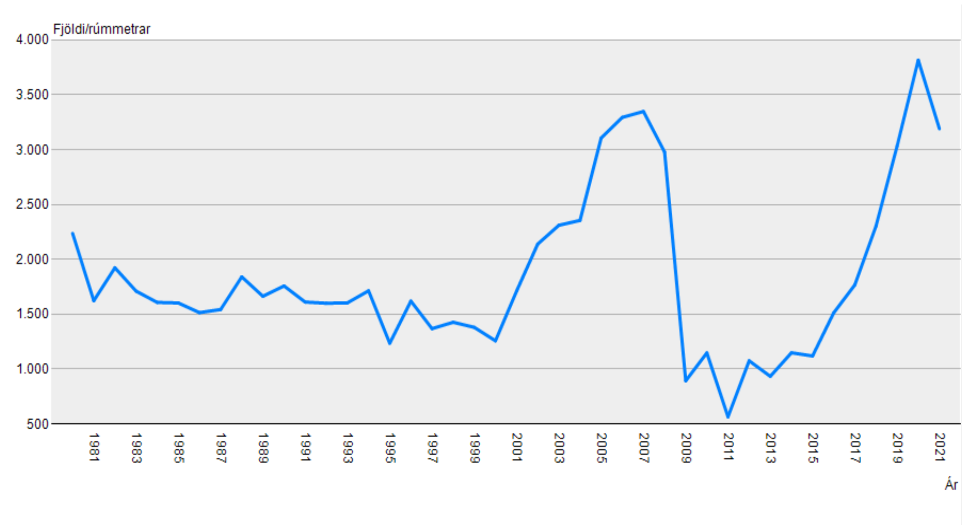


Figure 2.24 Completed Residential buildings in Iceland 1980-2021.

In 2022, the emission from Icelandic buildings was estimated for the first time: base year emission was 360.000 tons CO2eq. The largest sources of emissions are building materials, especially cement, (45%) and energy usage (30%). 74 measures have been defined that will be implemented in a public-private

[15] http://www.isavia.is/media/1/flugtolur2016finalenska.pdf

[16] www.isavia.is/media/1/flugtolur2016finalenska.pdf

cooperation in 2022-2030. The goal is to reduce emission from Icelandic buildings by 43% before 2030. The emission, the goal and the measures will be reviewed before end of year 2024.

2.6.9 Agriculture, land management and forestry

Approximately 6% of the total land area of Iceland is suitable for agriculture. A higher percentage is usable for grazing livestock but 25% of the country lies beneath 200 m above sea level. 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 significantly, especially for fodder, but is still heavily dependent on favourable summers. There is also a lot more variety in horticultural crops. Vegetables and flowers are mainly cultivated in greenhouses heated with geothermal water and lit with electricity in winter.

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 during the 1990s from an average of around 1 million seedlings annually in the 1980s to 4 million in the 1990s. Planting reached a high of about 6 million seedlings per year during 2007 – 2009 but was reduced after the financial crisis to about 3.5 million seedlings in 2012. 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 privately-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 is 1840 km2 covering 1.8% of the surface of Iceland. Native birch forest and woodland cover 1460 km2 and cultivated forest cover 380 km2.

The Soil Conservation Service of Iceland, an agency under the Ministry of Food, Agriculture and Fisheries, was founded in 1907. The main tasks of the agency are 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 around 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 decertified after over-exploitation and the speed of erosion is often magnified in certain areas by volcanic activity and harsh weather conditions.

Land reclamation activities focused in the beginning on areas in south and southwest Iceland where problems of drifting sand were most evident in threatening farms and fishing villages. After World War II the reclamation effort was spread more widely but still with a focus on south Iceland. With increased resources after 1974 reclamation activity was extended to many inland locations that were prime sources of sand along major rivers or near outlets of rivers. With detailed information acquired from mapping of erosion severity, recent reclamation activity has become wider spread, more selective and targeted.

2.6.10 Waste

Waste management in Iceland has undergone impressive changes in the 21st century with increased separate collection of waste for recovery purposes. There was a steady increase of the total amounts of waste up to 2008 when there was a peak and then a fast decrease following the economic crisis. The total waste per capita reached 2008 levels again around 2013. It reached a peak in 2016 but has been decreasing ever since. From the year 1995, the amount of waste destined for landfill or other final disposal has decreased by more than 70% while there has been a fast increase in the amount of waste for recovery. Figure 2.25 and Figure 2.26 shows the development of the amounts of waste and the fate of the waste during this period.

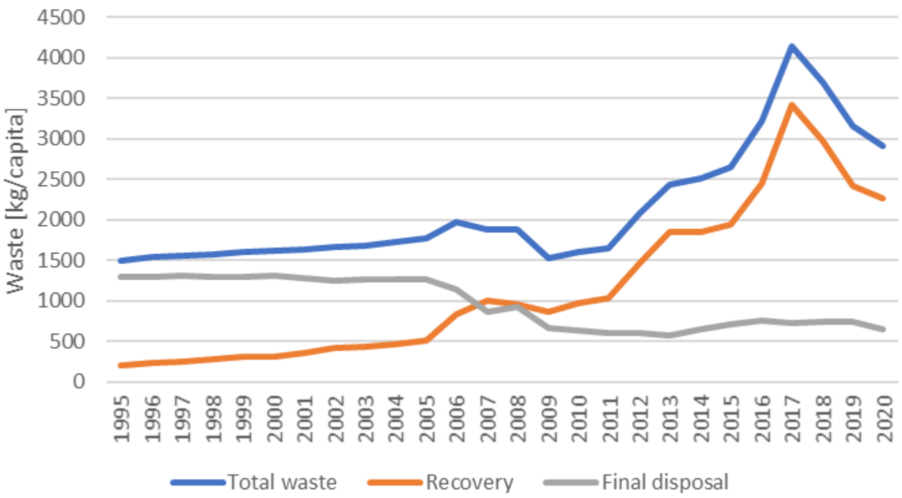


Figure 2.25 Changes in the amount of waste per capita in the years 1995 – 2020

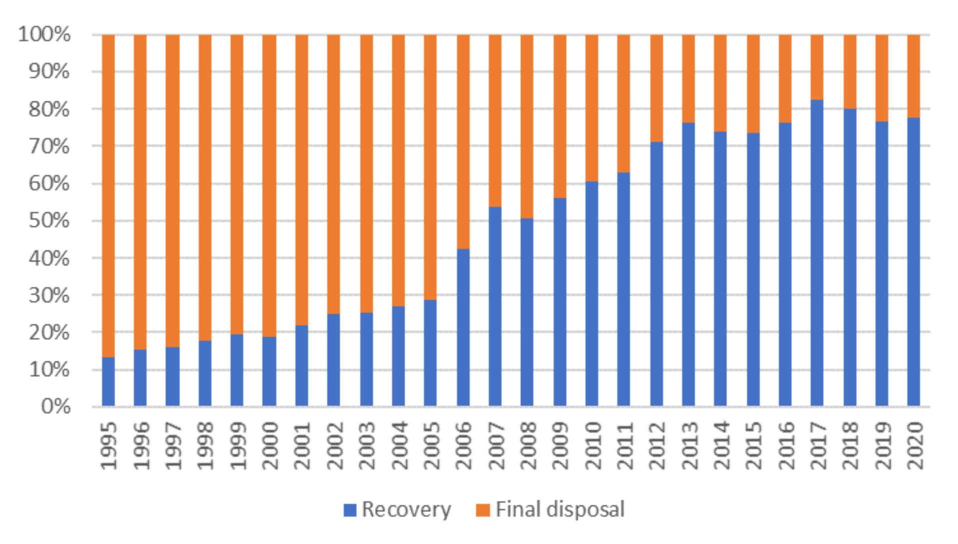


Figure 2.26 The development of the fate of waste in the years 1995 - 2020

Since 2002, there has also been great development in the composition of waste where mixed non-household waste has decreased very fast due to increased separation by the industry. More separation of waste has provided possibilities for increased waste recovery.

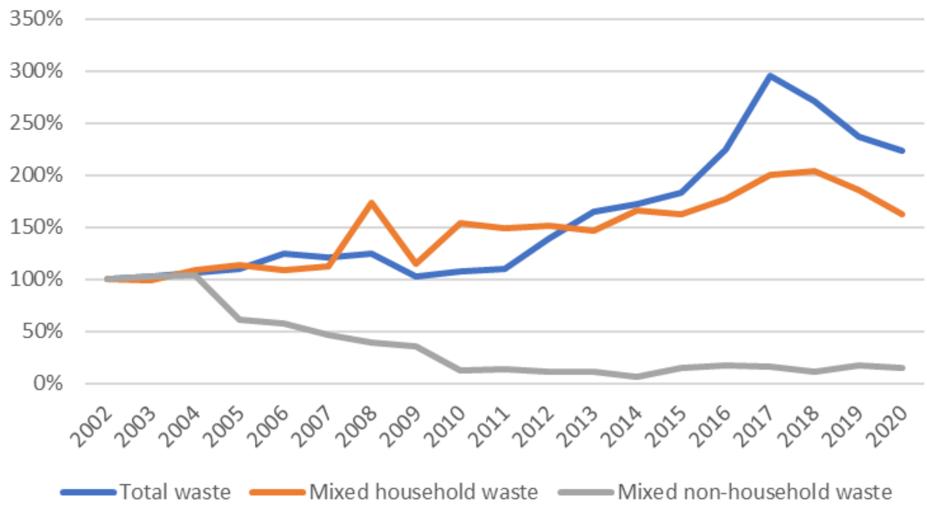


Figure 2.27 Proportional changes in the amount of waste per capita relative to 2002.

3. Impacts and adaptation measures

3.1 Climate variations

3.1.1 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, see Figure 3.1. This record shows that during the 19th century, temperatures were cooler than in the 20th century, and that the magnitude of inter-annual variations in temperature were larger. In the 1920s, there was a period of rapid warming, as also 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 years of Great Salinity Anomaly in the late 1960s, when sea ice was prevalent during late winter along the north coast. Conditions were rather cool in the 1970s with 1979 being the coldest year of the 20th century in Iceland. Since the 1980s, Iceland has experienced considerable warming, and in first decade of the 21st century, temperatures reached values comparable to those observed in the 1930s. The warmest year in the series was 2016. While there are pronounced inter-decadal temperature swings in Iceland, the long-term warming rate is similar to the global average, suggesting that the rapid warming in the period 1979 to 2021 is a combination of local variability and large-scale background warming. This remains true both for the annual average and individual seasons.

Figure 3.1 Mean annual temperature in Stykkishólmur 1798–2021.

Figure 3.1 illustrates the mean annual temperature in Stykkishólmur 1798–2021. Prior to 1850, the data are a composite of measurements from several stations and thus less reliable than the post-1850 data. The top panel shows the summer season (JJA), the bottom panel the extended winter season (NDJFM) and the middle panel the annual average. 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, has insufficient coverage in the Icelandic highland where precipitation tends to be greater than in lowland areas. Recently, an estimate for precipitation in all of Iceland during the last decades of the 20th century has been derived using high-resolution atmospheric reanalysis. The results show significant decadal variations in precipitation, and a tendency for higher amounts of precipitation during warmer decades. The long-term station records indicate that precipitation tends to increase by 4% to 8% for each degree of warming. Furthermore, several new studies suggest an increase in precipitation intensity during the warming of recent decades.

3.1.2 Climate projections

Based on the results of climate models, the currently observed warming is expected to continue. The warming rates differ between emission scenarios and between models. An analysis of the CMIP6 SPSS scenarios for many models showed that over the 21st century the warming is likely to be 1–4 °C on average see Figure 3.2 and increase in precipitation to be 2–5%. The uncertainty range is quite large, for temperature the span between the 5th and 95th percentile ranges was around 4 °C but for precipitation 20–25%.

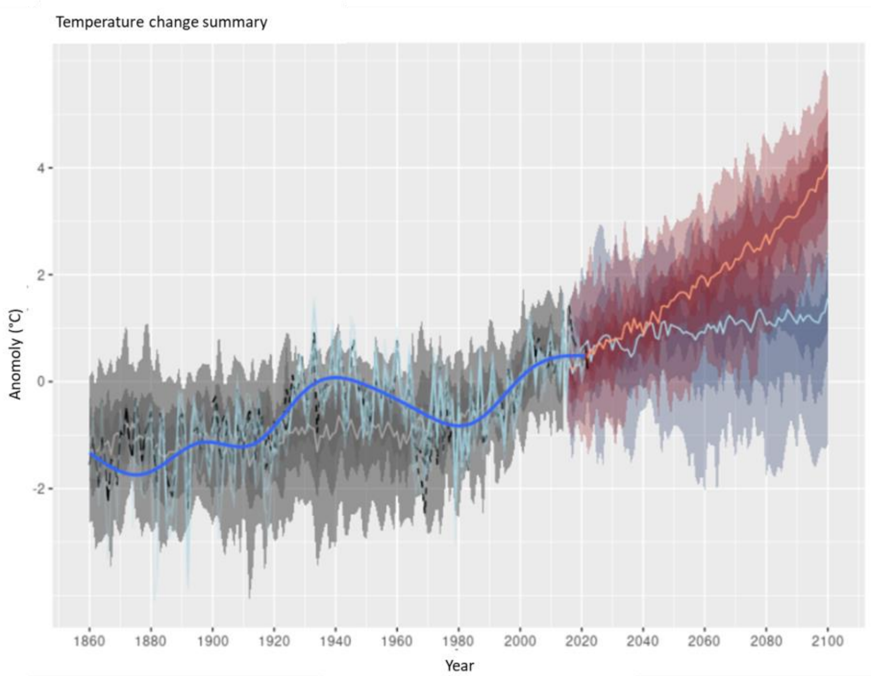


Figure 3.2 Warming in Iceland and surrounding areas.

Figure 3.2 illustrates warming in Iceland and surrounding areas. Estimated warming in a region covering Iceland and neighboring oceanic areas in the 21st century. According to the CMIP6 models for two different scenarios SSP1_2.6 (blue) and SSP5_8.5 (red). Thick lines indicate ensemble averages for the scenarios. Also shown in grey is the results of the 20th century CMIP6 experiments. Light blue and dashed lines indicate observations during the 20th century.

3.2 Variations in ocean currents

The climate of Europe and the northern North Atlantic is much milder than at comparable latitudes in Asia and North America. This is due to heat transport from the south with air and water masses. A key process in this respect is the so-called Atlantic Meridional Overturning Circulation (AMOC) in the North Atlantic. This circulation is due to sinking of ocean water, because of cooling of surface waters and ice formation at high latitudes. After sinking, this water is called deep water and it subsequently flows at depth to southern latitudes. In the northern North Atlantic, huge amounts of deep water are formed, e.g., in the Arctic Ocean, the Greenland 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, as well as through the Faroe–Shetland Channel.

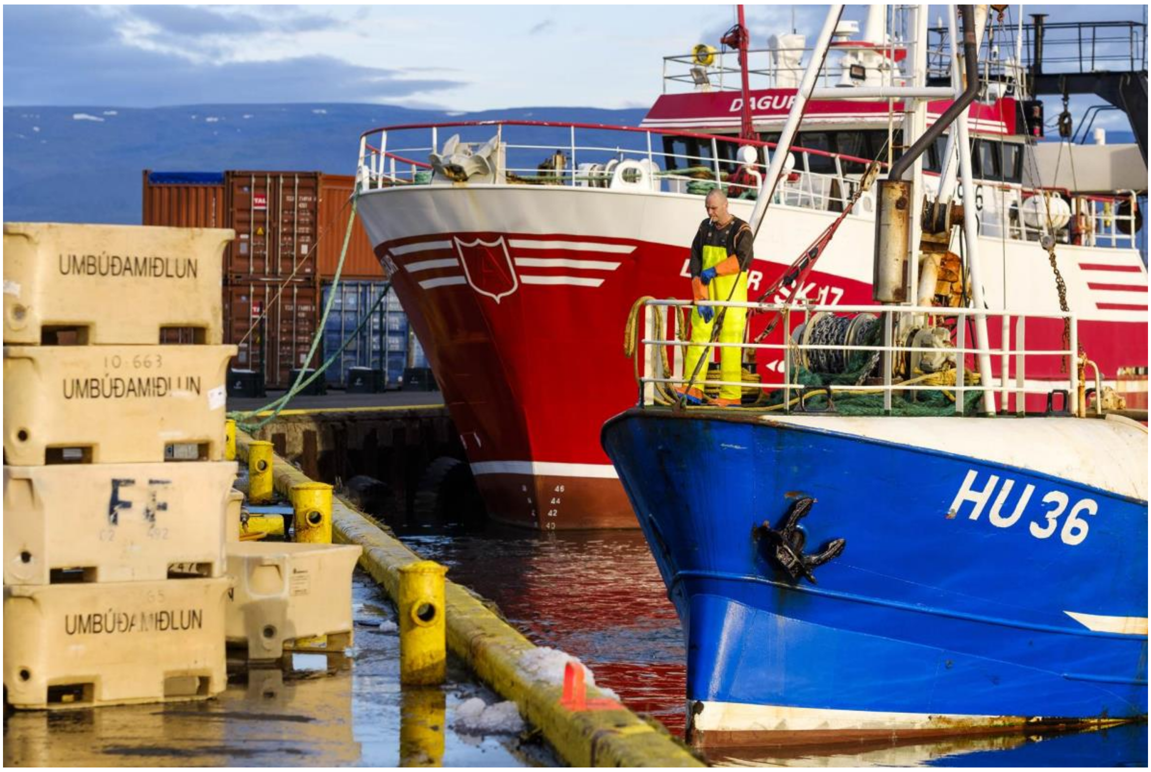
Many numerical models predict that the production of deep water will be reduced because of increasing greenhouse gases in the atmosphere. This happens when more fresh water is introduced to the Nordic Seas because of melting of glaciers, thawing of permafrost and increased precipitation that makes the surface layers fresher and therefore reduce the intensity of vertical convection. This in turn leads to reduced deep-water flow over the Greenland–Scotland Ridge and a compensating reduction of flow of warm surface waters into the Nordic Seas, thus inducing a lowering of the temperature in the area. Ice-core data from the Greenland Ice Sheet indicate that this can happen rather quickly or within decades. Research projects measuring changes in the fluxes over the Greenland-Scotland Ridge have succeeded in deriving a time series of the northward flux of Atlantic water and the southward flux of deep water as well as the associated heat fluxes. The time series now available have revealed that the flow of deep water across the Greenland-Scotland Ridge has been quite stable. The observations have shown that after the mid-1990s the flux of Atlantic water and the associated heat flux across the Greenland-Scotland Ridge increased. The increase has been attributed to both increased flow and increased temperature of the inflowing Atlantic water. In the sixth assessment report of IPCC (2021) it was concluded that there is medium confidence that the Atlantic Meridional Overturning Circulation (AMOC) will not experience an abrupt collapse before 2100, if it were to occur, it would very likely cause abrupt shifts in regional weather patterns and water cycle. While there is low confidence in 20th century AMOC change, it is very likely that AMOC will decline over the 21st century. The possible slowdown of the AMOC may reduce the rate of temperature rise near Iceland but is not likely to lead to lowering of the temperature.

3.3 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 of 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.

Since 1998 and until present temperature and salinity of the waters around Iceland have usually been above the long-term average. Similarly, over the last twenty years the salinity and temperature levels of Atlantic water south and west off Iceland have almost continuously been above the average. 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. Whether this indicates the beginning of a long-term period of increased presence of Atlantic water, resulting in higher temperatures and increased vertical mixing over the north Icelandic shelf is not possible to state at this stage.

Many parameters 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. However, observations by the Marine and Freshwater Research Institute indicate that changes in the marine ecosystem around Iceland during past two decades are likely to be related to the recent warming. The most marked ones and best registered are chances in abundance and distribution of many fish stocks.



To large extent the response of commercial fish stocks to a warming of the marine environment around Iceland has been similar to that which occurred during the warming between 1920s and 1960s. Thus, during recent warm period since 1996 marked changes have been observed in the distribution of many fish species. Southern commercial species have extended farther north (e.g. haddock, monkfish, mackerel, blue whiting, saithe), a northern species is retreating (capelin), rare species and vagrants have been observed more frequently (e.g. greater fork beard, blue antimora, snake pipefish, sea lamprey, Ray's bream, ocean sunfish), and 34 species, from both shelf and oceanic waters, have been recorded for the first time since 1996. Recent analysis of trends in annual groundfish surveys have observed a general shift to the northeast for majority of species observed. The magnitude of these changes will, however, be no less dependent on the success of future fisheries management aiming at long term sustainable level for all commercial species.

The Marine and Freshwater 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 time series from quarterly observations, since 1983, of ocean carbon dioxide at two sites near Iceland which differ significantly in oceanographic characteristics. The time series are invaluable for assessing long term trends and rates of change. They reveal rapid ocean acidification in the Iceland Sea at 68° N. The surface pH there 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 and 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 calcium carbonate saturation horizon which lies at about 1700 m is shoaling which results in large areas of sea floor becoming exposed to undersaturated waters with respect to aragonite (calcium carbonate). At shallower depths the sea water saturation state is falling with unknown consequences for benthic calcifying organisms.

The biological effects and ecosystem consequences of the carbonate chemistry changes are of concern and are being studied. Thus, it is hoped gain increased knowledge and to further understand the potential risk of ocean acidification in Icelandic waters.

3.4 Impacts on glaciers

Glaciers are a distinctive feature of Iceland, covering about 10% of the total land area. The largest glacier is Vatnajökull ice cap in southeast Iceland with an area of 7,720 km2 in 2019. Climate changes are likely to have a substantial effect on glaciers and lead to major runoff changes. The changes in glacier runoff are already substantial and are expected to increase in the future, and they are one of the most important consequences of future climate changes in Iceland. The 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 current glacier areas, and 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, a large, south-flowing outlet glacier from Vatnajökull ice cap. Due to thinning and retreat of the glacier, the outlet of river Skeiðará moved west in 2009 and the river merged with another glacier river, Gígjukvísl. The outlet of Súla river at the western part of the terminus followed in 2016 and merged with Gígjukvísl also. Consequently, all glacier meltwater from Skeiðarárjökull now flows under the bridge over Gígjukvísl and little water flows in the river courses of Súla and Skeiðará. Skeiðará was previously crossed by the longest bridge in Iceland, over a kilometer long, which has now been dismantled. Glacier downwasting in Iceland and other glacier areas outside the polar regions is of international interest due to the contribution of glaciers and small ice caps to rising sea level. Glacier variations in Iceland are monitored by a voluntary network of lay people who visit ca. 40 glacier termini annually and measure the change in the terminus position. The monitoring shows that today, most non-surging glaciers in Iceland are retreating (Figure 3.3). Tens of named glaciers have disappeared entirely since 2000.

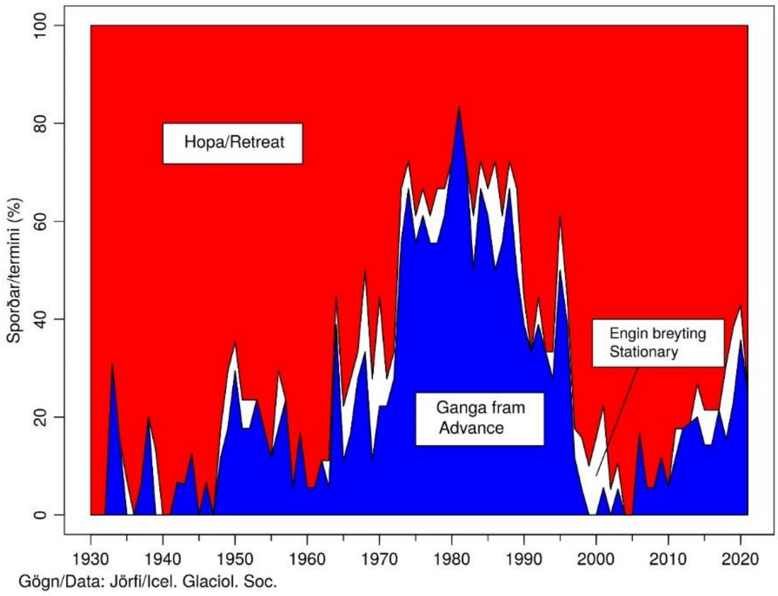


Figure 3.3 Annual proportion of monitored non-surging glacier termini.

Figure 3.3 shows the annual proportion of monitored non-surging Icelandic glacier termini that advanced or retreated in the period 1931 to 2021. The figure is based on data from 10–20 glaciers for most years. Source: The database of the Icelandic Glaciological Society.

Remote-sensing measurements of glacier topography from satellites and aircraft (optical stereo images and airborne lidar measurements) show significant thinning of the Icelandic glaciers during the 21st century. The glaciers are mapped regularly in order to monitor the currently on-going ice wastage. The Vatnajökull, Langjökull and Mýrdalsjökull ice caps were mapped using satellite images in late summer 2021 and Hofsjökull was mapped in 2020. The glacier maps and other available information about glacier mass balance and changes in glacier extent show that glaciers in Iceland lost ca. 550 gigatonnes of ice, 16% of their mass, between the end of the 19th century and 2021. Almost half of this ice melted after 1994/1995. Figure 3.4 shows the elevation change of Mýrdalsjökull in the period 2010 to 2021. The average lowering of the glacier surface is ca. 9 m over this period.

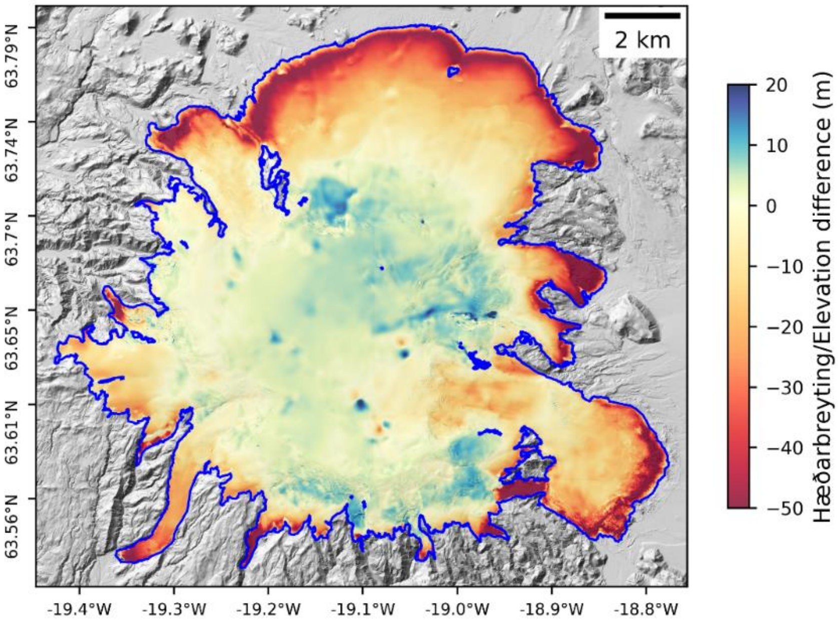


Figure 3.4 Elevation changes of Mýrdalsjökull ice cap.

Figure 3.4 Illustrates the Elevation changes of Mýrdalsjökull ice cap, based on aerial lidar measurements (2010) and Pléiades stereo images (2021). (Pléiades © CNES (2021), Distribution AIRBUS DS).

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 the central highland and SE-Iceland are now experiencing uplift (see Figure 3.5). The uplift does not, however, reach to the urban southwest part of Iceland, where subsidence occurs because of other geotectonic processes-. The uplift along the southeastern coast will counteract the impact of rising global sea level during the 21st century for this region of Iceland. The subsidence in southwestern part of Iceland will on the other hand exacerbate the impact of rising sea level in the North Atlantic Ocean around Iceland.

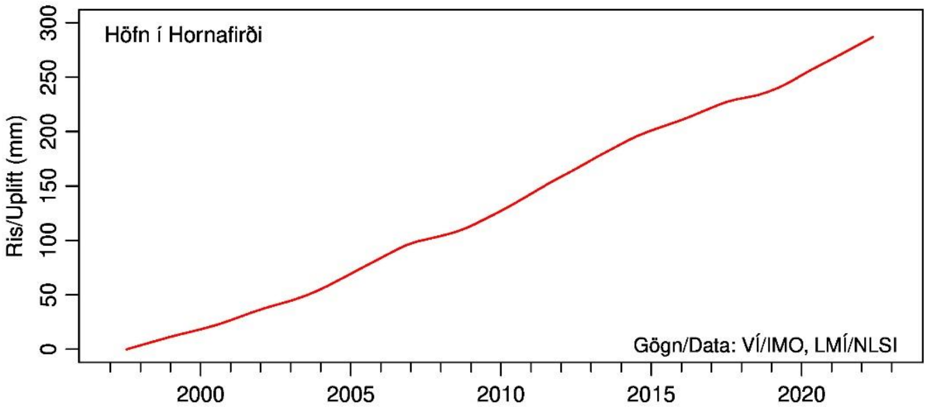


Figure 3.5 Crustal uplift measured by GPS at Höfn in Hornafjörður in SE-Iceland

Modelling of the Icelandic glaciers shows that glacier runoff will increase and that usable hydropower from the glacier rivers will increase by 20% until 2050. The current hydropower system can capture about half of this increase. The peak runoff is expected to occur in the latter part of the 21st century.

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 glacier 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 glacier areas in Iceland.

Studies on regional sea level rise reveal indicate that the sea-level rise in Iceland may be quite different from the global average. The main reason for this is that the melting of the Greenland ice sheet will affect the gravitational field around Greenland in a way that, with other things being equal, would lower sea level in the vicinity of Greenland. This effect can be calculated given assumptions about glacial melt, and its "fingerprint" mapped. When other changes, such as the thermal expansion of the oceans and the residual isostatic adjustment from the last glaciation are factored in, sea level in the vicinity of Greenland does actually rise, but less than the global average. Figure 3.6 shows results of such calculations (adapted from IPCC, 2013) for Iceland and the neighboring coastal ocean. The figure shows the sea-level rise around Iceland as a percentage of global sea-level rise for all four RCP scenarios examined by IPCC (2013) and includes sea-level rise due to thermal expansion, glacier melt, dynamical changes and the fingerprint of gravitational changes. Around much of the Icelandic coast the sea-level rise around Iceland is 30–40% of global average. Once vertical land motion is added it becomes clear that along the south coast of Iceland, the uplift is fast enough to out-pace the regional sea-level rise

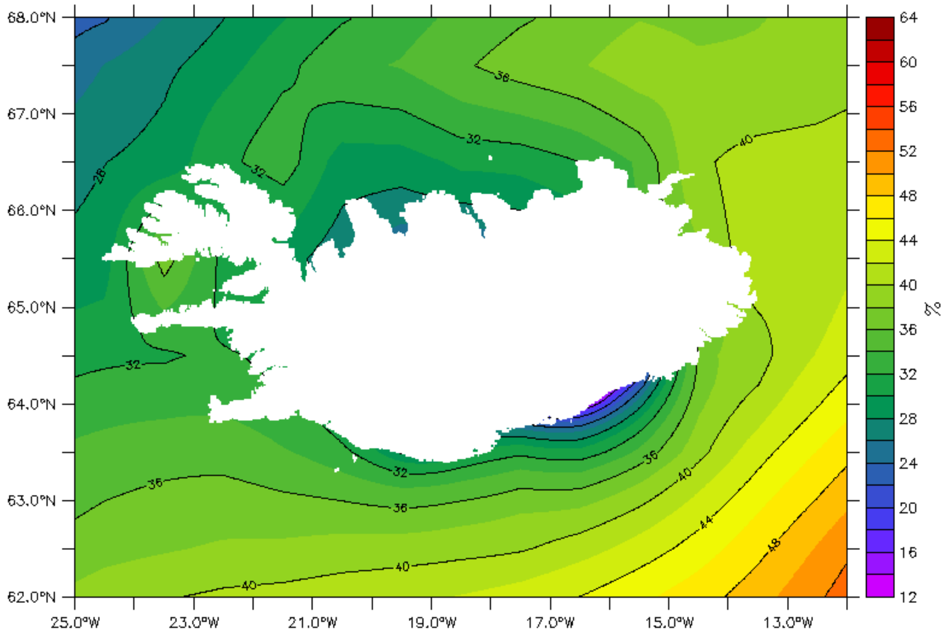


Figure 3.6 Sea level rise around Iceland by 2100.

Figure 3.6 illustrates the sea level rise around Iceland by 2100., as a fraction of the global averaged sea level change. Shown is the average fractional change for four different RCP scenarios spanning a significant range in warming during the 21st century. The effects included are sea-level change due to thermal expansion, ice melt and changes in the gravitational field due to melting of glaciers in Iceland and ice melt in Greenland. Adapted from IPCC, 2013.

Recent research using the CIMP6 projections has increased confidence in these counter-intuitive results and using model of sea level response it seems likely that the contributions from Arctic and Antarctic ice mass loss will close cancel in Iceland. This can be seen in Table 1 that shows projected sea level rise in Reykjavik under 4 different SSPs scenarios.

Table 1 Sea level rise in Reykjavik in 2100 split into contributions from different sources (median, 17th and 83rd percentile). Source[17181920]

	SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP5-8.5 *Low Confidence*
Stero- dynamic Sea Level	0.29 (0.20, 0.38)	0.34 (0.23, 0.46)	0.44 (0.30, 0.59)	0.44 (0.30, 0.59)
Glaciers	-0.05 (-0.10, -0.00)	-0.06 (-0.11, -0.01)	-0.07 (-0.12, -0.02)	-0.09 (-0.14, -0.02)
Greenland	-0.14 (-0.23, -0.07)	-0.20 (-0.28, -0.12)	-0.22 (-0.31, -0.15)	-0.31 (-1.02, -0.15)
Antarctica	0.13 (0.03, 0.34)	0.13 (0.03, 0.36)	0.13 (0.04, 0.40)	0.22 (0.03, 0.65)
Land Water Storage	0.03 (0.02, 0.04)	0.03 (0.02, 0.05)	0.03 (0.01, 0.04)	0.03 (0.01, 0.04)
Vertical Land Motion	0.01 (-0.03, 0.04)	0.01 (-0.03, 0.04)	0.01 (-0.03, 0.04)	0.01 (-0.03, 0.04)
Total (2100)	*0.26 (0.07, 0.52)*	*0.26 (0.05, 0.55)*	*0.32 (0.08, 0.65)*	*0.36 (-0.40, 0.84)*

3.5 Impacts on agriculture, land management and forestry

This chapter has been reviewed by experts from the Icelandic forest service and the soil conservation service of Iceland.

[17] Jet Propulsion Laboratory Sea Level Projection Tool

[18] Fox-Kemper, B., H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, A. B. A. Slangen, Y. Yu, 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In press.

[19] Garner, G. G., R. E. Kopp, T. Hermans, A. B. A. Slangen, G. Koubbe, M. Turilli, S. Jha, T. L. Edwards, A. Levermann, S. Nowikci, M. D. Palmer, C. Smith, in prep. Framework for Assessing Changes To Sea-level (FACTS). Geoscientific Model Development.

[20] Garner, G. G., T. Hermans, R. E. Kopp, A. B. A. Slangen, T. L. Edwards, A. Levermann, S. Nowikci, M. D. Palmer, C. Smith, B. Fox-Kemper, H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, Y. Yu, L. Hua, T. Palmer, B. Pearson, 2021. IPCC AR6 Sea-Level Rise Projections. Version 20210809. PO.DAAC, CA, USA. Dataset accessed at https://podaac.jpl.nasa.gov/announcements/2021-08-09-Sea-level-projections-from-the-IPCC-6th-Assessment-Report.

Approximately 60% of the total land area of Iceland is currently used for grazing and or fodder production and the raising of livestock[21]. 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 recent years and they are now becoming one of the staples. In addition to this there is considerable cultivation of vegetables and flowers in greenhouses heated with geothermal water and lit with electricity in winter.

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 increased considerably during the 1990s from an average of around 1 million seedlings annually in the 1980s to 4 million in the 1990s. Planting reached a high of about 6 million seedlings per year during 2007 – 2009 but was reduced after the financial crisis to about 3 million seedlings during 2010-2017. Around

[21] https://grolind.is/wp-content/uploads/2020/06/Kortlagning-beitilanda-2020.pdf

1100-1900 ha was afforested annually in the period of 1990-2007 but decreased to 500-800 ha in 2010-2017. Planting of native birch has been increasing proportionate to the total afforestation, comprising 27% of seedlings planted in the period 1990-2013 and over 30% since 2018. From its limited beginnings in 1970, state supported afforestation on farms and privately-owned land became the main channel for afforestation activity in Iceland, comprising about 80% of the afforestation effort in 2017. Since then, other projects have increased proportionately more, especially state supported planting on eroded land, mostly with native birch, and planting financed by the private sector, often specifically for CO_2 sequestration. Annual planting is again up to 6 million seedlings in 2022 and increasing. The total area of forest and other wooded land in 2017 was around 1945 km^2 covering 1.9% of the total surface of Iceland. Native birch forest and woodland cover around 1520 km^2 and cultivated forest cover around 425 km^2. That area is up to just over 2000 km^2 in 2022[22].

The Soil Conservation Service of Iceland, an agency under the Ministry of Food, Agriculture and Fisheries (BM) 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. Around 1900 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 often magnified in certain areas by volcanic activity and harsh weather conditions.

Land reclamation activities focused in the beginning on areas in south and south west Iceland where problems of drifting sand were most evident in threatening farms and fishing villages. After World War II the reclamation effort was spread more widely but still with a focus on south Iceland. With increased resources after 1974 reclamation activity was extended to many inland locations that were prime sources of sand along major rivers or near outlets of rivers. With detailed information acquired from mapping of erosion severity, recent reclamation activity has become wider spread, more selective and targeted. In 2021 the total extent of restored areas or areas undergoing restoration was estimated to be at least 3400 km^2.

3.6 Impacts on terrestrial ecosystems

Iceland‘s natural terrestrial ecosystems can be roughly divided into; heathland , wetlands, grasslands, woodlands, 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. However, new insect species that may have negative impact on the vegetation are also likely to establish[23]. All these changes will have effects on the function, structure and distribution of terrestrial ecosystems. Similar

[22] Þröstur Eysteinsson, Icelandic Forest Service, pers. com. (24.10.2022)

[23] Halldórsson, G., Sigurdsson, B.D., Hrafnkelsdóttir, B., Oddsdóttir, E.S., Eggertsson, Ó. & Ólafsson, E. 2013. New arthropod herbivores on trees and shrubs in Iceland and changes in pest dynamics: A review. Icelandic Agricultural Sciences, 26, 69-84.

changes are expected in Iceland[24] as in other parts of the high-boreal, sub-arctic and arctic areas, as described e.g. in the IPCC report from 2022. [25]

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 in 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. Indeed, it was recently shown (2011) that satellite-based vegetation index (NDVI) of the whole country during the period 1982-2010 has increased, especially after 2000. 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 do not 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.

The rate of successful introduction (intended and unintended) of arthropod species in Iceland has increased with warming climate and among them are several pest species on trees and shrubs. Higher temperatures have also led to changes in outbreak pattern and intensity of native pest species.[1]

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 could 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.

[24] https://www.vedur.is/media/loftslag/Skyrsla-loftslagsbreytingar-2018-Vefur-NY.pdf

[25] Pörtner, Hans-Otto, et al. "Climate change 2022: Impacts, adaptation and vulnerability." IPCC Sixth Assessment Report (2022).

Arctic Fox is the only native land mammal in Iceland. In a recent study it was shown that its growth and population size has varied with past climate fluctuations[26], that can be related to changes in its prey populations.[27] Four bird species have become extinct in Iceland since 1844 (one globally) but during the same period several 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.[28]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. Encroachment of shrubs and other tall vegetation due to warming temperatures as well as decreased grazing will influence habitat suitability of waders, of which many populations are of international importance.[29] It should also be noted that plans of extensive forestry in order to combat climate change pose a real threat to wader populations. [30] Breeding success of the Ptarmigan, an important game species in Iceland, has been shown to be closely related to precipitation and wind. [31]More extreme weather could therefore affect the species. There have been large-scale changes in many seabird colonies of e.g. puffins and guillemots in S- and W-Iceland in recent decades. This collapse has been linked to less abundance of their feedstock fish, such as sand eel, in the same region.[32] Oceanic temperatures have steadily risen off the S and W coast of Iceland during the past decades, but it is not fully understood how and if that has affected the population dynamics of the feedstock fish.

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. A new fish species, Flounder, has also colonized Icelandic freshwaters in S- and W-Iceland during the last decade and is currently increasing its distribution in N and E Iceland. Previously its northern limits were in the Faeroe Islands. How this will affect the river ecosystems is not known.

[26] Ester Rut Unnsteinsdóttir 2021. Íslenski melrakkinn - fyrsti hluti: stofnbreytingar, veiðar og verndun. Náttúrufræðingurinn, 91(3-4): 97-111.

[27] Pálsson, S., Hersteinsson, P., Unnsteinsdóttir, E.R. et al. Population limitation in a non-cyclic arctic fox population in a changing climate. Oecologia 180, 1147–1157 (2016). https://doi.org/10.1007/s00442-015-3536-7

[28] Náttúrufræðistofnun Íslands 2018c. Válisti fugla. https://www.ni.is/midlun/utgafa/valistar/
fuglar/valisti-fugla

[29] Tómas Grétar Gunnarsson 2020. Búsvæði og vernd íslenskra vaðfugla. Náttúrufræðingurinn 90 (2–3) bls. 145–162.

[30] Tómas Grétar Gunnarsson 2020. Búsvæði og vernd íslenskra vaðfugla. Náttúrufræðingurinn 90 (2–3) bls. 145–162.

[31] Ólafur K. Nielsen, Jenný Brynjarsdóttir og Kjartan Magnússon 2004. Vöktun rjúpnastofnsins 1999–2003. Fjölrit Náttúrufræðistofnunar, nr. 47 https://utgafa.ni.is/fjolrit/Fjolrit_47.pdf

[32] Freydís Vigfúsdóttir 2021. Sjófuglar. Í Guðmundur J. Óskarsson (ritstj.), Staða umhverfis og vistkerfa í hafinu við Ísland og horfur næstu áratuga. Haf- og vatnarannsóknir, HV 2021-14

3.7 Adaptation measures

National circumstances and institutional arrangements

Iceland is a large island located at the confluence of the North Atlantic and Arctic Oceans with a land area of some 103 thousand square kilometres, a coastline of 4,970 kilometres and a 200-nautical-mile exclusive economic zone extending over 758 thousand square kilometres in the surrounding waters. Iceland is prone to a multitude of hazards including extreme storms, floods, earthquakes, volcanic eruptions, landslides, and avalanches.

Climate change is contributing to shifts in the magnitude and scale of hazards, and the emergence of risks in areas where they were previously unknown.

The economy relies inter alia on fisheries and tourism and therefore potential impacts on these industries because of the climate change are of high importance.

The Ministry of the Environment, Energy, and Climate is responsible for the issue of climate change adaptation. The Icelandic Met Office operates the national knowledge centre for climate change adaptation (NKCCCA) supported by an Office for Climate Services and Adaptation, which is responsible for the coordination and communication of information related to the impacts of climate change. The centre also strives to generate knowledge and build tools for the municipalities to develop adaptation measures. One of its ongoing projects involves a pilot with 4 municipalities to create guidelines for adaptation planning at the municipal level.

Moreover, an Office for Natural Hazards at the Met Office oversees monitoring of many climate-related natural hazards and frequently in collaboration with the Icelandic Avalanche and Landslide Disaster Fund operated by the Ministry of the Environment, Energy, and Climate.

Many governmental research institutes also play a role in monitoring the impacts of climate change, such as the Marine and Freshwater Research Institute and the Icelandic Institute of Natural History. The Met Office convenes a Partnership for Knowledge Production on the Impacts of Climate Change and currently chairs its first executive committee with membership from other primary research institutions. The Icelandic scientific committee is currently working on Iceland's fourth scientific report on the impacts of climate change in Iceland, forthcoming in 2023. All of these actors and stakeholder are key to the designing of adaptation measures that are built on the best available science.

The Icelandic Climate Council is mandated to offer guidance on climate change adaptation and the council has both provided technical reports on the matter and exchanges with governmental officials on adaptation via council meetings.

Legal frameworks

In 2019, Iceland adopted new provisions to its 2012 Climate Change Act on the preparation of a plan on the adaptation of Icelandic society to climate change. As a first step towards this end, Iceland adopted its first National Adaptation Strategy (NAS) in 2021, following a white paper on climate change adaptation produced by an expert working group on the issue. The work was furthermore based on Iceland's reports on the impacts of climate change in Iceland and a discussion paper on adaptation by Iceland's Climate Council.

Iceland is currently working towards its first National Adaptation Plan with a steering group in place for the development of a proposal for fall 2023 on the governance and modalities of such a plan to the Minister of Environment, Energy and Climate. Currently, the steering group is advisory to a targeted stakeholder engagement process with expert workshops for the aggregation of risks and potential adaptation measures in different sectors of society based on the NAS.

Vulnerability analysis

The Icelandic scientific reports on climate change, published in 2000, 2008 and 2018, have offered a mapping of potential vulnerabilities because of impacts from climate change.

Avalanche risk assessments

The framework for the avalanche and landslide risk assessments is structured, through laws and regulations.

The Icelandic Avalanche and landslide Committee oversees the preparation of hazard assessments and decision-making regarding the construction of defensive structures in urban residential areas that are at risk from avalanches and landslides. These projects are partly funded by the Icelandic Avalanche and landslide fund. The fund is financed through tax on property in Iceland 0,3 ‰.

The Icelandic Avalanche and Landslide Committee operates under the authority of the Minister of Environment, Energy and Climate. The role of the Icelandic Avalanche and Landslide Committee according to act on protection against avalanches and landslides is:

- To discuss and take a position on local government proposals for the construction of defensive structures in dangerous areas.
- Taking a stand on proposals for the purchase or transfer of real estate or other valuables instead of building fortifications or using other defensive measures.

- To make proposals to the Minister of the Environment, Energy and Climate for financial support from the Avalanche and Landslide Fund for the projects mentioned above.

The municipal constructions discussed by the Icelandic Avalanche and Landslide Committee must be approved by the Icelandic Avalanche and Landslide Committee before they begin. Thus, municipalities cannot incur financial obligations before the Icelandic Avalanche and Landslide Committee's approval is available. The Icelandic Avalanche and Landslide Committee then prioritizes projects in consultation with the relevant municipality and the Icelandic Meteorological Office. After a comprehensive assessment was made of the vulnerability in urban areas and needs for avalanche protection in Iceland in 1997, the committee has been working according to that assessment.

Since the Icelandic Avalanche and Landslide Committee was established in 1996, avalanche and landslide protection, including the purchase of properties that will not be protected, have taken place in a total of 15 urban areas, and 6 of them have been completed. It is the government's policy that all avalanche and landslide prevention projects shall be completed by 2030.

Defensive structures can be financed up to 90% of the total cost by the Avalanche and Landslide fund, whereas the maintenance of the structures can be financed up to 60% of the total cost.

In addition to financing risk assessments and defensive structures in urban areas that are at risk of avalanche and landslides, the fund also finances research related to avalanche and landslides and other issues that are intended to enhance the risk assessment and adaptation measures.

Hazard- and risk assessments are conducted upon request by The Icelandic Meteorological Office. The Icelandic Institute of Natural History collects data on landslides and hazards caused by them in collaboration with the Icelandic Meteorological Office. A temporary authorization has been granted to pay the cost of risk assessment due to volcanic eruptions, water floods and sea floods, which are extremely urgent projects from the Icelandic Avalanche and Landslide fund.

The municipalities use the hazard and risk assessments for their land-use planning and contingency plans.

The Icelandic Meteorological Office also monitors the local risk of urban avalanches, as well as sending out general warnings for avalanches and issuing evacuations orders.

Avalanche is the only type of natural hazard where decision of evacuation is taken by the Icelandic Met Office. The decision is done in close collaboration with the local authorities. Decision making of evacuation of other types of natural hazard is taken by the National Commissioner of the Icelandic Police.

Intended adaptation efforts

Iceland is planning to introduce its first formal portfolio of adaptation measures alongside the establishment of its first National Adaptation Plan which is mandated by law and is currently being scoped through the expert stakeholder engagement process based on the 2021 National Adaptation Strategy.

Progress in implementation

Parallel to the long-term development of the National Adaptation Plan, the government has begun the planning and implementation of capacity building adaptation measures. A key element in Iceland's climate change adaptation policy world is the Office for Climate Services and Adaptation located at the Met Office. Moreover, the Government has specifically been engaging the municipalities and regions to facilitate the integration of the adaptation policy cycle on the municipal level. Currently, the Icelandic Regional

Development Institute is heading a project in collaboration with the Met Office and the National Planning Agency to pilot an approach to establish climate change adaptation within the municipal governance structure.

Monitoring and evaluation

Iceland foresees the development of an M&E system for adaptation as part of the development of the National Adaptation Plan. The current National Adaptation Strategy has as its goal that adaptation measures will be systematically monitored and evaluated based on a diverse set of criteria.

Cooperation, lessons learned

Iceland participates in Nordic cooperation focused on adaptation and plans to hold the 6th Nordic Conference on Climate Change Adaptation (NOCCA 6) in Reykjavik in the spring 2023.

Adaptation-related research

Climate change impacts on infrastructure 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. Rising sea level and consequent changes in ocean floods have also been taken into account in planning of harbour infrastructure and some coastal settlements by the Icelandic Road and Coastal Administration (IRCA), and its predecessor the Icelandic Maritime Administration (IMA), following recommendations from a 1992 report on expected sea-level rise. Some coastal communities have also in recent years carried out studies of the impacts of rising sea level on ocean floods hazard but so far, the results have not been formalized in as recommendations for explicit adaptation measures in the area plans for the respective communities.

4. Financial Assistance and transfer of technology

4.1 Iceland's International Development cooperation

International Development Cooperation is one of the key pillars of Iceland's foreign policy, with the main goal of contributing to the fight against poverty in the world's poorest countries and guided by the Sustainable Development Goals (SDGs).

For nearly four decades, Iceland's official development cooperation has placed focus on the sustainable utilization of natural resources, including fisheries and geothermal and other renewable energy sources. This has been grounded on Iceland's experience and expertise in utilizing its own resources for its social, economic and human development.

This legacy is maintained in Iceland's Policy for International Development Cooperation for 2019-2023 which identifies two priority areas: (1) enhancing social infrastructure and peace efforts and (2) the protection of the earth and sustainable use of natural resources. Under the second pillar, five areas are identified as priority areas; a) Increased use of geothermal energy and other renewable energy sources (pursuant to UN SDG no. 7). b) The protection and sustainable management of the oceans and waters (pursuant to SDG no. 14). c) Recovering land quality and limiting land degradation (pursuant to SDG no. 15). d) Increasing the resilience and adaptability of societies due to the impacts of climate change (pursuant to SDG no. 13). e) Sustainable economic growth and decent work opportunities for all (pursuant to SDG no. 8).

In line with best practices in development cooperation and OECD-DAC guidelines, Iceland's development cooperation in bilateral partner countries is based on close cooperation with local communities and their needs and is based on detailed needs assessment. The same preconditions apply to the activities of multilateral partners. However, it is worth noting that Iceland's first OECD-DAC Peer Review (2017) highlighted the need to further mainstreaming environmental activities across its development cooperation portfolio and strengthen the harmonization of climate change, business and development cooperation strategies within Iceland's Ministry for Foreign Affairs in accordance with the Kyoto Protocol. The Ministry for Foreign Affairs is developing an environment and climate change strategy, that will be supported by an action plan that will guide environmental mainstreaming in all development cooperation.

4.2 Methodology

Iceland endeavours to follow best practices in international development cooperation and important efforts to that end have been made in recent years. In 2012, Iceland began the process of implementing the OECD Development Assistance Committee (DAC) statistical reporting methods (Creditor Reporting System, CRS), including the usage of the Rio Markers as a methodology for tracking finance for adaptation, mitigation, desertification and biodiversity. While the Rio Markers have guidelines and technical eligibility criteria agreed within OECD-DAC, the process of assigning markers to projects and programs is subjective and can vary between institutions and the quantification of climate relevant contribution can equally vary between countries. Iceland currently reports all programs or projects as 100% climate relevant finance if it has been marked with either Rio-marker 1 ('Significant") or Rio-marker 2 ("Principal"). While core funding to multilateral institutions is not marked with Rio Markers or accounted for in the OECD DAC marker, Iceland puts forth these contributions in BR-CTF 7a. Contributions to multilateral agencies which main mandate is climate actions such as UNCCD, SEforALL and Green Climate Fund are included in this report.

With respect to core funding to multilateral institutions that don't have an explicit climate change mandate, although possible to retrieve information on climate relevant proportions of the projects they support from OECD-DAC, these contributions are not part of the information provided in the total climate related summary in this report. Apart from core funding, reporting on climate specific finance through multilateral institutions is identified based on an application of Rio markers in the same manner as bilateral climate-specific finance. Climate specific projects are those with climate change mitigation and climate change adaption markers, marked as having significant or principal objective in applicable category. Additional are cross– cutting projects which have more than one climate category with marked either significant or principal marker. All funds specified in this report have been disbursed.

4.3 Financing

The Icelandic Government is committed to reach the UN target of 0.7% of gross national income (GNI) dedicated to official development assistance (ODA). The conceivable objective is to raise the targets slowly and steadily, going from 0.21% in 2014, 0,28% in 2019 with a slight decrease 0,02% during 2020, ending the year at 0.26% despite a nominal increase of 300 million ISK. During 2022 the percentage of GNI is expected to reach the target of 0.35%.

The share of climate-specific projects of total official development aid (ODA) was 25% during 2019 and 20% during 2020.

More funds have been directed towards adaptation than to mitigation for both reporting years. All projects are reported in accordance with OECD DAC directives. For the year 2019, projects marked as with a significant or primary objective against adaptation were approximately 40% of Iceland's climate ODA or about 747 million ISK. Mitigation had approximately 29% of Iceland's climate ODA, or 546 million ISK as a significant or primary objective. Crosscutting had approximately 31% of Iceland's climate ODA or about 580 million ISK, with more than one marker as significant or primary objective.

There is no significant change in direction or trends between years, with a slight increase of projects dedicated towards adaptation and slight decrease in projects dedicated mitigation, and an increase in cross-cutting (in reference to table 1). A considerable funding decrease is between the years 2019 and 2020 (Table 2). This is explained by the completion of large climate projects during 2020, and not establishing new projects until 2021. One example of such project is the Geothermal Exploration Project which effectively ended in 2019. Iceland has an increased focus on earth and sustainable use of natural resources in the newly adopted international development cooperation policy and has drastically increased funds towards climate and environmental projects for 2021 and 2022.

The table below presents the division of Iceland's ODA contribution to climate´s categories divided; mitigation, adaptation, and cross-cutting environmental topics.

Table 2 Summary information climate categories

Type of support, division of total ODA	2019	2020
Adaptation	10%	8%
Mitigation	7%	4%
Cross – cutting	8%	8%

Type of support, division of climate ODA	2019	2020
Adaptation	40%	41%
Mitigation	29%	21%
cross – cutting	31%	38%

Table 2 provides a summary of both bilateral and multilateral projects with a marked focus on mitigation, adaptation and cross-cutting environmental issues.

Table 3 Summary information climate-specific projects (%)

	2019	2020
Total bilateral climate related funds	1.434.351.028	1.184.975.046
Total multilateral climate related funds	439.873.468	394.766.790
total climate ODA	1.874.224.496	1.579.741.836
Grand Total ODA	**7.530.368.125**	**7.838.014.734**
Total share of climate ODA of total ODA	25%	20%

Table 3 provides a summary from table 4 which enlist both bilateral and multilateral projects with a marked focus on mitigation, adaptation, and cross-cutting environmental issues. The following tables represent BR-VTF Tables 7a and 7b[33]. All detailed information is also found on the www.openaid.is website.

[33] See Iceland´s fifth biennial Reporting Common Tabular Format (BR CTF)

Table 4 Summary information climate-specific bilateral projects (ISK) categorized by type of support.

Mitigation	2019	2020
GRÓ training programs		
GRÓ Geothermal Training Program	251.000.002	130.615.750
GRÓ Land Restoration Training Program	141.449.999	105.000.000
Geothermal projects		
Expertise Geothermal Technical Advice – Fiji	1.820.286	
Expertise Geothermal Technical Advice – Kazakhstan	4.436.037	1.037.500
Technical Assistance Program in Geothermal Development - El Salvador	10.483.773	26.908.009
Geothermal Exploration Project in cooperation with the Nordic Development Fund (NDF)	38.872.862	38.260.338
Support to African Rift Geothermal Development Facility (ARGeo)	12.271.600	
Sustainable energy		
Energising Development, Mangochi District, Malawi	61.190.780	
ABC Children's Aid - Solar cells and batteries for ABC Burkina Faso		5.350.978
Total mitigation funds	**521.525.339**	**307.172.575**

Adaptation	2019	2020
WASH projects		
WASH Sierra Leone	167.587.707	119.627.000
Wash Liberia	25.134.000	12.468.600
Wash Uganda	94.920.000	
Wash Mozambique		99.097.327
Water and sanitation bilateral support – Uganda	61.830.414	47.395.152
Water and sanitation bilateral support – Malawi	84.823.466	85.818.057
Support to fisheries		
SDG Fund - Ocean Excellence - Sub-cooling technology for artisanal fisheries in Sierra Leone		1.000.000
Fund for collaborating with businesses - Marel - Improved quality of Vietnamese pangasius	2.839.400	
SDG Fund - Atmonia - Sustainable and Self-sufficient Production of Nitrogen Fertilizer in Cameroon		1.000.000
Buikwe, Uganda, school feeding program in response to COVID-19		58.839.000
SDG Fund - Aurora Seafood - Blue growth through new utilization of resources from the ocean		1.000.000
Technical assistance for the Lake Victoria Fisheries Management Improvement Project in Uganda	1.642.066	
Grants for participants from SIDS & W-Africa in the Rhodes Academy of Oceans Law and Policy study course on the law of the sea.	2.800.000	
Community Based Integrated Resiliency Program, Sierra Leone (BRIDGE)	26.086.396	15.373.785
Technical Assistance Program in Fisheries – Vietnam	8.116.703	932.017
Icelandic Consultancy work on seaweed aquaculture in the Philippines	3.973.403	
Icelandic consultancy work on aquaculture in Indonesia	4.133.470	
Expert advice to World Bank fisheries program for Albania		15.167.407
Operation of projects in regional cooperation - West Africa	26.583.073	21.642.420
GRÓ training programs[34]		
GRÓ Fisheries Training Program	222.000.001	166.221.000
Total adaptation funds	732.470.099	645.581.765

[34] GRÓ – International Centre for Capacity Development, Sustainable use of Natural Resources and Societal Change, that operates under the auspices of UNESCO.

Cross cutting	2019	2020
GRÓ training programs		
GRÓ Gender Equality Studies and Training Program	120.049.999	137.993.563
Gender and climate change		
Kebribeyah Climate Resilient Livelihood Project II		18.120.000
Community Resilience Project in Malawi	30.400.000	15.160.000
The Red Cross - Community Resilience Program II		35.710.000
Kebribeyjah Sustainable Livelihood Project, Ethiopia	27.157.334	13.578.667
Support for the participation of the National Rescue Representative in the international consultation with UNDAC / INSARAG	2.748.257	940.755
The Icelandic Red Cross and the International Federation of National Red Cross and Red Crescent Societies		10.717.721
Total Cross-cutting funds	**180.355.590**	**232.220.706**

Table 5 Summary information climate specific multilateral projects (ISK) categorized by type of support

Mitigation	2019	2020
SeForALL	25.168.000	25.809.600
Total mitigation funds	**25.168.000**	**25.809.600**

Adaptation	2019	2020
Least Developed Countries Fund	12.308.100	
DOALOS	3.000.000	6.000.000
Total adaptation funds	**15.310.119**	**6.002.020**

Cross cutting	2019	2020
World Bank		
Word Bank´s Blue Economy Programme (PROBLUE)	44.299.892	51.024.000
Energy Sector Management Assistance Program (ESMAP)	36.803.100	51.386.000
PROBLUE - Word Bank´s Blue Economy Program	48.688.800	
Energy Sector Management Assistance Program (ESMAP) - additional funding because of COVID-19		25.000.000
Donor Funded Staffing Program (DFSP), World Bank Group	117.933.050	8.272.588
AWEEF	18.685.500	
UNEP	521.928	428.634
FAO		
Food and Agricultural Organization of the United Nations (FAO) - PSMA Global international exchange system	20.507.806	-
The Food and Agricultural Organization (FAO)	9.441.589	13.005.197
WFP		
World Food Program (WFP) implementation of the School meal program in Mangochi, Malawi	42.523.614	41.291.420
World Food Program (WFP) framework agreement - core funding	49.976.555	49.977.731
UN Common agenda		2.567.600
UNCCD	508.015	
WEDO	9.505.500	
Multi-Partner Trust Fund (MPTF)		100.002.000
UNHCR		20.000.000
Total Cross-cutting funds	**399.395.349**	**362.955.170**

4.3.1 Provision of new and additional financial resources

Iceland is committed to assist developing countries in adapting to and mitigating the adverse effects of climate change and yet in 2020 Iceland did not increase 'new and additional' support, when compared to 2018.

There is no internationally agreed definition of what constitutes 'new and additional resources' under Article 4.3 of the UN Framework Convention on Climate Change. One definition, supported by several countries, is that 'new and additional financial resources' for climate-related activities should be additional to the international development aid goal of 0.7% of GNI.

Utilizing this definition and bearing in mind that Iceland's ODA reached its peak of 0,37% in 2008, Iceland would not be in the position to identify any new and additional financial resources for climate-related activities. As reported, Iceland had a slight decrease of 187 million ISK in climate funds from 2018 to 2020) and was therefore not able to report new and additional funding to the ODA portfolio. The new and additional funding is drawn from the growing aid program and has not diverted funds from existing development priorities or programs. To reiterate, Iceland looks at the decreasing ODA volumes in nominal terms in ISK from 2018 to 2020 to identify new and additional financial resources in climate-related activities, but not as a percentage of GNI. During the next phase of reporting, Iceland has increased the focus on climate and environment drastically, with considerable new and additional funding. This is Iceland's definition of new and additional financial resources in lack of international standard classification. There is a separate budget line in the State budget for environment and climate actions in international development cooperation. This budget line has been earmarked since 2012 and commenced with Iceland's Fast Start Finance commitments. Despite an earmarked budget line directed towards climate actions, climate projects can be found throughout the whole development budget, especially under the bilateral budget.

The environment and climate action portfolio is somewhat balanced between adaptation, mitigation and capacity building activities, and gives special attention to women's empowerment in the field of climate change and increasing access to renewable energy sources. The funding is channelled through multilateral agencies and trough bilateral work. Focus has been given to Iceland's longstanding bilateral partner countries, Malawi, and Uganda that are among the Least Developed Countries (LDCs).

4.3.2 Bilateral and regional financial contributions

There was a slight decrease to the bilateral development cooperation between 2019 and 2020; with a 11 % decrease. The decline in 2020 is marked by the Covid pandemic which clearly affected this work, especially towards technical assistance under geothermal and fisheries.

Iceland's bilateral work is with long-standing government partners in Malawi and Uganda. In both countries, the focus is mainly on collaboration at the district level where Iceland provides resources and technical assistance in support of district development plans, with the aim of strengthening basic service provision and institutional capacity. In accordance with OEDC DAC markers, Iceland classifies development support through international NGOs, to UN earmarked projects implemented by country offices and financial funding of the four United Nations University (UNU) Training Programs based in Iceland as bilateral work.

On the 1st of January 2020 the Programs became a part of GRÓ International Centre for Capacity Development, Sustainable use of Natural Resources and Societal Change, that operates under the auspices of UNESCO. Iceland emphasizes adaptation to climate changes in its climate-related bilateral work, which is integrated in its district development efforts in the partner countries, especially in education and water, sanitation and hygiene (WASH). Large adaptation projects in 2019 and 2020 include Iceland's support to WASH projects in Buikwe and Namayingo districts in Uganda and in Mangochi district in Malawi, providing rural communities with improved access to clean water and sanitation facilities. In collaboration with UNICEF, Iceland also supported a new initiative in Liberia and Sierra Leone on improving access to climate resilient WASH services in fishing communities to improve livelihoods and conditions, with around 270 million ISK over the reporting period. In 2019, Iceland started cooperation with UNICEF in Uganda on improving access to WASH in South-Sudanese refugee hosting districts in the country through a humanitarian-development nexus approach. Finally, a geothermal exploration project in the East African Rift Valley aims to build capacity and expertise in the field of geothermal utilization.

Most of Iceland's bilateral environmental contributions are channelled through the GRÓ Centre (before 2020 UN University training programs) based in Iceland. The GRÓ Training Programs provide support to climate change adaptation and mitigation in LDCs, gender mainstreaming, capacity building through the four programs: GRÓ Geothermal Training Program, the GRÓ Fisheries Training Program, the GRÓ Land Restoration Training Program, and the GRÓ Gender Equality Studies and Training Program.

Regarding environmental contributions to multilateral agencies, Iceland is a founding member of SEforALL, the only donor to African Women Energy Entrepreneurs Framework (AWEEF) which is hosted under UNEP and contributes to UNFCCD under UNFCCC. Of high importance to Iceland is the increased focus on energy and fisheries by the World Bank where Iceland supports projects such as Global Program on Fisheries (PROFISH) and the Energy Sector Management Assistance Program (ESMAP). It should be noted that Iceland is not a member of the Global Environment Facility (GEF) and has therefore not made any financial contributions to the organization.

4.4 Knowledge Transfer Through Capacity Building

Iceland contributes to strengthened capacity building in developing countries to enhance mitigation and adaptation efforts. Iceland has committed resources that are creating enabling environments for private sector investment, strengthening national and regional institutional and regulatory frameworks, and assisting developing countries to take practical actions to cut emissions. Recognizing that climate change disproportionally affects developing countries and aligned with Iceland's emphasis on LDCs in its development cooperation strategy, the Government of Iceland focuses its technology transfer and capacity building in low-income countries.

Financial resources and transfer of technology for the purposes of adaptation and mitigation of climate change have in recent years been channelled mainly through the public sector and not through the private sector. However, Iceland recognizes the role that the private sector can play in achieving the SDGs and is taking decisive steps for improvement in this area, including in its development cooperation strategy. Iceland is well-known for its technical expertise and multi-stakeholder partnerships, particularly in geothermal energy, and will build on this comparative advantage when engaging further with the private sector, especially in climate-related activities. Iceland's support to technology transfer in relation to the implementation of the SDGs includes a broad spectrum of activities. These activities comprise transfer of both hard and soft technologies. The extent of this technology transfer is significant and cannot be clearly separated from other activities in Iceland's international development cooperation, including financial flows. In fact, many development projects funded by Iceland include both technology transfer and capacity building components. Since they form an integral part of a project, it is not possible to accurately account for them separately.

Iceland's measures related to the promotion, facilitation and financing of the transfer of, or access to, environmentally-sound technologies, have a focus on renewable energy. The sustainable utilization of natural resources is a priority area in Iceland's development cooperation, where Icelandic technical expertise, extensive knowledge and experience of utilization of geothermal energy contributes to the SDGs. The GRÓ Geothermal Training Program (GRÓ GTP) has for many years played an important role in that regard.

Iceland has a longstanding commitment to GRÓ Centre for Capacity Development, Sustainability and Societal Change, that operates under the auspices of UNESCO and that runs four training programs based in Iceland. The Programs were until 2020 operated as UNU Programs (United Nations University): The GRÓ Geothermal Training Program since 1979, the GRÓ Fisheries Training Program, since 1997, the GRÓ Land Restoration Training Program, since 2007, and the GRÓ Gender Equality Studies and Training Program, since 2009.

The four GRÓ programs have a strong relevance when it comes to adapting to and mitigating climate change. The Geothermal Training Program is aimed at increasing the sustainable use of geothermal energy, the Land Restoration Training Program focuses on reclaiming land and fighting desertification, where particular attention is given to the interaction of climate change and land degradation. The Gender Equality Studies and Training Program also gives particular attention to climate change, with a special module on environment and climate change. Many of the fellows in the GRÓ Fisheries Training Program undertake research projects related to the impacts of climate change on fisheries systems and the communities that depend on aquatic resources.

All four programs are directly linked to national and public institutions in Iceland and draw on their experts for lecturing and training of fellows who come from LDCs and other developing countries. The fellows are trained in applicable science and research, relevant to their home country, and usually conduct their research with involvement from an official or research institutions in their home country. Through this method, the research is more likely to have an impact in the respective field in the home country and bring about further technological transfer. Fellows are chosen for and encouraged to further develop their leadership skills in order to further the transfer of knowledge after they return to their home country. Many fellows return to work in national expert institutions. Through the GRÓ training programs, Iceland has helped enhance the capacity of participating countries to adapt to and mitigate climate change through training of officials in the fields of geothermal energy, fisheries and sustainable land management sectors, as well as in gender equality.

Among the mitigation and adaptation programs Iceland has supported through multilateral channels are the two World Bank programs focused on the fisheries and renewable energy sectors. PROFISH aims at strengthening sustainable fisheries management, promote economic growth, ensure a healthy fish stock and enhance their yield.

ESMAP is a renewable energy program within the World Bank which assists low and middle-income countries to increase know-how and institutional capacity to achieve environmentally sustainable energy solutions for low carbon development, poverty reduction and economic growth. As part of the World Bank's response to the UN's Sustainable Energy for All Initiative (SEforALL), the Bank made an agreement with Iceland to collaborate on advancing geothermal energy utilisation in East Africa through five-year project between 2013 and 2017. Participating countries should at the end of the project have three key outputs from the project: A realistic assessment of potential geothermal sites; plans for further action where applicable, and; capacity to move forward on the basis of those plans and submit exploration drilling projects into funding pipelines. The project could extend to up to thirteen countries in the East Africa Rift Valley and is already under way in at least seven of them. The project in the East Africa Rift Valley is implemented in cooperation with several private partners and institutes, including technology transfer and capacity building to national experts and institutions in recipient countries.

The consequences of climate change affect women more severely than men. It is therefore important to include gender aspects in all discussion about climate change and programming. Iceland has actively promoted the important role of gender in the international climate negotiations, as well as supported several climate projects with the emphasis on women empowerment and gender equality, e.g., through organizations such as UN Women and the Women's Environment and Development Organization (WEDO). In this context a training course was developed by the GRÓ Gender Equality and Studies Program in close collaboration with Ugandan partners, and training and capacity building was provided for a selected number of experts and policy makers at the district level. In connection with our other Bilateral cooperation with Uganda.

Another area important to Iceland is the promotion of sustainable land management. Land degradation and desertification rank among the world's greatest environmental challenges, significantly affecting a range of issues such as climate, biodiversity, soil quality, food and water security, peace and human well-being, especially for the more vulnerable rural poor. By supporting the GRÓ Land Restoration Training Program, Iceland attempts to fight land degradation by strengthening institutional capacity and training of development country experts. The steps taken by Iceland to facilitate and finance the transfer of technology to developing countries and to build their capacity are taken into accordance with both the UNFCCC and Article 10 of the Kyoto Protocol.

5. Research and systemic observations

5.1 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 modelling and prediction, and large ongoing projects deal with mitigation measures, but there has been less research on socio-economic aspects.

5.1.1 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 modelling with a special focus on glacio-hydrology.

Although IMO research and evaluation of climate change is mainly centred on the climate of Iceland, the IMO has also been active in many inter-national climate research projects. Studies of the spatial characteristics and long-term changes in timeseries 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 to paleoclimatological work with their participation in many ice and sediment core projects. Much of this work has taken place within the University of Iceland. Some examples of research topics within that field and in related fields include:

- A review of changes in the extent of Icelandic glaciers for the last 100–200 years.
- A review of the mass of Icelandic glaciers for the last 100–200 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.

5.1.2 Modelling 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, changes in river runoff. The results of this work have been published in reports and peer reviewed articles.

5.1.3 Impacts of climate change

The IMO has led the scientific committee on climate change and the impacts of climate change in Iceland since 1999. The committee has published 3 reports since then (2000, 2008 and 2018)[35][36][37] and the next one is expected to be published in 2023.

The IMO has also led a series of Nordic-Baltic climate impact projects focusing on three main renewable energy resources; hydropower, biofuels and wind power. These projects were funded by Nordic Energy Research. In these 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 ensuing CES project had the goal of looking at climate impacts closer in time and assessing the development of the Nordic electricity system for the next 20–30 years. The project started in 2007 and finished in 2011 with the release of the book “Climate Change and Energy Systems – Impacts, Risks and Adaptation in the Nordic and Baltic countries”.

[35] https://www.vedur.is/media/loftslag/vedurfarsbreytingar_umhvrn_2000.pdf
[36] https://www.vedur.is/media/loftslag/visindanefndloftslagsbreytingar.pdf
[37] https://www.vedur.is/media/loftslag/Skyrsla-loftslagsbreytingar-2018-Vefur-NY.pdf

Following the CES project, two projects on the cryosphere and wind, were initiated by some of the participants in the previous climate and energy related projects. These were the SVALI and ICEWIND projects, both funded by the Top Research Initiative (TRI). The SVALI project examined the complex effects of climate change on Arctic glaciers, ice and snow. The projects tackle questions such as How fast is land ice volume in the Arctic and North-Atlantic area changing, and why? Will these processes continue to accelerate? What are the consequences for sea-level and ocean circulation? What are the implications for society? The ICEWIND project focuses on wind energy in cold areas and its main goal was to share knowledge between the Nordic countries and identify factors that delay or prevent the adoption of wind energy in the Nordic countries. In Iceland, the main focus has been on establishment of atlases for wind and icing as well as integration of wind power with other energy sources.

5.2 Systematic observation

This chapter has been reviewed by experts from the Icelandic Met office and the Marine and freshwater Research Institute.

The institutions most important for the observation of climate change are the Icelandic Meteorological Office (IMO) and the Marine and freshwater 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. Furthermore, the National Land Survey of Iceland (NLSI) directs measurement campaigns for mapping vertical and horizontal land motion in Iceland.

5.2.1 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 14 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, including 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 160 stations and about 25 in addition to this in cooperation with the National Power Company and the Maritime department of the Icelandic Road and Coastal Administration. A repository of data from the about 100 stations operated by the Public Roads Administration is also located at the IMO. Most 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 participated in the MATCH ozone-sounding program during the winter months from 1990 to 2012, and the data was reported to the WOUDC (World Ozone and Ultraviolet Radiation Data Centre), Canada.

The three GAW (Global Atmosphere Watch) stations are: the BAPM at Írafoss, Stórhöfði and Reykjavík. In Írafoss and Stórhöfði monitoring of the tropospheric ozone, carbon dioxide, methane and isotopes of oxygen and carbon are performed in cooperation with NOAA. Heavy metals and Persistent Organic Pollutants (POPs) in air and precipitation (currently POPs precipitation monitoring is only performed in Írafoss) are monitored and reported to AMAP and OSPAR, although the Stórhöfði station experienced a malfunction in the Eyjafjallajökull eruption in 2010 and ozone monitoring from there has suffered since. The data is reported to AMAP, EMAP og OSPAR-CAMP í NILU in Norway.

In Reykjavik, data on global radiation are collected and reported annually to the World Radiation Data Centre in St. Petersburg (WRDC).

The IMO also monitors hydrological conditions in Iceland and runs a network of about 120 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 glacial race 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 substantially in historic time, in particular in the most recent two to three decades; the decrease in glacier extent amounts to approximately 0,3–0,5% every year. The mass balance of the three largest glaciers, Vatnajökull, Hofsjökull and Langjökull, is monitored annually by scientists from the University of Iceland and the Icelandic Meteorological Office. The mass balance has been negative since 1995, with one excep-tion. The glaciers have lost ca. 275 km3 of ice since 1995, which corre-sponds to ca. 8% of their total volume.

The Icelandic Meteorological Office participates in the Global Cryosphere Watch (GCW) international collaboration established by the World Meteorological Organization (WMO) to fosters collaboration in observing all components of the cryosphere, The GCW has established procedures for accessing, sharing and utilizing cryosphere data and for developing value-added analyses and indicators based on in-situ, space-based, and airborne observations of the cryosphere. The outlines of Icelandic glaciers are delineated regularly, using maps, aerial photographs and satellite images. These data are delivered to an international database, e.g., by World Glacier Monitoring Service in Switzerland and Global Land Ice Measurements from Space (GLIMS) in the US.

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 millimetres. CGPS stations are therefore an excellent tool to monitor crustal deformation.

These stations allow IMO staff to monitor isostatic crustal changes that occur as a result of glacier mass loss due to climate change.

5.2.2 Ocean climate observing systems

Both the Marine and Freshwater Research Institute (MFRI) and the Icelandic Meteorological Office (IMO) contribute to ocean climate observations. The IMO and MFRI have been supporting Meteo France in deploying surface drifters with barometers and SST for weather observations and climate in recent years. The MFRI maintains a monitoring net of about 70 hydrobiological stations on 10 standard sections (transects) around Iceland with most of the sections extending beyond the continental slope. These stations are monitored three to four times per year for measurements of temperature and salinity and once or two times a year for phosphate, nitrate and silicate and once a year for phytoplankton and zooplankton. Some of these stations have been monitored regularly since around 1950. The MFRI has monitored carbonate system parameters on two time series stations northeast and west of Iceland since 1983. A network of about 10 continuous sea surface temperature meters is maintained at coastal stations all around the country.

The MFRI has been involved in several monitoring projects of ocean currents, in cooperation with European and American scientists. This work has included European and Nordic projects such as the Variability of exchanges in the northern seas, West-Nordic Ocean Climate, Meridional Overturning Exchange with the Nordic seas (MOEN), Arctic-Subarctic Ocean Flux-Array for European Climate: west (ASOF-W), Thermohaline Overturning - at Risk? (THOR) and the North Atlantic Climate (NACLIM) project, which all involved the monitoring of fluxes of water and heat over the Greenland – Scotland Ridge.

6. Education, training and public awareness

6.1 General policy toward education, training, and public awareness

The educational system in Iceland is administered by the Ministry of Education and Children and The Ministry of Higher Education, Science, and Innovation. The Ministry of Education and Children prepares educational policy, oversees its implementation, and is responsible for educational matters at all educational levels up until university level, which the Ministry of Higher Education, Science and Innovation is responsible for. Education has traditionally been organised within the public sector, but there are few private institutions in the school system, all of which receive public funding.

The National Curriculum Guide[38] from 2013 applies to all grades and subjects in compulsory schools and further specifies what is to be coordinated in all Icelandic compulsory schools. Based on the objective articles of the preschool, compulsory school, and upper secondary school acts, six fundamental pillars of education have been defined for the competence that pupils should achieve at compulsory school. One of the six pillars is "Education towards sustainability", which concerns the interplay of the environment, economy, society, and welfare. Sustainability includes respect for the environment, sense of responsibility, health, democratic working methods, and justice, not only at present time but also for future generations. Environmental protection, climate change and biodiversity are examples of tasks to be tackled. Sustainability is considered a prerequisite to understand the importance of one's own welfare and that of others. Education for sustainability further encompasses that in their studies children and youth come to grips with diverse problems and points of controversy. Teaching and working methods of the school are to be interwoven with the idea that the aim of education is capability for action. This involves training in democratic working methods and that children and youth are trained to be interested in and want to take part in society.

Key policy documents of the government contain the priorities of the Icelandic government regarding sustainability and climate change; Welfare for the future (first published in 2002 and revised in 2007 and 2010), the Climate Change strategy (2007) and Climate Action Plan (first published in 2010, with new and updated plans published in 2018 and 2020). Those policies contain sections and stipulations on actions regarding education, public participation, awareness raising, media and the role of civil society in general. In September 2018 the government launched a Climate Action Plan which includes actions regarding education, training, and public awareness. The Action Plan was updated in June 2020 and two status reports have been issued since, in 2021 and 2022. In 2021 a White Paper on Climate adaptation was issued.

Individual local authorities have taken steps toward increased sustainability and climate change awareness. Reykjavik city has, in cooperation with Festa – the Icelandic Centre for Corporate Social

[38] https://www.government.is/topics/education/curriculum/

Responsibility (CSR)[39] taken decisive steps towards increased climate change awareness and actions within companies in the city. The companies were asked to sign a joint declaration on actions intended to fight climate change and adapt to it. The declaration has been signed by nearly 200 companies. Those companies who sign are invited to participate in organised training, dialogue events, conferences and workshops on climate change and CSR. Furthermore, extensive information is available on Festa's website on the progress of the companies who have signed the declaration, along with other information on climate change and corporate responsibility.

Reykjavík is also one of three municipalities whose mayors have signed the Global Covenant of Mayors for Climate & Energy[40] - an international alliance of cities and local governments with a shared long-term vision of promoting and supporting voluntary action to combat climate change and move to a low emission, resilient society. The other two municipalities are Akureyri and Hveragerði.

Some other municipalities have chosen different paths for working towards increased sustainability and climate change awareness. Several municipalities have earned the EarthCheck[41]silver certification and another example is the small municipality Djúpavogur joined the international Cittaslow movement[42] in 2013.

[39] https://samfelagsabyrgd.is/en

[40] https://www.globalcovenantofmayors.org/

[41] https://earthcheck.org/

42 https://www.cittaslow.org/

6.2 Primary, secondary, and higher education

A fundamental principle of the Icelandic education system is that everyone is to have equal access to education irrespective of sex, economic status, geographic location, religion, disability and cultural or social background. 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 must by law attend 10 years of compulsory education from the age of 6 to 16. Upper Secondary Level is the third educational level which generally incorporates the age group from 16 to 19. Everyone has the legal right to enter school at that school level, irrespective of their results at the end of compulsory schooling. Those that have the right to enrol in upper secondary school also have the right to study until the age of 18.

There are currently seven higher education institutions in Iceland that fall under the auspices of the Ministry of Higher Education, Science, and Innovation: The University of Iceland and the University of Akureyri are public universities. The Agricultural University of Iceland and Hólar University College are public universities formerly under the auspices of the Ministry of Agriculture. Reykjavik University, Bifröst University and Iceland University 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 emphasis on education and research in the field of natural resources and environmental science is growing. Thus there are several programmes available, such as a two year diploma studies and a master's programme in natural resources sciences at the University of Akureyri; a master's programme in Environment and Natural Resources studies at the University of Iceland and a doctor's degree in

Environmental studies; BSc and MSc degree in Nature and Environmental Science at the Agricultural University of Iceland and a MSc in Sustainable Energy at the University of Reykjavík, in addition to a variety of courses on sustainability, climate change and environmental issues available in all of those institutions.

The Eco-Schools Programme[43] an international project funded by the government and managed in Iceland by the NGO Landvernd (The Icelandic Environment Association)[44]Eco-Schools is a programme for environmental management and certification which aims at enhancing environmental education and to strengthen environmental policy in schools. It is designed to implement sustainable development education in schools by encouraging children and students to take an active role in how their school can be run for the benefit of the environment. Schools that fulfil the necessary criteria are awarded the Green Flag for their work, which they keep for two years, before they need to renew their permission to flag the Green Flag.

Each Eco-School forms an environmental committee and works towards an Eco-Code within the school. Schools can choose to work on up to 13 themes and set two-year goals for one or two of them at a time. Landvernd assesses their work and recognises those who meet the requirements with a Green Flag. The themes are: climate change, transportation, consumption, global equality, energy, water, waste, ecosystem restoration, biodiversity, nature conservation, local community, public health and wellness and landscapes.

New environment assessment checklists have been developed for students to evaluate the status of environmental issues within their schools, such as climate change, transportation, and consumption.

As a part of the Eco-School programme, Landvernd participates in a European programme on climate change education. The goal of the programme is to design educational material for the upper secondary school level on complex environmental issues to support students' ability to take action on the climate change issue.

In 2021, 186 schools at all school levels participated in the programme, this includes 26% of all kindergartens, pre-schools, 53% of all elementary and secondary level schools, 47% of high schools and 29% of universities.

The programme is open to other schools, such as Sunday schools summer schools and schools of work, according to the international guidelines of the Eco-Schools Programme. The programme is financially supported by the Ministry of the Environment, Energy and Climate and the Ministry of Education and Children, as well as municipalities throughout the country.

6.3 Public information campaigns

In April 2021, climate change was one of the themes of the biannual conference on environmental issues hosted by the then Ministry for the Environment and Natural Resources, now Ministry of the Environment, Energy and Climate. The conference is attended by the environmental sector, the public and stakeholders and is one of the largest regular environmental events held in Iceland. The conference got an extensive

[43] https://www.ecoschools.global/

[44] https://landvernd.is/english/

coverage by the Icelandic media and evoked experience exchange and discussions on climate change in the Icelandic society.

The special climate change agenda of the government issued in 2015 introduced the project “Melting glaciers – a natural laboratory to study climate change”, implemented by the Vatnajökull national park and the Icelandic Meteorological Office. The co-operation was renewed in 2019, and evolves around the visibility of climate change derived from the melting glaciers in Iceland with the target to increase people’s awareness of climate change. The project involves dissemination of information to the public and education material on retreating glaciers, such as an educational brochure in Icelandic and English on the subject published in late 2017, both in paper and online[45]. A special educational web for the project was launched in 2018[46] , which will be updated in parallel with a new website of Vatnajökull National Park. An annual newsletter has been published since 2018 and is available on the Icelandic glacier web portal www.islenskirjoklar.is, providing an overview of glacier changes from all institutes involved in glacier research in Iceland. The web portal was opened in spring 2022, partly funded by the Icelandic Climate Fund, and hosts glacier measurements carried out in Iceland, including mass balance, glacier termini positions and glacier outlines. A comprehensive photographic archive of Icelandic glaciers is part of the web portal, including historical photographs and repeat photographs.

In projects associated with “Melting glaciers”, Icelandic scientists are producing new maps of the glaciers and updated information about their extent. These new data make it possible to visualize the rapid

[45] https://www.vatnajokulsthjodgardur.is/static/files/Utgefid-efni/VJP-sameiginlegt/horfandi-joklar_2017_pdf-af-baekling.pdf
[46] https://www.vatnajokulsthjodgardur.is/en/areas/melting-glaciers

changes that are taking place on the glaciers and they are used to update information on the glaciers in the new glacier web portal and in the annual newsletter. These data are, furthermore, submitted to international scientific databases where they become part of a global dataset about glacier changes that is used in global assessments about glacier changes that are published regularly.

Teaching material for guides working with tourists within Vatnajökull National Park was published in 2018. An active conversation is ongoing with tourism operators to bridge the gap between the scientific community and glacier guides and others. This includes presentations on glacier and climate change in co-operation with Katla geopark, Vatnajökull National park and others. Information signs were installed on three hiking trails in front of Skaftafellsjökull, Heinabergsjökull and Breiðamerkurjökull, where visitors are presented with information about the glaciers and imagine the transformation caused by their melting.

As a part of the project “Melting glaciers”, visual video presentations of changes that have occurred at the outlet glaciers of Vatnajökull since the 1980s and 1990s have been created by Kieran Baxter at the University of Dundee in collaboration with the Research Center of the University of Iceland in Hornafjörður. The videos combine historical aerial photographs from National Land Survey of Iceland with new drone imagery. They are created with advanced 3D technology that allows striking comparison of the photographs separated by >30 years. These videos and other visual products created for “Melting glaciers” have been presented a several meetings and conferences as well as in educational material about glacier changes produced by the IMO.

The Ministry of the Environment, Energy and Climate manages annually the Day of the Environment (April 25th) and the Day of the Icelandic Nature (September 16th), both of which are celebrated national wide. The former day is concentrated on international environmental issues such as climate change and sustainability. On those days the Minister of the Environment, Energy and Climate grants chosen individuals, media, school children or companies awards for their commitment for the environment and these awards tend to get the attention of the mainstream media.

Several public campaigns conducted in Iceland by public and private parties contribute to the reduction of emissions. One of those is the annual “Bike to work” campaign[47], conducted by the National Olympic and Sports Association of Iceland with financial support from i.e. the public sector. The campaign – which over a period of two weeks encourages the public to leave their car at home and bike, walk or use public transport to work – has been widespread and successful, with good participation from the public. The same association conducts other campaigns aiming at encouraging people to use their own powers to transport – such as the “Lífshlaupið” campaign (where all kind of physical movement or sport count), and the “Bike to School” and “Walk to School” campaigns directed towards students.

In 2021, six of the largest municipalities in Iceland with just over 60% of the population, participated in the European Mobility Week[48], September 16 – 25, encouraging people to use environmentally friendly methods for transportation. In Iceland, this campaign is coordinated by the Ministry of the Environment, Energy and Climate.

[47] https://hjoladivinnuna.is/

[48] https://mobilityweek.eu/home/

The Eco-School project has proven to be a successful method, not only for increasing environmental awareness at schools but also in the homes of the children as they bring forward their knowledge on environmental issues and climate change to their parents and other family members. At the university level awareness raising projects are conducted, such as the annual “Green Days” at the University of Iceland organised by the students of the masters Environment and Natural Resources Programme.

Over the past years, media interest in climate change issues has increased considerable and many of Iceland’s media now provide frequently an extensive coverage of climate change related issues; examples of this are TV series on both the mitigation of climate change (Hvað höfum við gert) and what can be done about it (Hvað getum við gert).

Due to Iceland's small population, the government’s access to national and local media is relatively open, leading to a higher proportion of information dissemination on environmental issues. Information officers working for the Ministry of the Environment, Energy and Climate and its institutions have a direct and personal contact to key players within the mass media which gives them unique opportunity to present information through the largest TV and radio channels as well as the mainstream newspapers.

6.4 Training programmes

Iceland runs four training programmes, of which three benefits directly the fight against climate change.

The Geothermal Training Programme (GRÓ GTP)[49] is a postgraduate training programme, under the auspices of UNESCO, aiming at assisting developing countries in capacity building in geothermal research

[49] https://www.grocentre.is/gtp

and development to enhance their use of renewable energy sources. The programme consists of six months annual training for practicing professionals from developing and transitional countries with significant geothermal potential, as well as an opportunity for outstanding fellows to pursue MSc and/or PhD degrees through cooperation with the University of Iceland and Reykjavík University. Also, the GRÓ GTP offers a variety of geothermal short courses on site in developing countries as well as other training activities.

The objective of the GRÓ Gender Equality Studies and Training (GRÓ GEST)[50] Programme is to use a multidisciplinary approach to promote gender equality and social justice in low to middle income, conflict and post-conflict countries through education and training. GRÓ GEST is currently involved in a project on gender and climate change in Uganda.

GRÓ GEST has offered a full PhD scholarship, in collaboration with Makerere University, Uganda. Furthermore, GRÓ GEST supports the implementation of two short courses on gender and climate change in Uganda in collaboration with Ugandan partners at Makerere University and several government agencies and ministries.

GEST has previously produced study material and offered training courses on gender and climate change in Uganda, piloted in 2012-2013, and implemented again in 2019, and in Malawi in 2021. The overall objective of the course is to build knowledge and understanding of the causes of climate change and its impact on development and gender relations in Uganda/Malawi, and thus contributing to the strengthening of local capacity to design and implement gender-responsive climate change policies, strategies and programmes.

In 2021 GRÓ GEST financially supported the implementation of a Solar Sisters Nigeria initiative to bring awareness of advanced affordable solar power to rural communities in Nigeria through boosting the clean energy business enterprises of women. The initiative reached over 7000 energy users in 30 communities; contributing to the clean energy conversion in rural Nigeria.

GRÓ Land Restoration Training Programme (GRÓ LRT)[51] is a capacity development programme in the field of land restoration and sustainable land management, and has from the beginning been hosted at the Agricultural University and run in cooperation with the Soil Conservation Service of Iceland. GRÓ LRT was established in 2007 and run as part of the United Nations University from 2010-2019. In 2020, GRÓ LRT became part of GRÓ International Centre for Capacity Development, a category 2 UNESCO Centre based in Reykjavik, and is funded by the Government of Iceland and part of the country's international development cooperation.

GRÓ LRT's core activity is an intensive six-month postgraduate training in Iceland on ecological restoration and sustainable land management, custom-built for working professionals in developing countries faced with severe land degradation. As from 2022, the six-month training is eligible for 30 ECTS credits, meaning that fellows completing the training successfully also receive a Postgraduate Diploma in Ecosystem Restoration and Sustainable Land Management from the Agricultural University of Iceland. Since its

[50] https://www.grocentre.is/gest

[51] https://www.grocentre.is/lrt

establishment in 2007, 175 working professionals have participated in the six-month training, coming from 14 countries in Africa and Asia.

Since 2017, GRÓ LRT has expended into two new areas. Firstly, providing financial and technical support to develop and deliver short courses in its partner countries for working professionals in the fields of ecological restoration and sustainable land management. These courses are designed and delivered in cooperation with the GRÓ LRT partner institutions in Africa and Asia, and since 2017 GRÓ LRT has organised six such courses, three in Uganda, two in Mongolia and one in Ethiopia. Secondly, offering scholarships to former GRÓ LRT fellows, who have completed the six-month training programme, to pursue graduate studies at Icelandic universities in land restoration and related subjects. Five former fellows have received scholarships from GRÓ LRT since 2017, four for master's degree studies and one for PhD studies.

6.5 Resource or information centres

The website of the Icelandic government[52] contains official information on climate change; f.x. the government's Climate Action Plan, work on an adaptation policy, relevant acts, regulations, and policies, Q&A's about climate change, information on the United Nations Framework Convention on Climate Change and important external links. An English version of the government's website[53] was launched in January 2018, with updated information about Iceland and climate change issues and links to relevant information on websites of other institutions.

Extensive information about climate change is available on the websites of the main institutions in the field of climate change, such as the Environment Agency of Iceland (EAI)[54]. At the EAI website, general information on possible and probable effects is to be found, as well as information on the causes, types of greenhouse gases, the Paris agreement and the ETS. Also, the web contains specific pages on how individuals can make a difference in their daily lives. The latest NIR (inventory reports) are available online. Among the most popular webpages of the EAI site is www.graenn.is (e. green.is) on how consumers can decrease their negative impact on the environment, including the climate. The EAI website highlights few indicators on the state of the environment, where climate change is one of six main categories[55]. The indicators are updated yearly and include i.a. yearly average heat and changes in Vatnajökull glacier. The EAI also frequently disseminates information about climate change issues via it's social media. This includes popular online lunch talks on various environmental issues, which the general public can relate to. EAI also oversees the Green Steps Program (Græn skref)[56], which is developed for government agencies in Iceland with the overall aim of decreasing environmental impact from daily operations in the public sector, as well as the Icelandic Association of Local Authorities' toolbox[57], which gives local authorities support in meeting their climate policy demands.

The Icelandic Meteorological Office[58] is another important resource. In 2021 it became the home of the Knowledge Centre on Climate Change Adaptation. The Knowledge Center is a forum of information on

[52] https://www.stjornarradid.is/verkefni/umhverfi-og-natturuvernd/loftslagsmal/
[53] https://www.government.is/topics/environment-climate-and-nature-protection/climate-change/
[54] https://www.ust.is/
[55] https://www.ust.is/graent-samfelag/graenn-lifstill/
[56] https://graenskref.is/
[57] https://loftslagsstefna.is/sveitarfelog/
[58] https://www.vedur.is/

climate changes' effect on Iceland for the academic community, local governments, firms/companies, institutions and the general public. The Meteorlogical Office's official website also has a sub section on climate change containing extensive information on the background and science material on climate change. There the mechanisms behind climate change are explained in a simple language that should appeal to the public; the content of the IPCC reports is made accessible, both in English and Icelandic as well as news and information on the climate change impact in Iceland.

The websites of the Soil Conservation Service of Iceland[59] and the Icelandic Forest Service[60] provide information on climate-related challenges these institutions are engaged in.

Most of the institutions mentioned above, including the Ministry, have established and maintain Facebook pages and/or other social media to disseminate their information to the public, i.a. news and information on climate change. This has proven to be an important information channel, considered the limited financial resources of those institutions, as it is inexpensive, easily accessible and that most Icelanders have a registered Facebook account.

Other information sources worth mentioning are e.g., the website of Orkusetur (Energy Centre)61 where the public can access information and calculators for diverse private energy use, such as on household electricity and heating, transportation, and carbon emissions. The website also provides short informative videos on private energy use and how to reduce it.

A variety of educational material on environmental issues, climate change included, is accessible on the website of the Directorate of Education (DE)[62]. This includes electronic books, videos, an interactive web-hub etc. The material is facilitated in cooperation with different agents, such as the EAI, environmental NGO's and others. Also, educational material on climate change is to be found on the website http://www.erjordinihaettu.com (Is the Earth at Risk?), the Nordic web https://nordeniskolen.org, and as part of NGO Landvernd's (The Icelandic Environment Association) website as a part of their Eco-Schools programme.

In addition, several privately-run websites and Facebook-groups and -pages disseminate news and information on climate change, such as www.loftslag.is, www.himinnoghaf.is, a Facebook-group for discussion and news on climate change, a Facebook-page called Paris 1,5 in addition to a number of pages and groups focusing on specific environmental issues contributing to climate change.

6.6 Involvement of the public and non-governmental organisations

In 2012 the ratification of the Aarhus Convention entered into force in Iceland, ensuring the public right to participation and information on environmental matters. The governments work on increasing NGO's and the public involvement in the field of climate change and environmental protection started over a decade earlier when the Ministry for the Environment established a formal platform for cooperation with environmental NGO's. The purpose is to ensure dialogue and consultation between the Ministry and the environmental NGO's, which is realised i.a. in an annual meeting between the Minister and the NGO's

[59] https://land.is/
[60] https://www.skogur.is/
[61] https://orkusetur.is/
[62] https://mms.is/namsefni

representatives. In all 18 NGOs participate in the platform, including Iceland's largest organisations in this field.

Many of the NGO's working in the field of environmental protection receive a financial support for their operation from the government as well as funding for specific projects. Amongst those projects are the Eco-School project described before, diverse projects enhancing bicycling as a climate friendly mean of transport and a long-term educational project for youths on revegetation and land care in connection to biodiversity and climate change (Vistheimt með skólum)[63]. Additionally, the government has sponsored the participation of NGOs representatives at COP meetings of the UNFCCC. The government support diverse other NGO's projects which fully or partially aim at fighting climate change.

The government also supports specific private projects on climate change, such as research projects on emissions from landfills in Iceland and a research comparing the legal framework of Iceland and Europe regarding climate change.

The government also supports specific private projects on climate change, such as research projects on emissions from landfills in Iceland and research comparing the legal framework of Iceland and Europe regarding climate change.

[63] https://landvernd.is/graenfaninn/vistheimt-skolar/

6.7 Participation in international activities

Iceland participates in many different international activities. The participation in the European Mobility Week, the Bike to work international campaign and Eco-Schools programme are examples of participation in public projects across borders. The GRÓ-training programmes are examples of international cooperation with regards to education and training.

Icelandic authorities participate in diverse international cooperation programmes with regards to public information dissemination on the environment, including climate change. An example of this is the cooperation between the Environment Agency of Iceland with the European Environment Agency (EEA). Press releases from the EEA concerning climate change developments are distributed by the member countries on agency/Ministry websites and to national and local media. Information and best practice are also shared between member countries.

The Ministry of the Environment, Energy and Climate participates in an active network of communication and information officers from environment Ministries and national environmental agencies in the Nordic countries: Denmark, Norway, Sweden, and Finland as well as the Nordic Council of Ministers. The network meets annually and shares experience and information. Iceland has been active in the Nordic information cooperation during the latest COP meetings and has participated in various side events at the Nordic pavilion at the COP conference sites during the last years.

Iceland also participates in the platform for national coordinators working on the European Mobility Week. Iceland participates on average in one or two meetings of this platform annually, where participants exchange information and plan and coordinate the annual Mobility Week.