Landsvirkjun

ENVIRONMENTAL REPORT 2012

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CH_4	Methane
CO_2	Carbon dioxide
CO	Carbon monoxide
dB	Decibles
E_0	Maximum sustainable production
EINHI	East Iceland Natural History Institute
GB	Green accounting
GHG	Greenhouse gas emissions
GWh	GW per hour
H_2S	Hydrogen sulphide
HFC	Hydrofluorocarbons
IHA	International Hydropower Association
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LULUCF	Land Use, Land Use Change and Forestry
N_2O	Nitrous oxide
PFC	Fluorocarbons
SF_6	Sulphur hexafluoride
Enthalpy	Geothermal energy content of liquid kJ/kg
VHÍ	School of Engineering and Natural Sciences of the University of Iceland
WWF	World Wildlife Fund

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Birds of Iceland

The official number of bird species in Iceland is debated but there are thought to be 75 breeding bird species and a number of birds attempt to settle on the island every year, without much success. The country is visited by a number of migrating birds and a variety of waders that nest in Greenland and Canada but choose Europe and North Africa as their winter habitat. In the spring and autumn the vagrants arrive and a total of 370 bird species have been spotted in Iceland.

An increase in re-forestation and a warming climate is likely to increase the diversity of Iceland's birdlife. A number of sparow species will find comfort in the new forests and there will be an increase in duck species choosing not to head southward as winter falls. All bird species in Iceland are protected unless protection orders are officially lifted.

Five Icelandic birds grace our environmental report this year: the Great Northern Loon, the Long-tailed Duck or Oldsquaw, the Harlequin Duck, the Falcon and the Northern Wheatear.

The Harlequin Duck *Histrionicus histrionicus* is a small, resident duck and protected species in Iceland. The male duck is decorative and is associated with 'the clown' in many European languages. It takes its name from Arlecchino, Harlequin in French; a colourfully dressed character in Commedia dell'arte. In Icelandic we call the duck the "the stream duck" as its main habitat is that of spring rivers with a strong current as well as the choppy coast of Iceland.

A statement from the inspector of Landsvirkjun's environmental report

EFLA Consulting Engineers have reviewed Landsvirkjun's Environmental Report for the year 2012, and hereby confirm that the report contains information relevant to significant environmental aspects in Landsvirkjun's operations. The information presented is consistent with the company's monitoring of key characteristics that can have significant environmental impact. This report also contains results of monitoring required by the Company's operation permits.

Helga Jóhanna Bjarnadóttir

Helga Jóhanna Bjarnadóttir,
Director – Environment, EFLA Consulting Engineers

With Sustainable Utilisation and Profitability as Guiding Principles

The Icelandic nation is faced with a number of promising opportunities. In recent years we have been purposeful in identifying opportunities in order to generate profit from Landsvirkjun's operations. If we are capable of embracing these opportunities in a sensible manner, then the benefits for Landsvirkjun and the Icelandic nation could be considerable.

We place a great emphasis on increasing the profitability of the Company but our commitment to society and the environment we live in cannot be compromised. Landsvirkjun has played an important role within Icelandic society in the last few decades. We take this role seriously and are dedicated to fulfilling these expectations in such a manner that we can look back with pride.

The same is true of the environment. Our responsibility towards the environment is tremendous. Our operations are such that they are bound to bring about change and cause disruption to the environment. We are therefore obligated to tread carefully and to keep sustainability at the forefront in all our endeavours.

If we are to organise our projects successfully, by efficiently generating energy with sustainability and progressiveness as guiding principles, then we cannot manage our operations with only profitability in mind. We must be purposeful in our approach to environmental and societal matters. It is our social responsibility.

The Company can bring profit to society by efficiently generating energy in consensus with society and in harmony with nature, and by being proactive in creating diverse and lucrative opportunities for an economy on the cutting edge of the international market.

Hörður Arnarson,
CEO of Landsvirkjun

Summary

Landsvirkjun operates according to an ISO 14001 certified Environmental Management System. The Company is committed to an awareness of environmental issues and is purposeful in preventing any negative impact that might come as a direct result of its operations.

Geothermal heat – electricity generation for 2012: 490 GWh

- In 2012, 490 GWh of electricity was generated using geothermal energy. Thermal fluid; a mixture of steam and water is utilised. In total, 5,857 thousand tonnes of steam and 5,230 thousand tonnes of separation water were used.
- The environmental impact of electricity generation is reduced by the re-injection of separation water. Re-injection reduces the amount of pollutants otherwise discharged into surface water. In 2012, approx. 2,563 thousand tonnes of separated water was re-injected into the geothermal reservoir.
- The emission of hydrogen sulphide (H_2S) from Landsvirkjun's geothermal stations is monitored. In 2012, approx. 5,536 tonnes of hydrogen sulphide was released into the atmosphere as a result of electricity generation and 120 tonnes were re-injected. The concentration of hydrogen sulphide is measured in the Bjarnarflag area and has never surpassed the limits set by regulations on concentrations of hydrogen sulphide in the atmosphere.
- The concentration of heavy metals and nutrients in waste water discharged into surface waters from Krafla and Bjarnarflag power stations is below environmental limits when it reaches Lake Mývatn.

Hydropower –electricity generation for the year was 11.822 GWh

- During the energy generation process, every effort is made to maximise the utilisation of water stored in the reservoirs and to eliminate unusual fluctuations in flow rate, or sudden water level changes, by steering the water. Sudden changes in water levels in reservoirs or in the flow rate of rivers can have a negative effect on soil, on ecosystems and on society.
- Overall, the water budget for the water year 2011/2012 was satisfactory. The water budget for 2012 was satisfactory during the first 5 months of the year but the summer was below average, lasting until September.

Fuel usage

Fossil fuels are used for vehicles and various machines in Landsvirkjun's operations. Oil is also used to operate a number of diesel generators. Diesel oil is mainly used to power vehicles and successful efforts have been made to reduce consumption at the Company's power stations, resulting in a 6% decrease between years. Landsvirkjun's Headquarters has used methane to power its vehicles.

Continued success in waste separation and recycling

In 2012, there was a significant reduction in the overall production of waste matter in Landsvirkjun's operations. The amount of waste varies between years and is directly related to the amount of scheduled maintenance. Waste sorting has increased measurably in the last few years in all of the Company's operational areas and there was a notable reduction in unsorted waste in 2012.

Noise

The operational areas at Krafla and Bjarnarflag, where geothermal electricity generation takes place, are identified as industrial areas. The Icelandic regulation on noise specifies a reference limit for industrial zones of 70 dB(A) at site boundary. Landsvirkjun makes a concerted effort to reduce noise in areas close to popular tourist destinations at Lake Mývatn ensuring that sound levels do not exceed 50 dB(A), which is the reference equivalent sound level value for residential areas. The noise levels have been kept within these limits in the last few years but they went over 50 dB(A) at three of the monitoring stations in 2012.

Environmental mishaps

In 2012 there were two environmental incidents in Landsvirkjun's operations and both were in connection with the steering of flow rates in the Sogid area. Working methods are reviewed after such incidents in order to prevent them from re-occurring. Specialists reviewed any possible effects on the ecosystem in the Sogid area and assessed the need for any necessary action.

GHG emissions continue to decrease between years

- The greatest amount of GHG emissions are emitted from geothermal utilisation (75%) and from the reservoirs at hydropower stations (24%). Emissions are also caused by the burning of fossil fuels, air travel and the disposal of waste matter (1% of the total emissions from Landsvirkjun).
- Landsvirkjun's total land reclamation area is now 140 km^2. Landsvirkjun's carbon binding efforts are assessed according to the size of their land reclamation areas and coefficients which were assessed via research to be 22,000 tonnes of CO_2-eq per year. GHG emissions from Landsvirkjun's operations were 54,000 tonnes CO_2-eq which is a reduction of 4% from the year 2011. If carbon binding is included then Landsvirkjun's emissions were 32,000 tonnes of CO_2-eq and have therefore decreased by 7%.
- The carbon footprint of Landsvirkjun's geothermal stations this year was approx. 78 tonnes of CO_2-eq for every GWh generated and 76 tonnes of CO_2-eq per GWh generated if carbon binding is included.
- The footprint of Landsvirkjun's hydropower stations was 1.1 tonnes of equivalents, expressed as CO_2-eq per GWh generated in 2012. If carbon binding is included then it is evident that Landsvirkjun has, via carbon binding in soil and vegetation, actually negated the emissions from its energy generation and in fact; carbon binding measures exceeded emissions from electricity generation equivalent to 0.65 tonnes CO_2-eq per GWh of hydropower generated.

International Hydropower Sustainability Assessment Protocol

In the last few decades, preparation measures for new hydropower projects worldwide have made tremendous advancements with regard to environmental and societal issues. A Hydropower Sustainability Assessment Protocol has been developed on the initiative of the International Hydropower Association (IHA), in order to assess how successfully hydropower projects adhere to the international criteria for sustainable development. The first assessment took place in 2012 and was an assessment of the Landsvirkjun's preparation work for the Hvammur hydropower project in the lower regions of Thjórsá. Landsvirkjun fulfils the requirements for "good practice" in 20 out of the 21 topics assessed and achieved 'Proven Best Practise' in over half of the topics assessed. Communications & Consultation did not fulfil the requirements for best proven practice. Landsvirkjun has taken all the recommendations put forward by the assessors into serious consideration and is in the process of reviewing and improving practices where needed.

Research on fish in the water catchment area in the lower regions of the Thjórsá River

Extensive research on the fish stocks in the Thjórsá River has been on-going since 1973. The research objectives include monitoring possible changes to the river ecosystem and an assessment of the effects upon fish stock, with a view to developing mitigation measures as a result of the proposed hydropower stations in the lower regions of the Thjórsá River.

The construction of the hydropower stations in the upper regions of the water catchment area had a considerable effect on the water flow in the lower regions of the river and sediment levels have decreased. This has created a more favourable environment for the salmon stock, supporting its growth and an increase in fishing in the last few years. The Institute of Freshwater Fisheries has proposed mitigation measures which are likely to be needed, as a result of the proposed power station.

General Information

Landsvirkjun has a certified environmental management system, in accordance with the international environmental standard ISO 14001. The Company has established an environmental policy and has worked systematically to reduce the impact of its operations.

The Policy states that the Company's intentions and aspirations are to become a leader in environmental matters and the Company Policy supports the intention to become carbon neutral. Landsvirkjun has published environmental reports since 2006, describing the Company's environmental monitoring and goals concerning environmental issues. The Environmental Report for 2012 includes numerical environmental data for the operational year 2012 as well as information regarding changes since 2008. The report covers important environmental monitoring issues related to the operations of Landsvirkjun, including improvements to natural resource utilisation and greenhouse gas (GHG) emissions. Landsvirkjun's carbon footprint is calculated; the carbon footprint is a measure of anthropogenic GHG emissions and their impact on climate change. The report also presents results from a variety of interesting research projects on environmental issues. The data published is either actual figures or calculated figures based upon measured values and have been reviewed by EFLA Consulting Engineers.

The information in this report is given to the 'best of knowledge' and is considered accurate. The report is organised as follows: the first part contains general information regarding the Company's operations and the environmental management system. The second part of the report describes the monitoring of environmental aspects, i.e. environmental aspects other than atmospheric emissions. The third part focusses on GHG emissions, emissions of hydrogen sulphide from geothermal power stations and Landsvirkjun's carbon footprint. The second and third parts of the report contain coverage of specific issues and research projects. One annex is attached to this report, where tables and detailed numerical data regarding the first part of the report can be found.

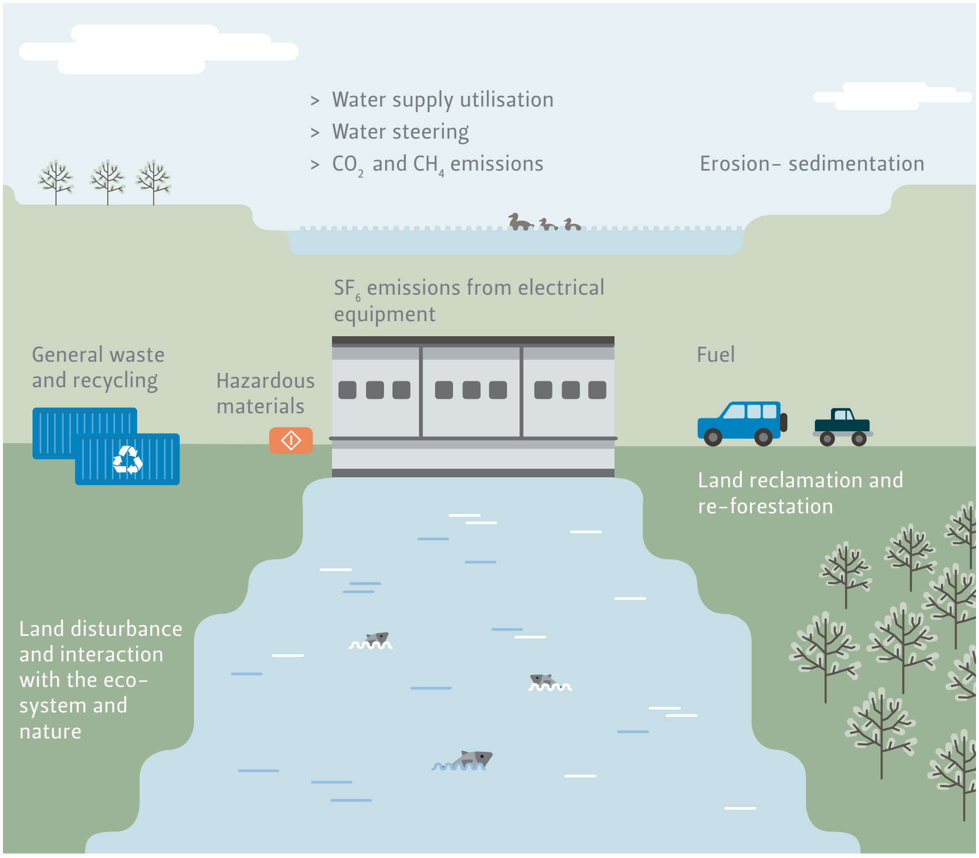
The Great Northern Loon *Gavia immer*, is a large, strong duck that is an intrinsic part of Icelandic lakes. The summer population is only 300 pairs that nest by the water's edge and feed on fish. The bird mostly resides in the sea over the winter months. The call of the Great Northern Loon is entertaining as it whines, yodels and laughs insanely.

Landsvirkjun's Environmental Policy

Landsvirkjun is a leading company in the field of environmental responsibility and promotes sustainable development in Icelandic society. Landsvirkjun is committed to identifying and minimising the environmental impact of its operations. In order to ensure continued success in this field, the Company monitors significant environmental aspects and makes systematic efforts for improvement. Landsvirkjun ensures that every legal requirement relating to the environment is fulfilled and sets more stringent requirements upon the Company, as appropriate.

Landsvirkjun makes every effort to ensure that its employees, as well as others working for the Company, have the capability and expertise to carry out its environmental policy. Landsvirkjun's environmental policy and reports are open to the public, thus encouraging transparent and productive dialogue. The Company has enjoyed success in its management of environmental affairs.

Figure 1 — Important environmental aspects in Landsvirkjun's hydropower operations.



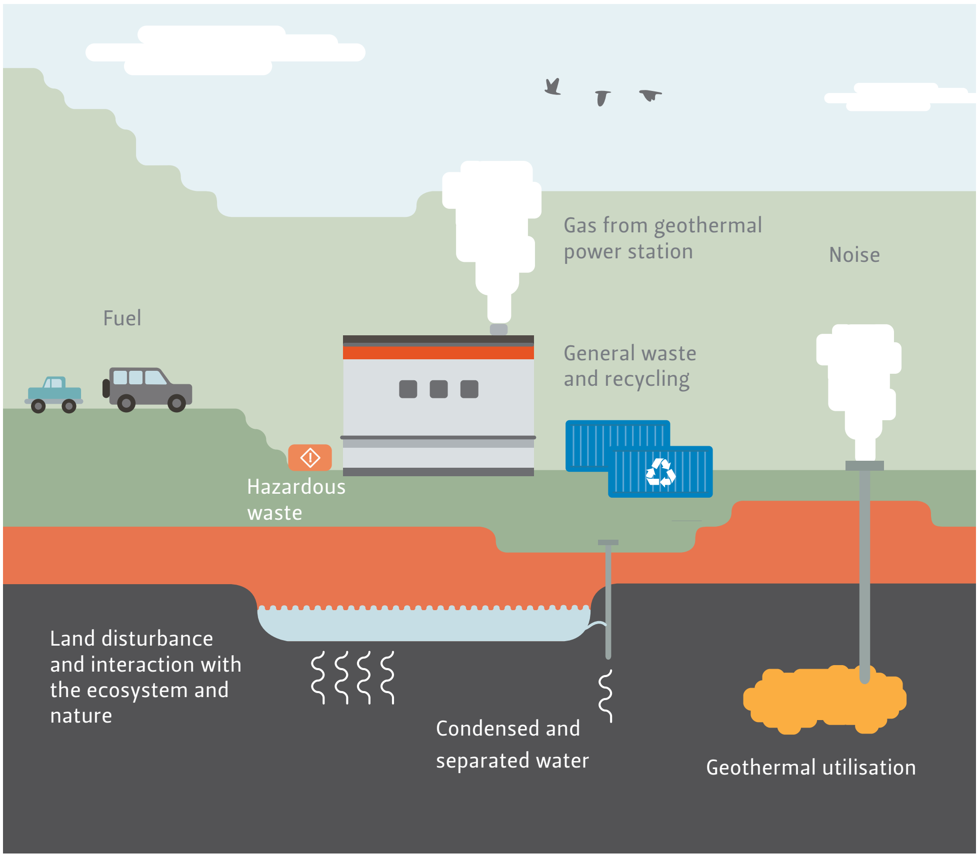
Landsvirkjun's objectives in environmental aspects:

1. Operation without environmental mishaps
2. Operation in harmony with the natural ecosystem
3. Better use of resources
4. Reduced greenhouse gas emissions
5. Reduced waste

Monitoring and control of environmental aspects

To fulfil the environmental policy and its objectives, significant environmental issues within Landsvirkjun's operations are monitored and the 'control methods' are defined. An overview of the main environmental aspects with regard to the operation of Landsvirkjun's hydropower and geothermal stations can be seen in **Figures 1 and 2**. This report releases information on the Company's monitoring of these aspects in 2012.

Figure 2 — Important environmental aspects in Landsvirkjun's geothermal operations.



Landsvirkjun's Electricity Generation

Landsvirkjun's operations in 2012 are divided into five main divisions: the Energy Division, the Research and Development Division, the Project Planning and Construction Division, the Finance Division and the Marketing and Business Development Division, as well as the Human Resources Division, the IT Division and the Corporate Office.

Figure 3 provides an overview of Landsvirkjun's operations as the Company's Environmental Management System is defined. The Company's operations are divided into electricity generation at the Company's power stations in five operational areas; the Sogid area, the Mývatn area, the Thjórsá area, Blanda Station and Fljótsdalur Station. Additionally, Landsvirkjun's operations include the Energy Division, the Research and Development Division, the Project Planning and Construction Division and the Company's offices in Reykjavík and Akureyri. **Figure 4** shows the location and capacity of Landsvirkjun's power stations.

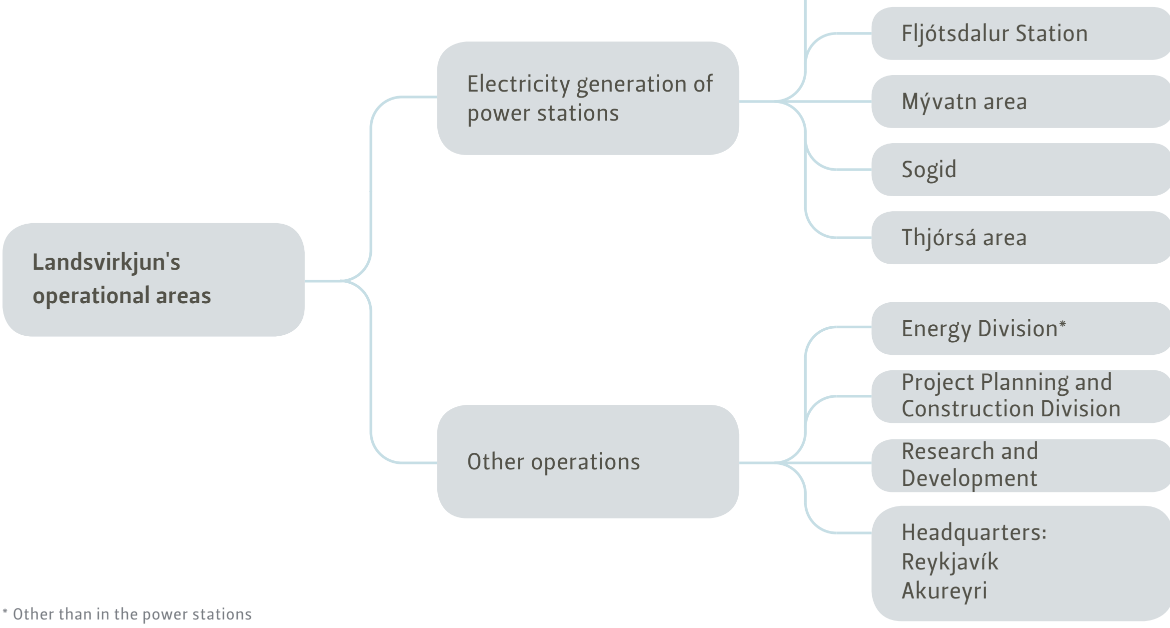
Landsvirkjun's total electricity generation in 2012 was 12,312 GWh, which is a 1.4% decrease from the previous year as a result of a drop in generation.

As in recent years, approximately 96% of the total electricity generation was from hydropower and 4% from geothermal power. Landsvirkjun's electricity generation in 2012 represented approx. 70% of Iceland's total electricity generation.

Energy losses and Landsvirkjun's own usage of energy in the power stations reached a total of 128 GWh in 2012. This is mostly attributed to 'own energy use' in the power stations

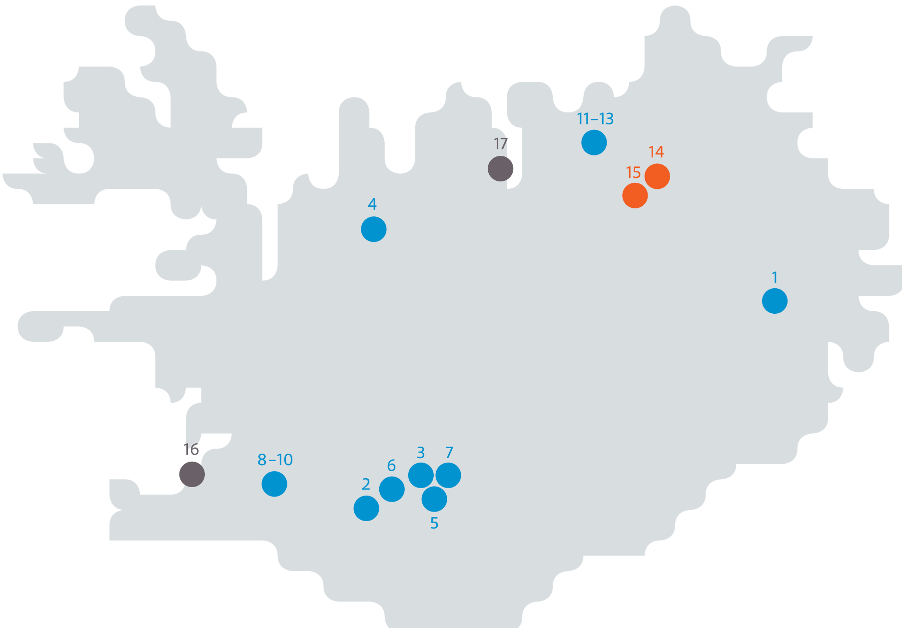
A more detailed overview of electricity generation and energy losses can be found in the Annex.

Figure 3 — Landsvirkjun's operation as defined for the Company's environmental management.



* Other than in the power stations

Figure 4 — Location of Landsvirkjun's operational areas and capacity of Landsvirkjun's power stations.



	Hydropower stations	MW
1	Fljótsdalur Station	690
2	Búrfell Station	270
3	Hrauneyjafoss Station	210
4	Blanda Station	150
5	Sigalda Station	150
6	Sultartangi Station	120
7	Vatnsfell Station	90

		MW
8	Írafoss Station	48
9	Steingrímsstöd Station	26
10	Ljósafoss Station	15
11	Laxá Station III	14
12	Laxá Station II	9
13	Laxá Station I	5

	Geothermal power stations	MW
14	Krafla Station	60
15	Bjarnarflag Station	3

	Operations
16	Reykjavík
17	Akureyri

Monitoring Environmental Aspects

This chapter discusses the monitoring and control of environmental aspects that have been defined for Landsvirkjun's operations, other than those that relate to atmospheric emissions and greenhouse effects.

Better utilisation of natural resources and the reduction of atmospheric GHG emissions are among Landsvirkjun's environmental objectives. Landsvirkjun's main natural resources for electricity generation are geothermal heat and rivers. Other resources are fossil fuels and land use (in connection with land reclamation), forestry and the responsible handling of nature and its ecosystems.

The utilisation of geothermal resources is controlled to minimise the risk of depleting the resource, thus promoting the sustainable utilisation of natural resources. The provisions for the utilisation of water resources are also well defined and regulated to prevent any negative impact on the soil, ecosystems and society in each operational area. The use of fossil fuels is recorded and limits are set to reduce consumption. Information is collected on the Company's actions with regard to land reclamation and forestry as well as its interaction with the natural environment and ecosystems.

The Icelandic Falcon *Falco rusticolus islandicus* is a large, fast flying bird of prey with a wing span of 130 cm. It is a resident bird in Iceland and there are believed to be 3–400 breeding pairs in the country. The falcon's main food source is the Ptarmigan but it also hunts other birds such as the Blackbird and various waders. The adult falcon has a permanent point of residence but does not create a nest: it lays its eggs on the cliff edge or in the abandoned nest of the Raven. The bird is protected.

Utilisation of Natural Resources

Utilisation of geothermal energy

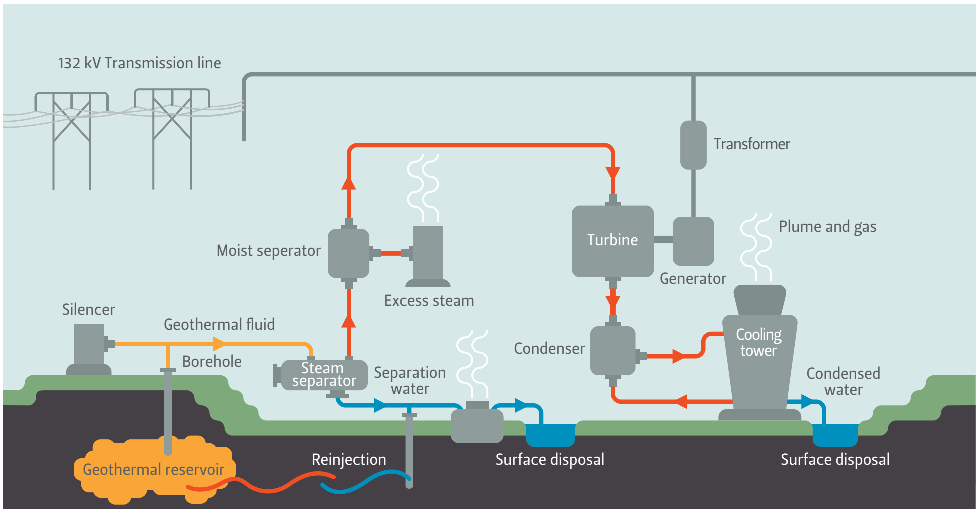
Landsvirkjun owns and operates two geothermal power stations in the Mývatn area; the Krafla and Bjarnarflag Stations. In addition to generating electricity, Landsvirkjun operates a heat exchange station for Reykjahlíd heating utility and provides warm water and steam to the nature baths at Jardbadshólar, and to local industry.

This utilisation of steam is a step towards increasing the overall utilisation of natural resources and engaging in the many opportunities for better utilisation. Examples of better utilisation include the use of geothermal heating to support greenhouse production of vegetables and the production of fuel. The design process for the new geothermal station at Bjarnarflag included the use of more efficient equipment than that used in older stations; it will be possible to utilise 180°C separated water and non- condensable (NC) gases (i.e. carbon dioxide).

During the utilisation process for generating electricity, using geothermal heat in high-temperature fields, geothermal fluid is extracted from the boreholes. Geothermal fluid is composed of steam, water and the various gases present in the steam. Every effort is made during operations to utilise the geothermal fluid extracted from the geothermal system in an efficient manner. After utilisation the fluid is disposed of by re-injecting it back into the geothermal reservoir, by releasing it deep into the groundwater stream or by releasing it at the surface. **Figure 5** provides a simplified overview of the utilisation of geothermal heat for electricity generation.

The main environmental effects from geothermal utilisation are disturbances caused by construction work and material extraction, the visual impact of man-made structures and steam release, noise pollution, the release of gases into the atmosphere

Figure 5 — Overview of the utilisation of geothermal heat for electricity generation.

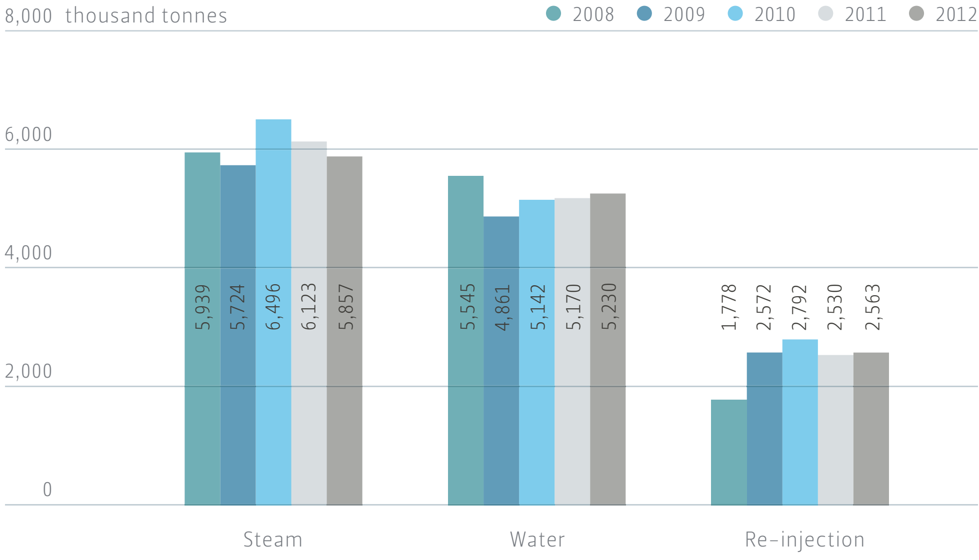


and chemicals into surface waters. Any change to groundwater levels can affect geothermal surface activity. The reduction of the groundwater table, due to utilisation, can increase surface activity and similarly increased precipitation can increase the groundwater level and thereby decrease surface activity. Furthermore, the removal of geothermal fluid from the geothermal reservoir can cause minor land subsidence, within the utilisation area, and increase seismic activity in the geothermal reservoir.

Landsvirkjun provides hot water and steam to the nature baths and to local industry in the Mývatn area as a step to better utilising natural resources.

To ensure the sustainable utilisation of this resource, the high temperature geothermal system in the Mývatn area is monitored regularly. The recording of the volume of geothermal fluid extracted from the system is based upon the capacity evaluation of boreholes and the duration of flow testing. Generally, the boreholes are measured once or twice per year, but can be measured more frequently if the need arises. The capacity of each borehole is calculated based on these measurements and the total annual power generation is estimated. A distinction is drawn between boreholes that are in operation, i.e. connected to a power station to generate electricity, and boreholes used for research. After the geothermal fluid extracted from boreholes in operation has passed through steam separators, the steam is utilised for electricity generation and the water is either disposed of at the surface or returned into the geothermal reservoir via re-injection. The energy content, or enthalpy, of the geothermal fluid

Figure 6 — Quantity of steam and water utilised for electricity generation in Landsvirkjun's geothermal stations between 2008 and 2012 and the quantity of separated water re-injected during this period.



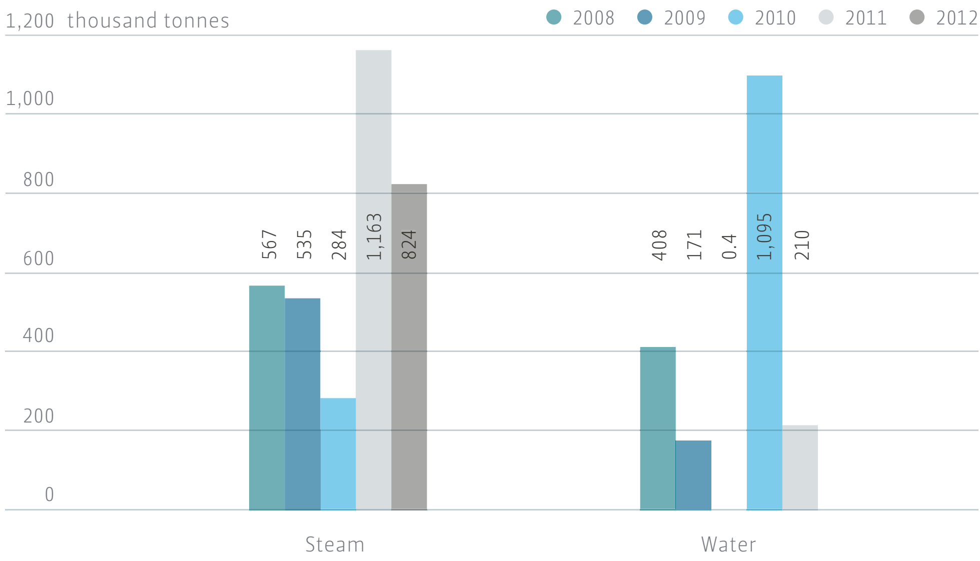
is typically calculated based upon power measurements, but samples are also collected from the geothermal fluid for chemical analysis. The operation of geothermal power stations depends on the quality of the geothermal fluid, and many design parameters are entirely dependent upon the chemical composition of the geothermal fluid. The risk of scaling and corrosion is particularly relevant. Samples of geothermal fluids are analysed annually to monitor these factors and additional samples are collected more frequently if the need arises.

Electricity generation

Figure 6 shows the quantity of geothermal fluid (water and steam) utilised to generate electricity during the period 2008-2012. In 2012, 5,857 thousand tonnes of steam were used to generate 490 GWh of electricity and released 5,230 thousand tonnes of condensed and separated water in the process. Of this, 2,563 thousand tonnes of separated water was re-injected into the geothermal reservoir. The volume of water in geothermal fluid has remained steady throughout the past few years but the amount of steam fraction has decreased after a considerable increase in 2010 when a new borehole was introduced. The deterioration of production within the boreholes is the main reason for this decrease. The temperature of the borehole affects the proportion of water and steam in the geothermal fluid. A lower temperature means a decrease in the energy content of the geothermal fluid and an increase in water loss.

Separation water from Krafla has been disposed of via deep ground re-injection since 2002. Re-injecting separation water from geothermal power stations reduces the environmental impact of electricity generation at the surface and supports the sustain-

Figure 7 — Quantity of steam and water released by exploratory drilling by Krafla and Bjarnarflag between 2008 and 2012.



able utilisation of the geothermal system. Re-injection reduces the quantity of contaminating compounds, for example heavy metals that are released into surface waters. Sufficient knowledge about the reservoir, before the onset of reinjection, is required to avoid any cooling of the geothermal reservoir. The results of research conducted on the effects of re-injection and modelling show the impact of electricity generation on the geothermal systems, with regard to drawdown, temperature and the chemical composition of the geothermal fluid. The experimental re-injection of approximately 60 l/s in the Krafla area from 2002-2008 did not have any effect on the capacity of nearby boreholes. Work has been on-going since 2008 to increase the capacity of pumps used for re-injection. Deep disposal trends remained stagnant between 2011 and 2012. Equipment capable of pumping 105 kg/s or 80% of separated water to a depth of over 2000 metres was taken into use at the end of 2012.

Research

Extensive exploration drilling has been completed in the past few years as a result of the proposed geothermal station projects in the northeast of the country. **Figure 7** shows the quantity of geothermal fluid utilised as a result of exploration drilling in 2008-2012. Exploratory drilling was much less in 2012 than in the previous year (there is no re-injection associated with the exploration drilling).

Nine boreholes were excavated between 2006 and 2009 as a result of the proposed expansion of the Krafla Station (Krafla II). Four of these have been connected to the steam utility at the Krafla Station. Research is being conducted on the utilisation of three more boreholes. Two of the nine boreholes will not be utilised by Krafla Geothermal Station; one cannot be used due to distance and the other as a result of its temperature. Three boreholes were drilled between 2006 and 2008 as a result of the proposed power station at Bjarnarflag. The estimated capacity of these boreholes is expected to be 30 MW.

Nine boreholes were drilled between 2002 and 2012 for research purposes in connection with Þeistareykir. There were changes to the ownership of Þeistareykir ehf. in 2012, when Landsvirkjun acquired 100% of the company. The amount of steam and water released as a result of the research on Þeistareykir in 2012 was 173 thousand tonnes of steam and 22 thousand tonnes of water.

Landsvirkjun has mainly focussed on preparation measures for geothermal sites in the northeast of the country. As a direct result of this, Landsvirkjun has not undertaken any drilling for boreholes in the Hágöngu area but surface research continues. There is a borehole in the area that was drilled in 2003.

Utilisation of water resources and reservoir management

Electricity generation in hydropower stations is controlled by steering the inflow of water from intake reservoirs and into the power stations. During the energy generation process every effort is made to maximise the utilisation of water stored in the reservoirs and to eliminate unusual fluctuations in flow rate, or sudden water level changes. Sudden changes in water level in reservoirs or in to the flow rate of rivers can have a negative effect on soil, on ecosystems

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The Nature of Geothermal Energy

Geothermal energy naturally stores tremendous amounts of thermal energy which accumulates in the bedrock over thousands of years. Thermal energy is maintained via a naturally occurring thermal stream which can differ in size and between areas. The thermal stream originates from two sources. On the one hand it is fed by the earth's core and on the other hand from magma that seeks out the earth's crust. The renewal of energy stores via thermal conduction occurs at such a slow rate that if measured on the scale of the average lifetime it would be deemed an endless source.

However, the renewal of energy sources in the high temperature thermal systems in Iceland is significant because of the size of the thermal stream; delivered by magma and capable of 'keeping up' with the harnessing of thermal energy within these areas. Moreover, the amount of thermal energy stored in the bedrock within the thermal system is generally so substantial that any harnessing of the area utilises only a small proportion of the available energy store.

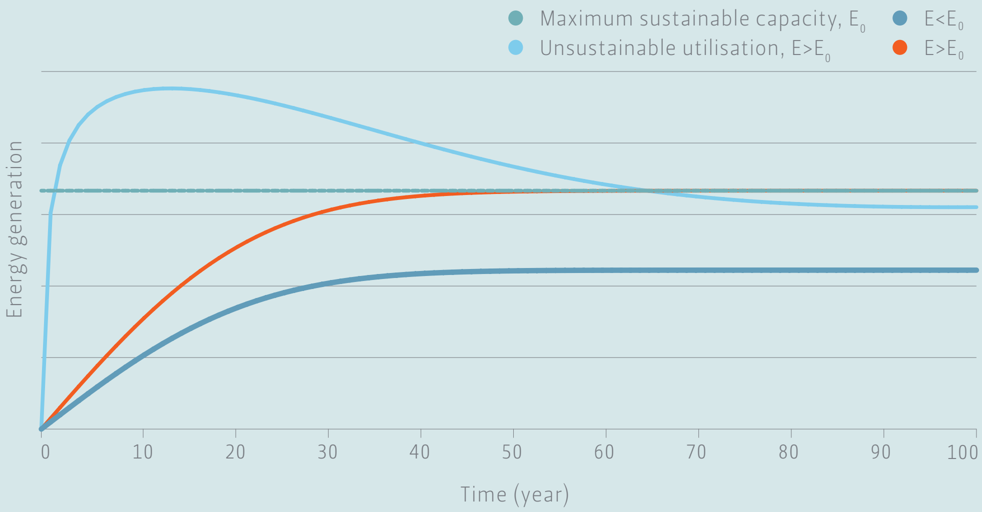
It is primarily the water source within the thermal system that must be maintained as the systems have variable water sources. A loss of pressure, as a result of water extraction from the thermal system can decrease the power of energy generation and can alter the surface activity of the thermal areas.

Landsvirkjun strives to ensure the sustainable utilisation of any thermal sources it is entrusted with. Sustainable utilisation is reliant upon a number of uncertainties; the size and nature of the thermal system and the evolution of energy technology. A specialist team appointed by the Ministry of Industries and Innovation, pertaining to the sustainable utilisation of thermal energy sources convened and assessed the following definition of the sustainable processing power of geothermal areas:

> Within each geothermal energy area and for each processing method/level there is a maximum operating level: E_0. When the processing method/level is less than the E_0 then it is entirely possible to extract energy from the system for at least 100 years. If the processing method/level is higher than the E_0 then it is impossible to extract energy for such a long period of time. Geothermal energy processing less than or equal to E_0 is defined as 'sustainable' whereas processing above the E_0 is not sustainable (Jónas Ketilsson et al, 2010).

The term "sustainable processing capability of geothermal energy" is explained further in Figure 8. The maximum sustainable processing capability of E_0 is uncertain in the initial part of utilisation and Landsvirkjun has therefore chosen to pursue the direction of approaching the sustainability target in smaller phases. The time between phases is utilised to collect data with regard to the systems reaction to processing and subsequently reviewing the processing method/level.

Figure 8 — Diagram of the concept "sustainable geothermal generating capacity" (Jónas Ketilsson et al. 2010)



Another method for utilising geothermal energy is to increase processing at a rapid rate and to surpass the maximum sustainable processing capacity. During this process the maximum capacity of the station is maintained temporarily (i.e. for 20 years) by drilling new boreholes. Maintenance drilling is discontinued when the thermal energy drops so dramatically within the geothermal reservoir that new boreholes cannot supply enough energy to be worthwhile. Eventually the processing slowly diminishes within the area until a new balance between processing and the renewal of the geothermal energy system is achieved.

This equilibrium in generation should therefore be close to the 'maximum sustainable capacity' level but is also reliant upon timescale, economic factors, technological advancement etc. There are indicators that this method is the most likely to achieve 'maximum sustainable capacity' and is also more efficient. An example of this type of production can be found in the Laugarnes system in Reykjavík; a low temperature system where a tenfold increase in production was achieved to create a new balance, which has remained stable since the 1970s. The Geysi area in California is another example where electricity generation temporarily rose to 2000MW and then decreased; it is now approaching the state of equilibrium and has a capacity of 750 MW. This process could be compared to that of the farmer maximising his milk supply by milking his cows as regularly as possible after they have given birth.

and on society. Landsvirkjun has sought out solutions to minimise these fluctuations, in cooperation with specialists and the local population. The reservoir management for all of Landsvirkjun's hydropower stations is defined in procedures on fixed limitations of water flow. Temporary limitations have also been established for river flows; salmon fishing in rivers and the flow rate of waterfalls. There were two deviations from the fixed limitations in 2012; both in the Sogid area (see more details in the chapter on environmental incidents).

Figure 9 shows a forecast from December, 2011 for Landsvirkjun's total water resources in 2012 and how they were utilised. The dark blue line shows the median content, which is an estimated average, while the red line is the measured real content. Hydrology is usually defined according to the 'water year', which is the period from the 1st of September to the 31st of August. Overall, the status of the water year 2011/2012 was good. The water budget for the year 2012 was satisfactory during the first 5 months of the year but the summer was below average, lasting until September. The water supply during the last few months of 2012 was unsatisfactory. In the beginning of 2012 the status of the distribution reservoirs was exceptional as 'drawdown' did not occur until the end of November in 2011. The winter was mild and the water flow was above average at all of Landsvirkjun's stations. The summer was rather dry and water flow was below average except for the water source from the glacier supplying Hálslón which was well above average in July and August. All distribution reservoirs filled successfully except for Þórisvatn (because of construction work at Búdarháls hydropower station). Drawdown began in Hálslón in late September and in the beginning of October in Landsvirkjun's other reservoirs. There was a dry period from the autumn and up until the New Year and this rapidly affected the distribution reservoir system; the reservoir stores at year-end were approx. 1000 GWh lower than they were at the beginning of the year.

Flow in the Jökulsá River in Fljótsdalur

Conditions outlined in the operational permit for Fljótsdalur Station state that Landsvirkjun shall steer surplus water supplies during the tourist season and attempt to reach the average flow rate in the Jökulsá river channel and the Kelduá river channel in July and August (in good water years). In dryer years, Landsvirkjun shall place an emphasis on maintaining the flow in the river channel of Jökulsá í Fljótsdal and River Kelduá, as long as there is surplus water running through the spillways.
As a result of the good water status in the summer of 2012; all the water from the Jökulsá River in Fljótsdal passed through the river channel from the 1st of June and up until the 9th of October and the summer was used to complete repairs on the dam at Hraunaveita.

The water flow in Jökulsá River in Fljótsdal during the summer of 2012 was natural water flow. **Figure 10** shows the measured summer water flow in the Jökulsá River in Fljótsdal during the summers of 2011 and 2012 in two areas; by the Hrakstrandarfoss waterfall (the highest waterfall in a row of waterfalls in Fljótsdal) and by Hóll above the Fljótsdalur Station (before the river merges with the outflow of the Fljótsdalur Station: **Figure 11**). The water flow in the Jökulsá River in Fljótsdal was a healthy average well into and beyond the summer of 2012, with the exception of two weeks of low flow rate in June. This is a transition from the year before but the average flow in August is similar in both years and the average water flow rate corresponds between 1962 and 2007.

Figure 9 — Estimated distribution sources for the operational year 2012 and measured real values for the year.

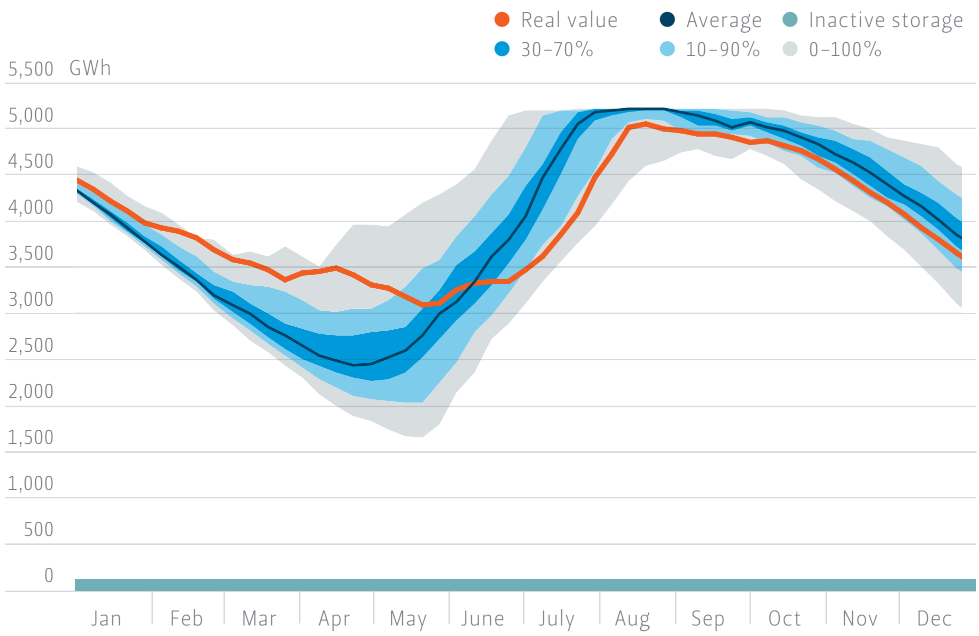


Figure 10 — Flow in River Jökulsá í Fljótsdal at Hóll and Hrakstrandarfoss Waterfall in the summers of 2011 and 2012.

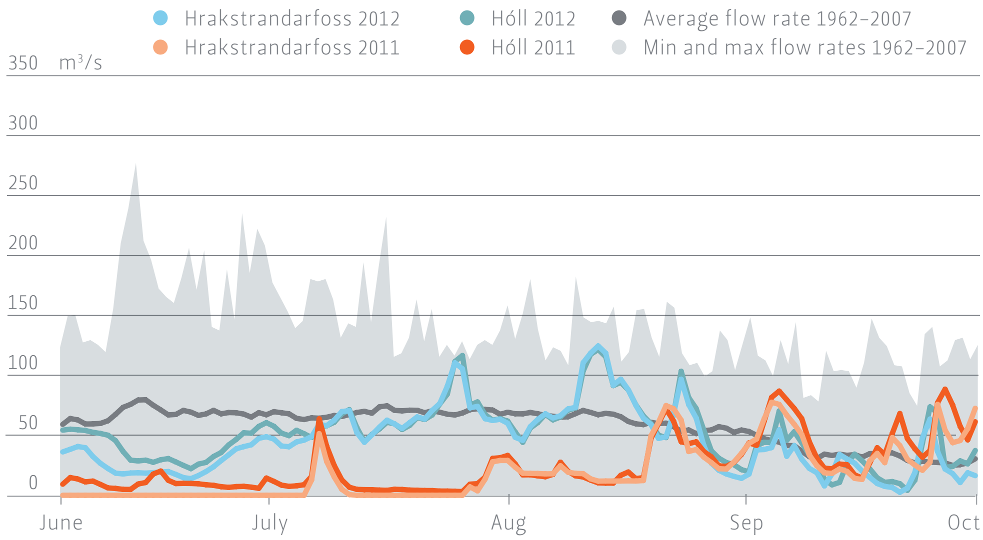
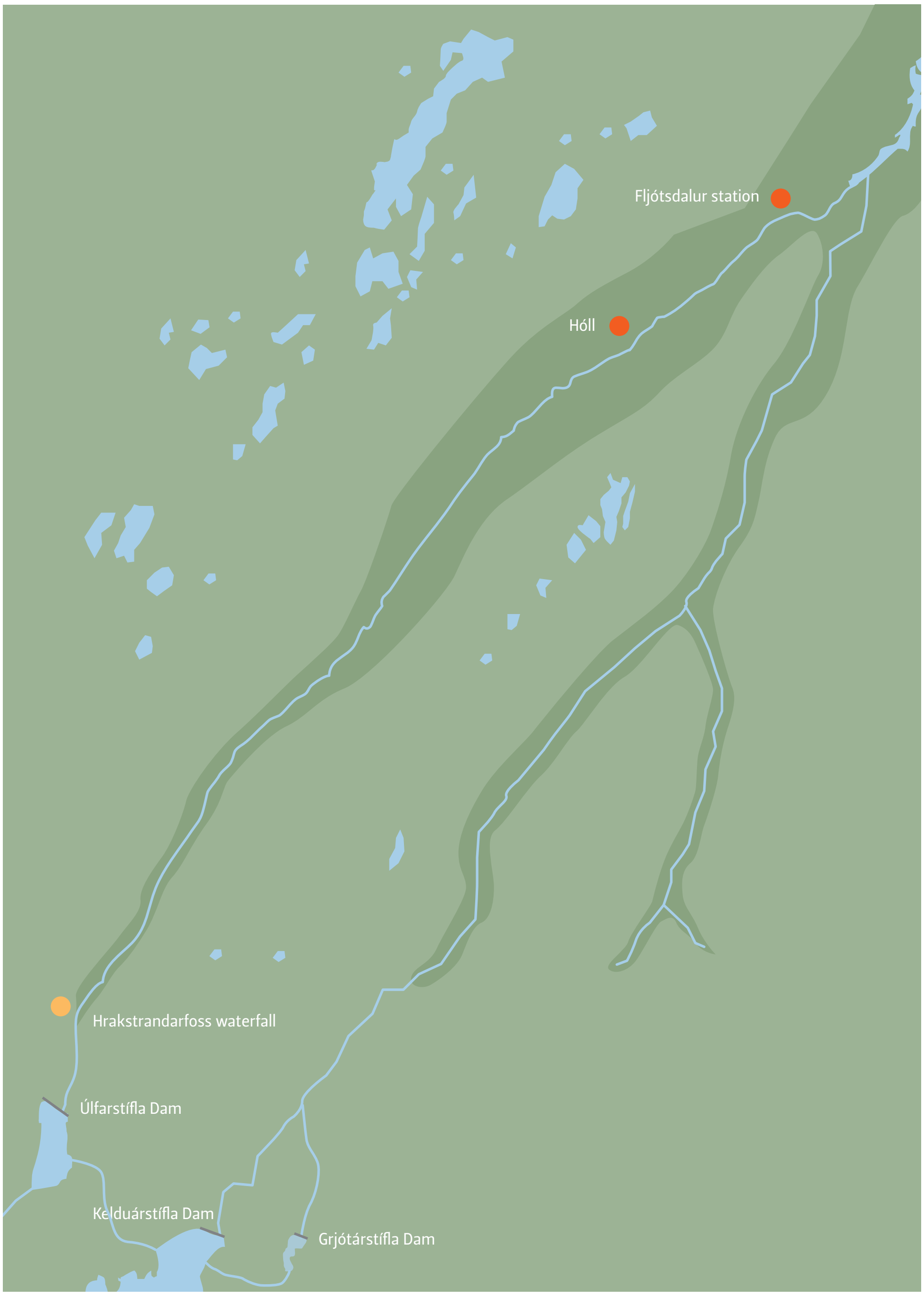
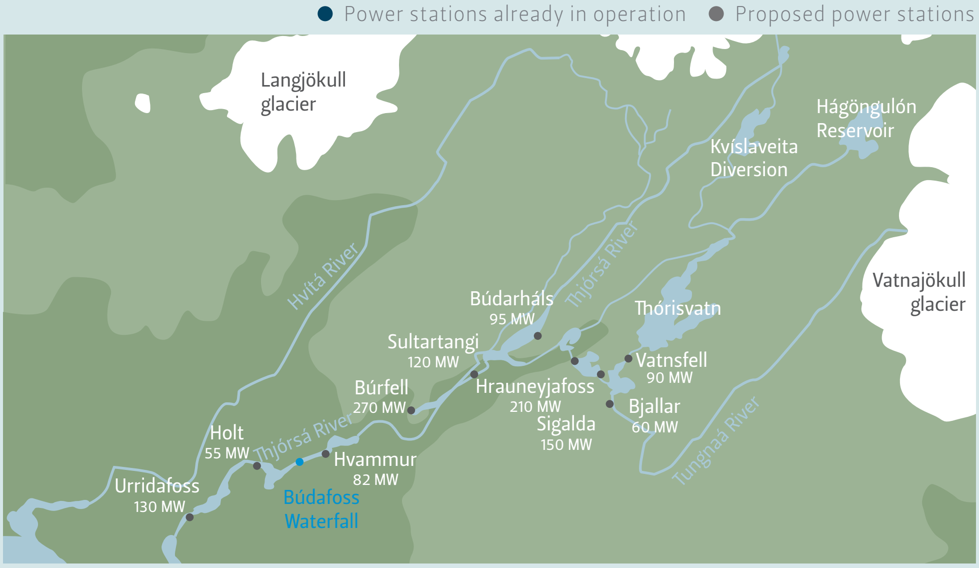


Figure 11 — Water flow in Jökulsá River at Fljótsdalur is measured by Hrakstrandarfoss Waterfall and by Hóll.



Research on Fish in the Thjórsá Water Catchment Area

Figure 12 — Power stations already in operation and proposed power projects in the water catchment area of Thjórsá and Tungnaá.



Extensive research on the fish stocks in the Thjórsá River has been on-going since 1973. The research objectives include monitoring possible changes to the river ecosystem and assessing the effects on fish stock with a view to developing mitigation measures (pertaining to the proposed hydropower stations in the lower regions of the Thjórsá River).

Fish migration

The salmon stock in Thjórsá is large and the average catch in the river between 1991 and 2010 was approx. 3000 salmon. In the last ten years there has been a significant increase in angling activity and the average catch between 2006 and 2010 was 5000 salmon (Figure 13). The construction of the hydropower stations in the upper regions of the water catchment area had a substantial effect on the water flow in the lower regions of the river and sediment levels decreased. This has created a more favourable environment for the salmon stock, supporting its growth and an increase in fishing in the last few years. A fish ladder was constructed by Landsvirkjun in 1991 by the Búdafoss Waterfall. Migration has increased over the ladder from year to year and salmon now spawns above the ladder (Figure 14). The largest natural habitat for the salmon can be found between Búdafoss and Urridafoss Waterfalls and juveniles raised in the river must pass the proposed station at Urridafoss to reach the sea.

The effects of power stations on fish stocks in the absence of mitigation measures

If mitigation measures are not implemented, in connection with the proposed power projects then the dams for the intake reservoirs will preclude fish from migrating up-river. New power stations could delay the migration of salmon, possibly increasing stress levels in the fish and could therefore reduce spawning activity. Trauma to migrating smolt caused by passing through the station turbines is also an issue for consideration.

Proposed mitigation measures

The Institute of Freshwater Fisheries has indicated that the measures most likely to reduce the effects of the proposed power projects on salmon stocks are: the guarantee that the river channel of Thjórsá will not run dry in any area and that a minimum flow rate is ensured in areas where important spawning, nursery and migration habitats are present.

Recommendations for a fish ladder by the proposed Urridafoss and Hvammur hydropower stations have been put forward as experience of the fish ladder by Búdafoss Waterfall has proven successful. The design of the power stations has also been altered. The intake reservoirs by the Urridafoss and Holt hydropower stations have been lowered which increases the water flow rate in the reservoirs.

This will have a positive effect on migration factors, living conditions and the migration of smolt back into the sea. A specially designed juvenile bypass system would be installed at Urridafoss. The head is highest there and all smolt in the river must pass through the station. Landsvirkjun has also expressed its willingness to construct a similar juvenile bypass system by Hvammur hydropower station which would provide much needed experience of such a project before construction begins at Urridafoss.

Figure 13 — Salmon fishing in Þjórsá and tributaries; by net and by angling between 1951 and 2011.

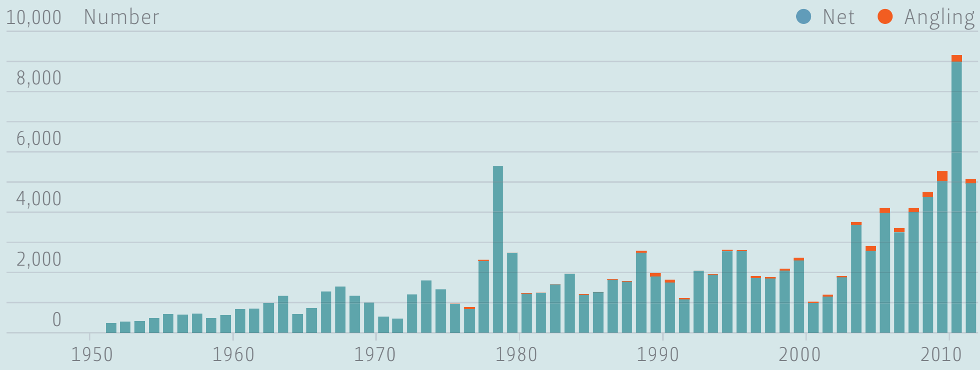
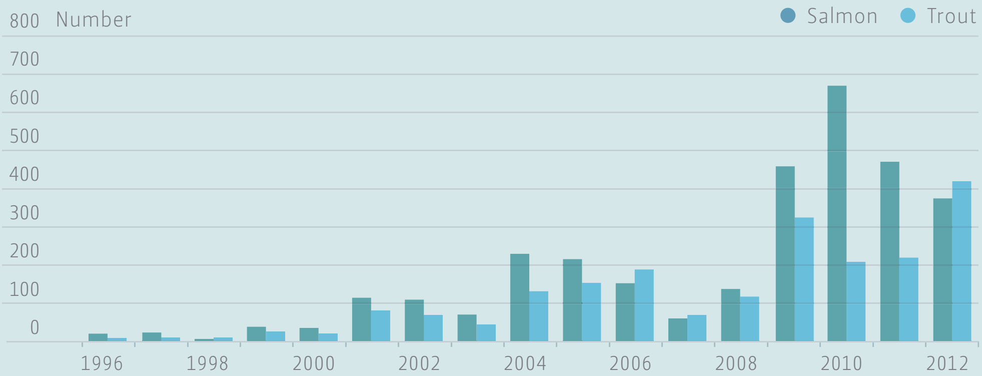


Figure 14 — Salmon and trout migration via the fish ladder at Búdafoss 1996 – 2011.



Erosion and sedimentation

Steering water in river channels and reservoirs combined with the stress caused by wind, wave and water, can cause erosion on the banks of reservoirs. Sediment deposits in glacial rivers can result in the formation of gravel banks in reservoirs and by their coastline. Changes to the waterways are mapped and immediate action is taken when the need arises. No such actions were needed in 2012.

Regular research is conducted on the Hálslón and Blöndulón reservoirs. A number of factors are monitored including soil stabilisation, vegetation reinforcement and coastal monitoring. The development of coastal erosion and the possible formation of sand fronts as a result of sand encroachment are monitored in the Hálslón area. Research and monitoring has been on-going since 1993 at the Blöndulón Reservoir. Particular emphasis is placed on monitoring erosion on the banks (detachment), sand blown into the area from the beach and on monitoring the fertiliser distributed in sand eroded areas and vegetation reinforcement in these same areas.

Regular research is conducted on soil stabilisation and vegetation reinforcement in the Hálslón and Blöndulón reservoirs

Fuel

Landsvirkjun aims to reduce greenhouse gas emissions (GHG) and the reduction of fossil fuel consumption is a part of this objective. The burning of fuels causes the release of various gases, including GHGs, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O). Carbon monoxide (CO) and suspended particulate matter are also released and are detrimental to the environment. Fossil fuels are used for vehicles and various machines in Landsvirkjun's operations. Oil is also used to operate a number of diesel generators which amongst other things supply lighting equipment in the area and are used for the operation of valve systems in the highlands. The proportional division of the consumption of fossil fuels by Landsvirkjun in 2012 can be seen in **Figure 15**. Diesel oil accounts for 91% of consumption (similar to last year) and petroleum consumption accounts for much less; or 9%. In 2012, 504 kg of methane was utilised to power cars at the Company headquarters.

The total consumption of fossil fuels during Landsvirkjun's operations between 2008 and 2012 can be seen in **Figures 16a** and **16b**. The consumption of petroleum has remained stable between 2008 and 2012. Petroleum consumption has decreased at the various power stations and consumption levels are at their lowest since 2008. However, petroleum consumption increased considerably in the Project Planning and Construction Division in 2012, mainly as a result of construction activity. Use of diesel has remained stable in the last three years and its consumption is stagnant at the various power stations. **Figure 17** outlines diesel consumption between 2008 and 2012 divided between areas of operation. The highest consumption rates were in the Thjórsá area as has been the case in recent years. This is mainly due to the fact that this is one of Landsvirkjun's largest power generation areas and the operational area is extensive.

The fuel consumption of the Project Planning and Construction Division is mainly related to construction work at Búdarháls and research on geothermal energy in the northeast of the country.

Figure 15 — Fuel usage in Landsvirkjun's operations in 2012.

Figure 16a — Petroleum use in Landsvirkjun's operations 2008–2012.

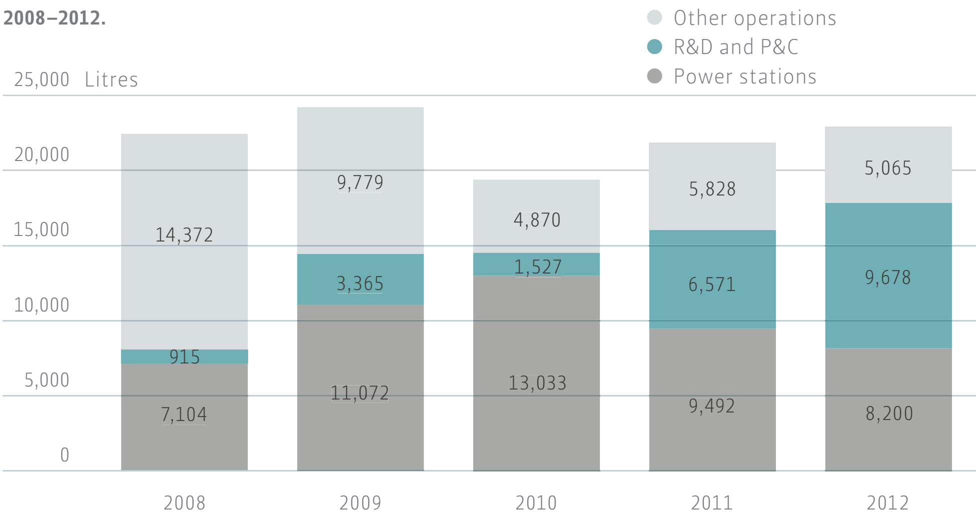


Figure 16b — Diesel oil use in Landsvirkjun's operations 2008–2012.

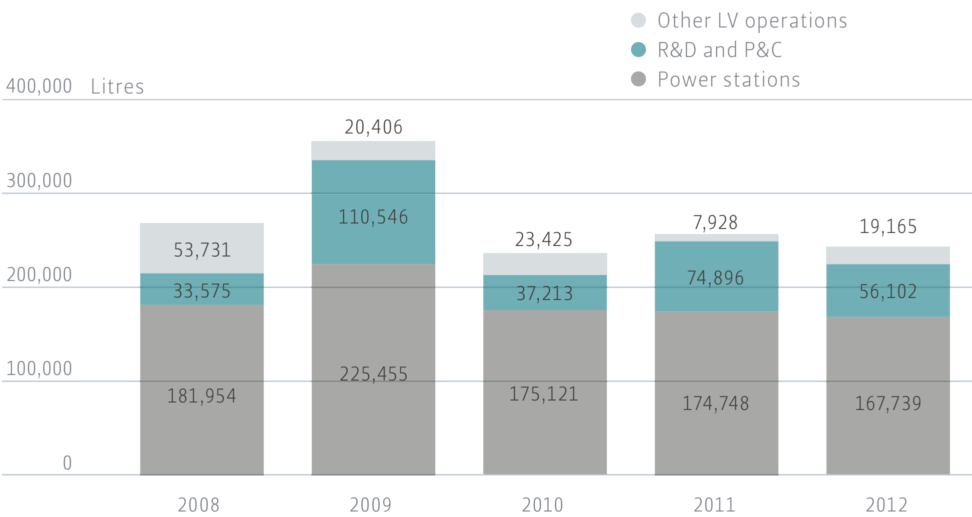


Figure 17 — Diesel oil consumption in Landsvirkjun's operations between 2008 and 2012; by station as well as average consumption at each base during the same period.

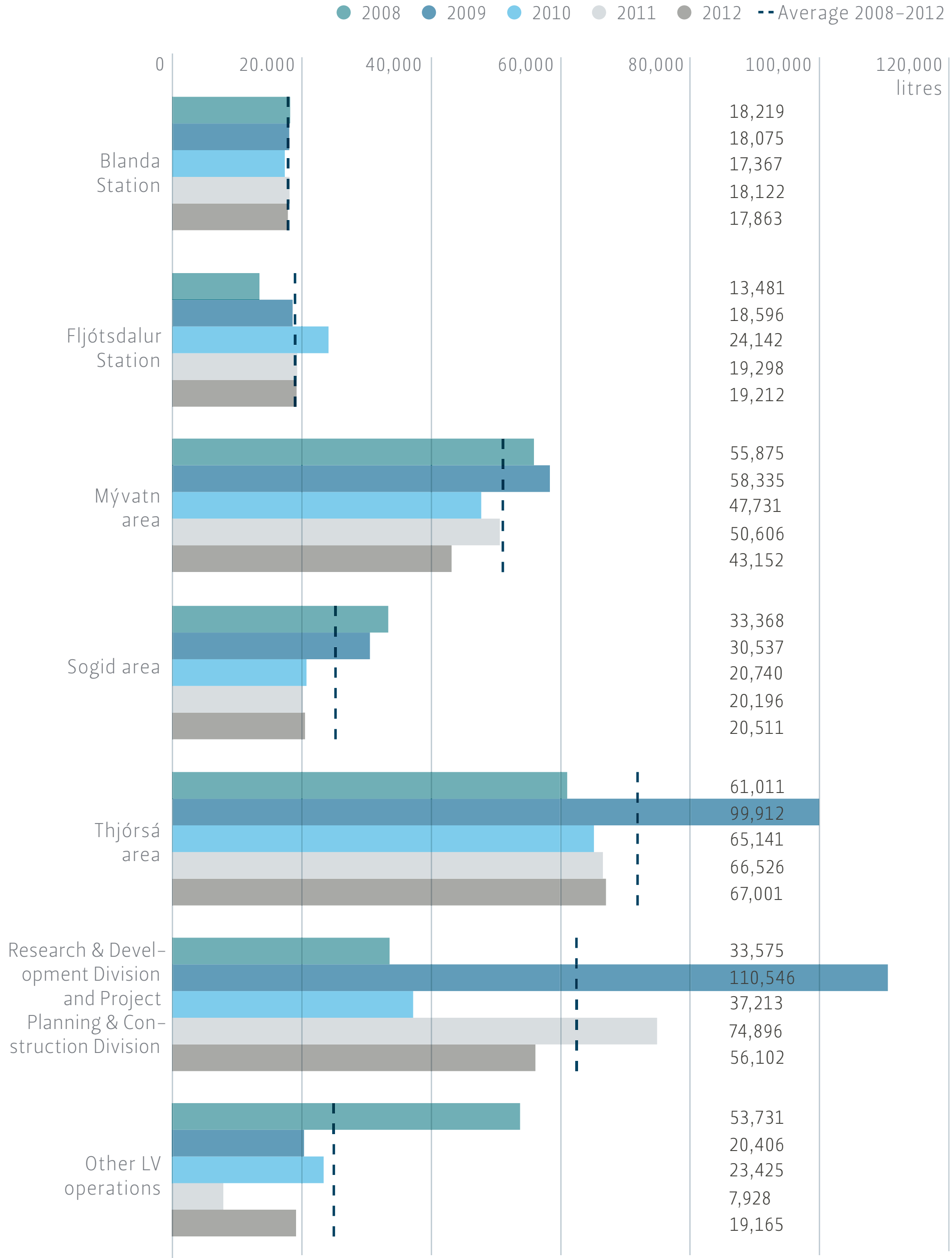


Figure 18 — Pamphlet on requirements and recommendations for contractors and service agencies with regard to environmental and safety issues.

Disturbance to land and cooperation and interaction with nature and its ecosystems

All of Landsvirkjun's major construction works cause land disruption which can have an impact on both nature and the ecosystem. Land disruption is caused by the construction of reservoirs, dams and diversions, by the construction of roads and underground cables, as well as mobilisation and the drilling of boreholes. The chemical contamination of soil or water can be caused by oil leaks from oil storage tanks, vehicles, equipment and by the handling of hazardous and waste materials.

Environmental threats are assessed in all of Landsvirkjun's projects and necessary action is taken to reduce the likelihood of any such incidents occurring. In order to ensure the implementation of the environmental and safety policy by all employees, Landsvirkjun has released a set of requirements and recommendations on environmental and safety issues that contractors and service agents are expected to follow.

Environmental threats are assessed in all projects carried out by Landsvirkjun and the appropriate action is taken to reduce the likelihood of any such incident occurring.

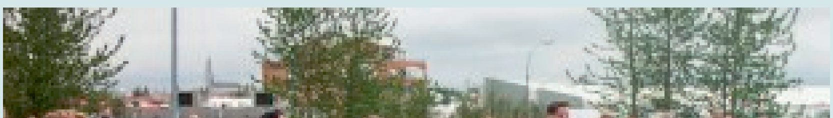
Clean- up project at Kárahnjúkar

Figure 19 – The Impregilo premises during construction (top photograph) and after the clean-up (bottom photograph).

The construction area at the Kárahnjúkar was extensive and as a result, disturbance to the land was inevitable. Once construction work was completed, the clean-up project began and was on-going between 2008 and 2011. The aim of the clean-up project was to reinstate disturbed land to such a point that it would become indistinguishable from the untouched areas around the site. Figures 19 and 20 show the Impregilo premises during construction and after the-clean up.

More information on the clean-up of construction areas can be accessed at http:// www.sjalf-baerni.is in index 2.8: Clean-up of Mines and Material Mounds and Landsvirkjun's report LV-2012/011.

Figure 20 — Work site by one of the intake tunnels during the construction (top photograph) and the same area after clean-up (bottom photograph).



Reindeer

The East Iceland Natural History Institute is responsible for monitoring reindeer numbers in summer grazing areas under the auspices of the government. Part of the research requires an assessment of the health of reindeer and other factors used to decide on hunting permit numbers. The operational permit requires Landsvirkjun to supply additional monitoring, pertaining to the effects of Kárahnjúkar. Landsvirkjun has been responsible for the yearly monitoring of reindeer numbers within the affected area of the station; the area north of Brúarjökull glacier (since 1993) which the School of Engineering and Natural Sciences of the University of Iceland has attended to (Figure 21).

The numbers are recorded during the spring time via aerial photography. The results show that the less snow during the spring period the more reindeer stay within the area and numbers increase well into June. Cold periods with snow and rain can create problems as the reindeer abandon the area temporarily.

Reindeer numbers increased in the area between 1995 and 2000 but then decreased slowly until 2007 (Figure 22). The latest figures show a slow increase within the Kárahnjúkar area. Despite an increase in numbers within the Kárahnjúkar area the total number of reindeer residing to the west of the glacier during the first part of the summer remains similar to what it has been (in the Kringil Rivers and to the north of them).

In addition to the monitoring conducted by the University of Iceland, monitoring has also been conducted in reindeer calving areas in the Snæfellsness wilderness. This began in the spring of 2005 and is overseen by the East Iceland Natural History Institute. The aim of the monitoring is to assess whether or not the construction work in the affected area of Kárahnjúkar has had any effect on calving trends such as their choice of calving area, pregnancy duration and the number of offspring.

A number of variables pertaining to the distribution of animals and calving trends have been recorded since monitoring began. The reindeer seem to abandon the area during the calving period. However it is difficult to assess whether this comes as a result of human intrusion in the area or as a result of their choice of highland area.

Figure 21 — Research area at Snæfellsöræfi and Fljótsdalsheidi.

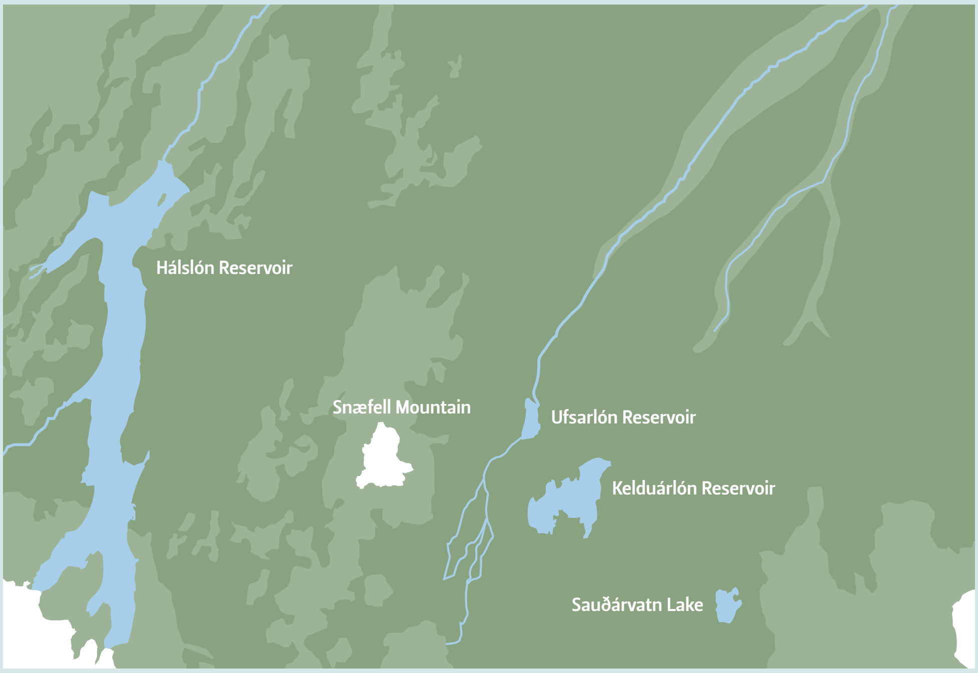
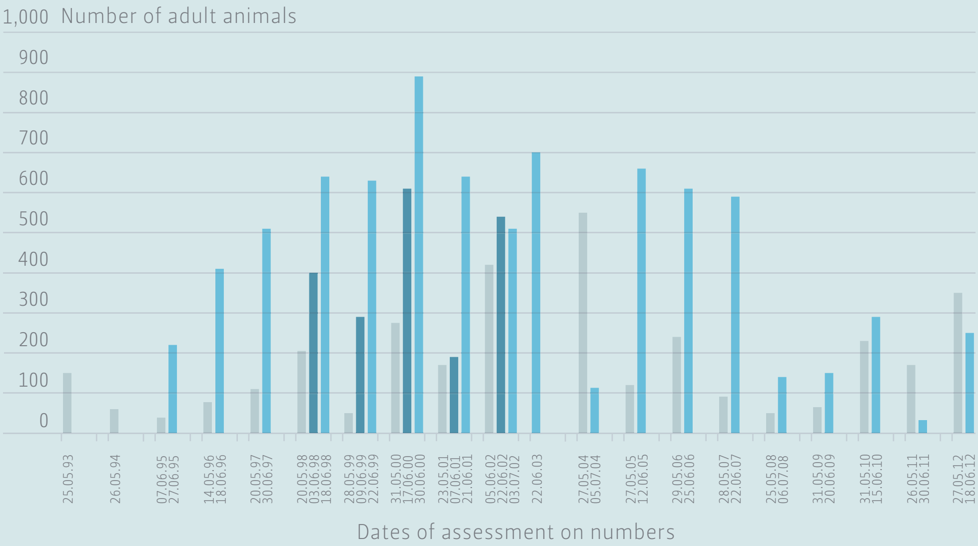


Figure 22 — Results of survey on reindeer numbers. The light blue columns are the results from the calving period at its highest. Other columns are results from the presence of reindeer in the area at any given time.



Land Reclamation, Re-forestation and Carbon Binding

Landsvirkjun has been responsible for extensive land reclamation and re-forestation efforts in the neighbouring areas of its stations for the past 45 years; both independently and in cooperation with others including the Iceland Forest service, the Soil Conservation Society of Iceland, Forestry associations and local residents. The total amount of land reclaimed as a result of Landsvirkjun's efforts is 140 km^2 (Hugrún Gunnarsdóttir, 2009).

The actual binding of carbon dioxide (CO_2) in Landsvirkjun's forest areas in 2011 was 670 tonnes CO_2 equivalents

The aim of land reclamation is to reinstate land quality, to reduce disturbance to vegetated areas and to stop soil erosion and vegetation destruction. Climate change has also affected Landsvirkjun's utilisation of land reclamation with a view to carbon binding measures.

Landvirkjun aims to be a carbon neutral company and is in the process of outlining a plan in order to achieve this goal. It would be preferable to achieve this via extensive domestic measures. Assessments must be carried out to estimate the accurate rate of carbon binding in vegetation and soil.

An agreement was reached in 2010 with the Soil Conservation Service of Iceland and the Iceland Forest Service that Landsvirkjun's land reclamation areas would be a part of the national assessment of carbon binding. The evaluation was built on internationally recognised assessment methods, took place in 2010 and 2011, and will be repeated every five years. This evaluation will offer a more accurate assessment of the efficiency of carbon binding than methods used in previous years. The results were analysed in 2012 and documentation on the re-forestation areas was completed. The results for the land reclamation areas are nearing completion.

Some of Landsvirkjun's main land reclamation areas can be found all over the country including Audkúlu and Eyvindarstadarheidar by the Blanda Station, the Krákárbotnar, the Mývatn area, Jökuldalsheidi and land reclamation areas pertaining to the Fljótsdalur Station, re-forestation areas in the Sogid area and re-forestation and land reclamation areas in the Thjórsá and Tungnaá River areas.

The results of the evaluation on Landsvirkjun's re-forestation areas show that they did not fulfil all the stringent international standards with regard to the minimum size of forests (0.5 hectares). The density of trees should be more than 10% and the minimum height of trees should be 2 metres (Arnór Snorrason, 2011). The re-forestation measures in Búrfell were not included as Landsvirkjun's involvement in the scheme has not been outlined. The total surface area of Landsvirkjun's re-forestation areas is 135 hectares which was previously estimated to be 260 hectares. The actual binding of carbon dioxide (CO_2) in Landsvirkjun's forest areas in 2011 was 670 tonnes CO_2-eq. This means that binding per hectare is approx. 5 tonnes CO_2-eq. This carbon binding is lower than previously estimated by Landsvirkjun as in this case the carbon binding is being conducted in young re- forestation areas. Mean - coefficients (5.9 tonnes CO_2/hectare) were used for carbon binding in re-forestation during the forests lifetime. As anticipated, the measurements showed significantly less binding in young forest areas than in older forest areas.

Binding could therefore be expected to increase considerably in this 135 hectare forest area owned by Landsvirkjun, in the near future. For more information see the report released by Landsvirkjun LV-2012/062.

The evaluation of land reclamation areas owned by the Company is nearing completion and preliminary findings show that carbon binding in lowland areas is higher than expected. The figures from the highland areas such as the Jökuldalsheidi area have not been confirmed. It is therefore still unclear if the Landsvirkjun total land reclamation area is as large as previously estimated.

Despite the fact that carbon binding via land reclamation is significantly less than that achieved via re-forestation; land reclamation has more weight in Landsvirkjun's green accounting. This is mainly due to the fact that the land reclamation areas (140 km^2) are much more extensive than the re-forestation areas (135 hectares). Since the 'real value' for carbon binding in Landsvirkjun's land reclamation areas is still unclear the decision was made to assess carbon binding for 2012 using the system previously used (estimated coefficient values). According to this method the estimated carbon binding achieved via land reclamation is 22,000 tonnes CO_2-eq per year.

The number of plants planted in the vicinity of Landsvirkjun's power stations between 2008 and 2012 can be seen in **Figure 23**. The number of plants planted in 2012 was significantly less than that of previous years whereas the number of plants planted between 2008 and 2012 varies.

In recent years planting work has been most active in the Thjórsá area but nothing was planted in the area in 2012 as a result of the late delivery of plants. The Hekla Forests were able to use the plants and planted them during the autumn period (not within the Landsvirkjun forest area). The reorganisation of re-forestation in the Thjórsá area is currently being undertaken in cooperation with the Hekla Forest. New areas have been identified for vegetation in the next few years. **Figure 23** shows the number of plants planted between 2008 and 2012 by Landsvirkjun's summer employees in cooperative projects that go by the name of "Many hands Lighten the Load". The scale of the planting project has decreased but Landsvirkjun participation in a variety of cooperative projects every year can vary. The carbon binding achieved as a result of these projects is not included in Landsvirkjun's green accounting as they are not under the auspices of the Company.

The total amount of commercial fertiliser distributed by or paid for by Landsvirkjun between 2008 and 2012 can be seen in **Figure 24**.

In addition to planting work and the distribution of commercial fertiliser Landsvirkjun also utilises garden waste from Landsvirkjun's power stations for land reclamation, as well as small amounts of seeds and manure which are spread annually.

The main figures on Landsvirkjun's land reclamation and forestry in 2008–2012 can be found in the Annex.

Figure 23 — Planting in the vicinity of the power stations and planting in connection with the project "Many hands Lighten the Load".

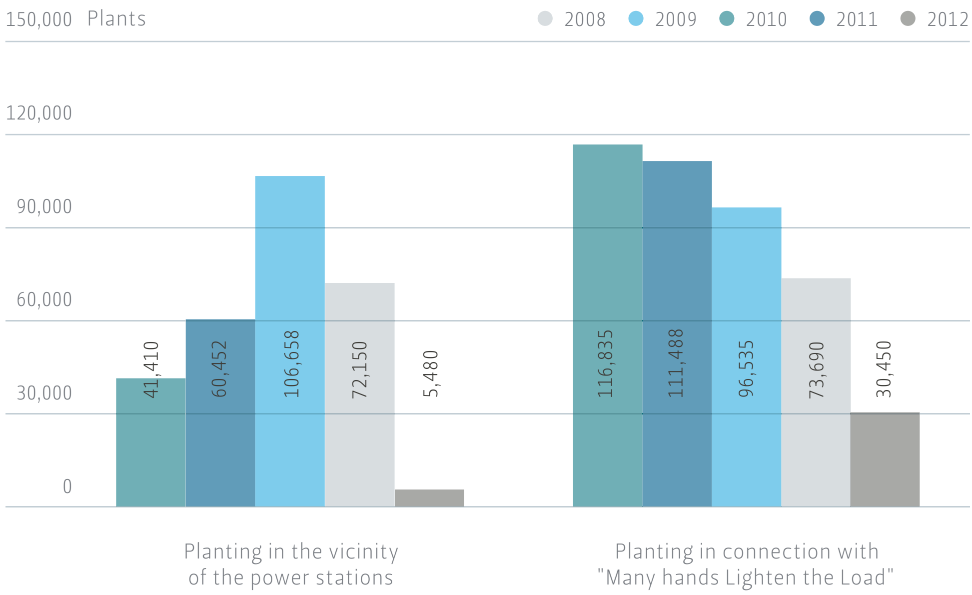
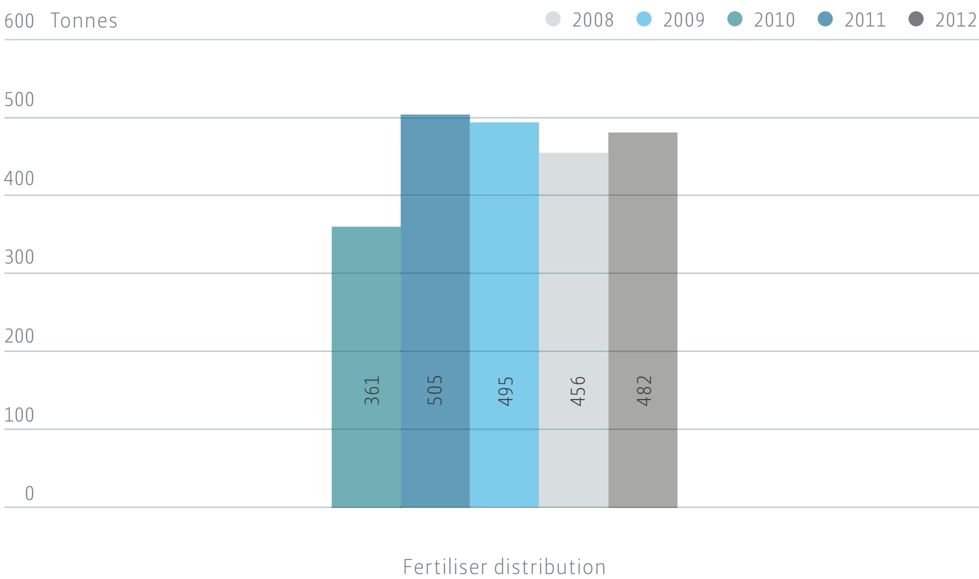


Figure 24 — Quantity of commercial fertiliser distributed between 2008 and 2012.



Surface Emissions from Geothermal Stations

The efficient use of natural resources and the reduction of polluted substances released into the environment are some of Landsvirkjun's main objectives.

Condensed and separation water (waste water) from geothermal power stations contain heavy metals and nutrients, the source of which is partly from geothermal fluid, and as a result of corrosion in machinery. The natural concentration of these substances varies between areas and is contingent upon volcanic activity and groundwater flow. High concentrations of these chemicals can have an impact on the ecosystem.

The effects of waste water from the Krafla and Bjarnarflag Stations are monitored annually

Waste water from Krafla Station is partly disposed of into surface waters and partly re-injected into the geothermal reservoir. The aim of re-injection is to maintain pressure in the geothermal reservoir and to reduce environmental impact. Water disposed of into surface waters flows into a nearby stream, Dallækur (Hlídardalslækur). Waste water released from Bjarnarflag Station is disposed of into Bjarnarflag Reservoir and disperses to the groundwater through a crevice in the western part of the reservoir.

The chemical composition of the geothermal fluid is analysed annually in all boreholes as well as in several other locations. The operation permit authorises the discharge of waste water with the proviso that the con-

Figure 25 — Groundwater flow and sampling stations monitoring the chemical composition of excess water from the Krafla and Bjarnarflag Stations.

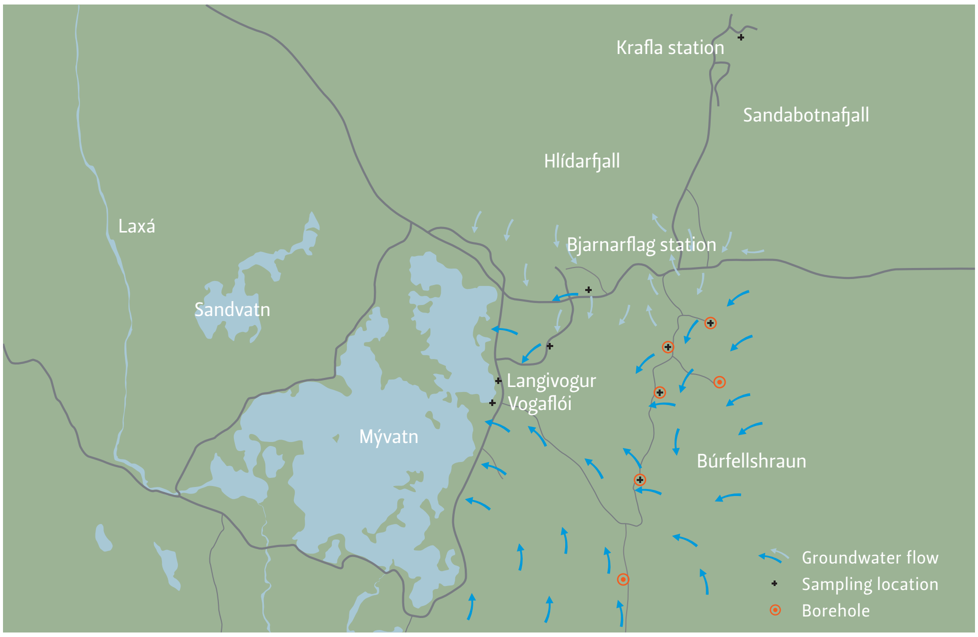
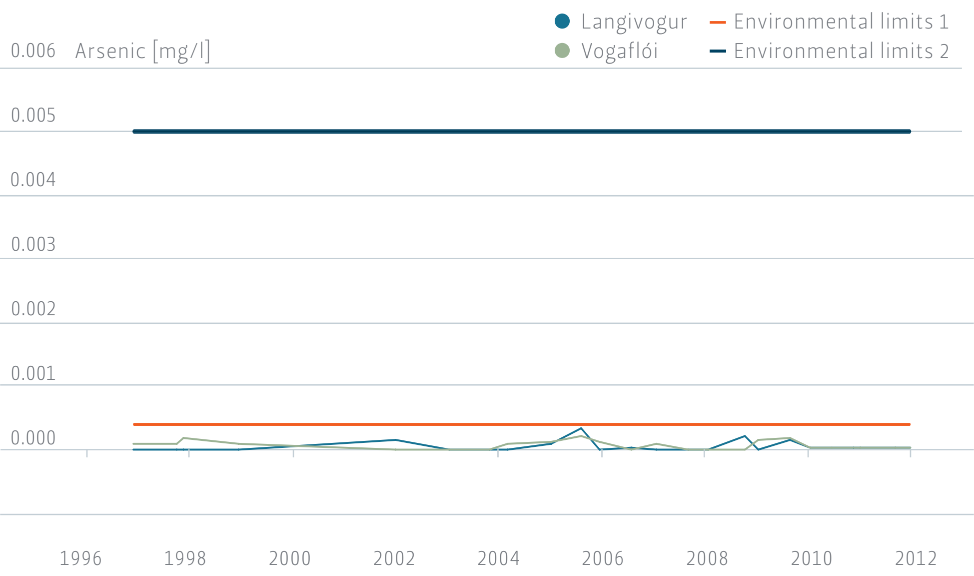


Figure 26 — Concentrations of arsenic in groundwater by Vogaflói and Langivogur and the environmental limits I and II: Regulation No. 796/1999 (Sigurdur G. Kristinsson et al. 2013).



centration of pollutants is below environmental limits set for environmental limit value I, when the water reaches Lake Mývatn. Limit values are defined in Regulation 796/1999 on water pollution prevention.

Every year, independent researchers monitor the effects of waste water from the Krafla and Bjarnarflag Stations. Samples are collected at monitoring stations (**Figure 25**) and the concentration of natural chemical elements, such as arsenic, are monitored. Waste water from Krafla and Bjarnarflag Stations is not believed to cause a significant environmental impact because of the high dilution potential in the area and high ground water flow. Research and measurements have shown that the impact from waste water decreases quickly and the concentration of polluting substances in the water is below limit values, defined in regulations when the water reaches Lake Mývatn (Sigurdur G. Kristinsson et al., 2013; Halldór Ármannsson and Magnús Ólafsson, 2002). The Environment Agency receives an annual report with results from measurements. In case of deviations or unexpected results the monitoring plan is revised in cooperation with the Environment Agency.

Figure 26 shows the concentration of arsenic in groundwater samples collected at Langivogur and Vogaflói in 1997–2012 at Lake Mývatn. The figure shows that the concentration of arsenic is well within the limit values for environmental group I (0.4 µg A s/l) at both locations during that period. More detailed information on discharge at surface from geothermal power stations can be found in the Annex.

Waste

It is Landsvirkjun's objective to increase the amount of recycling and thereby reduce general unsorted waste that is landfilled or incinerated.

Quantity and type of waste

It could be said that overall satisfactory results have been achieved in the sorting and recycling of waste from Landsvirkjun's operations. The total quantity of waste generated in 2012 amounted to approx. 177 tonnes, which is a substantial decrease from the previous four years. Approx. 80% of the waste went to recycling or re-use and 20% was disposed of. The type and composition of waste generated in 2012, by waste category, is shown in **Figure 27**.

The amount of unsorted waste in all of Landsvirkjuns operational areas between 2008 and 2012 can be seen in **Figure 28** (as well as the averages for the same period).

In recent years, the amount of unsorted waste has decreased in all of Landsvirkjun's operational areas. The greatest quantity of unsorted waste originated from Fljótsdalur Station as a result of clean-up efforts in the construction area for the Kárahnjúkar Hydroelectric Project. This operation has been on-going since 2010 and was still active in 2012. There were changes in the Sogid area this year that led to the temporary discontinuance of waste measurements. It is therefore assumed that the amount of unsorted waste from the Sogid area is similar to that of the last year, and so the figures shown in this report are those from 2011.

The registration of unsorted waste form the Krafla Station was unsatisfactory in 2009 and 2010 and so the amounts for this period have therefore been estimated to be equal to that of 2011.

Figure 27 — Percentages for waste composition in Landsvirkjun's operations in 2012; divided by type.

	%
Waste for recycling/ reuse	
Earth and minerals, glass and porcelain	31
Metals and various equipment	21
Timber	9
Paper, cardboard & packaging	7
Organic waste	7
Hazardous materials	3
Tyres	<1
Plastic	<1
Printing cartridges	<1
Household items	<1
Waste for disposal	
Waste for landfill	17
Waste for incineration	4

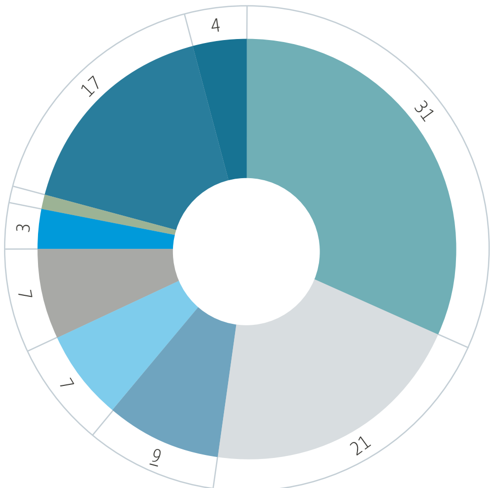
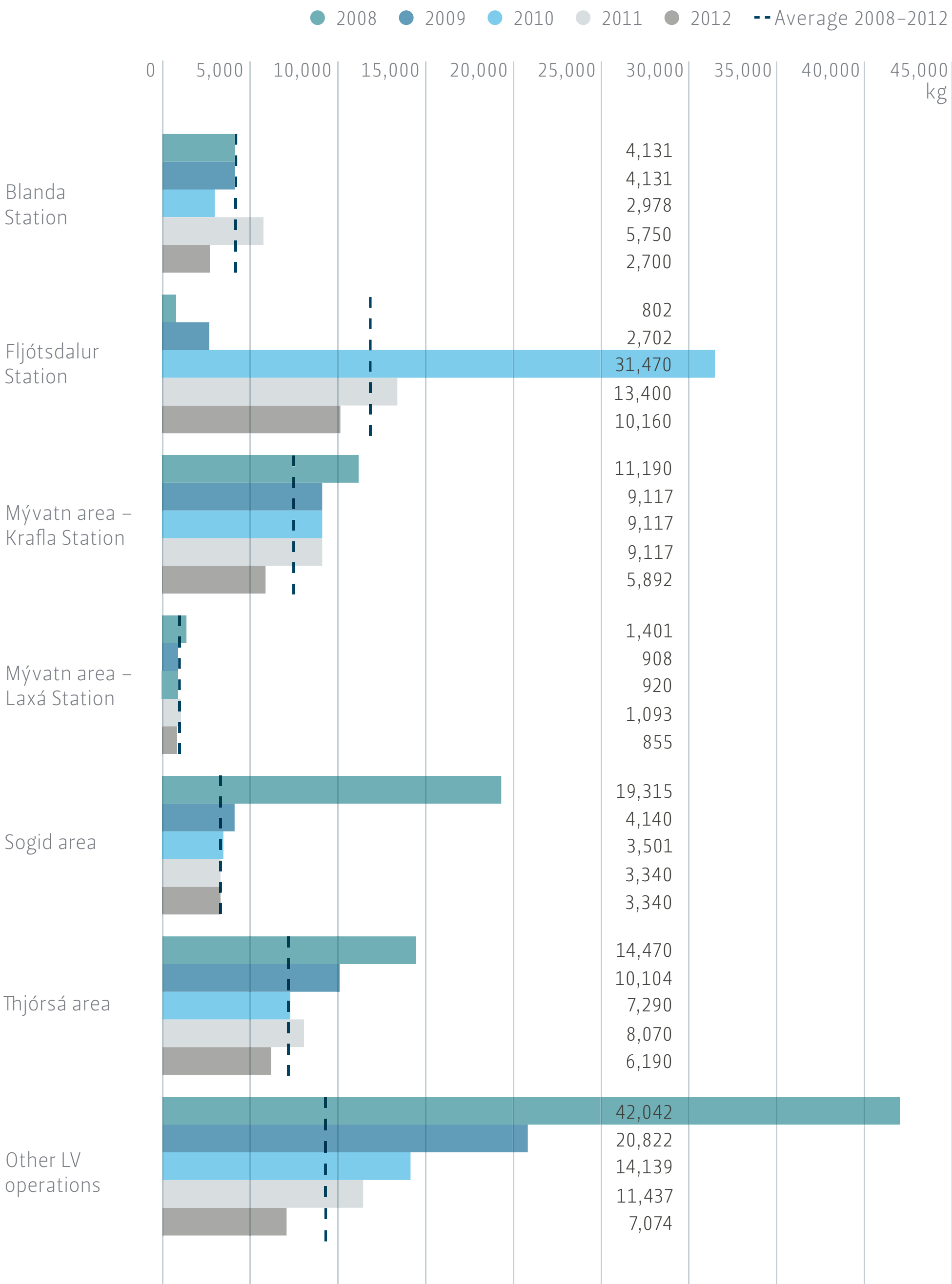


Figure 28 — Quantity of unsorted waste in Landsvirkjun's operational areas 2008–2012.



Inert waste from Landsvirkjun's operations in 2012 is mostly from the Laxá Station and comes as a result of the removal of the headrace pipe in 2011. The inert waste from the construction work involved is registered in 2012, when it was disposed of. The waste was mostly concrete and steel, which was sent for recycling as much as possible. Inert waste such as earth and rock/gravel materials are not considered to have a negative impact on the environment.

The sorting and recycling of waste has increased at all of Landsvirkjun's bases

In 2012, Landsvirkjun purchased new housing for a part of the Research and Development Division as well as a storage unit. The refurbishment of the building left 10 tonnes of waste material which was partly sorted by Landsvirkjun but for the most part sorted by Sorpa Waste Management.

The quantity of hazardous materials generated depends, as for most other waste, on the extent of maintenance work each year. In 2012, approx. 12 tonnes of hazardous materials were produced, which is considerably less than in previous years. The majority is waste oil. Variations in the quantity of waste oil are partly because waste oil is collected in tanks and the disposal is irregular. For example, the Sogid area in 2011; accumulated amounts of waste oil from 2011 and 2010 were disposed of. The transformer oil at the Fljótsdalur Station was recycled within the area by mixing it with diesel oil and using it to power vehicles at the station. **Figure 29** shows the type and composition of hazardous materials generated in Landsvirkjun's operations in 2012. The amount of hazardous waste produced by Landsvirkjun varies between years and is always sent to an authorised receiver.

Figure 29 — Percentages of hazardous materials produced by Landsvirkjun's operations in 2012.

	kg	%
Oil	2,231	48%
Batteries	1,181	26%
Various hazardous waste	654	14%
Organic hazardous waste	259	6%
Hazardous materials packaging	233	5%
Inert hazardous waste	57	1%
Toxins	12	<1%

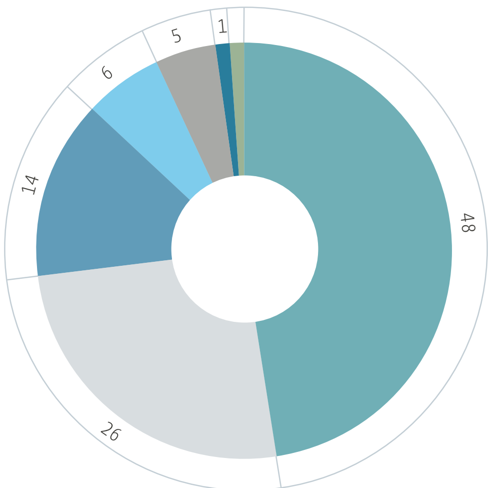


Figure 30 shows the quantity of waste generated in Landvirkjun's operations in the last five years (2008–2012). It is evident that the quantity of waste within each category varies between years, which can be mainly explained by waste generated by maintenance work. These fluctuations between years make it difficult to set objectives for reducing the quantity generated in each waste category. Landvirkjun's emphasis is therefore on increasing recycling, to reuse and to decrease the quantity of unsorted waste for landfill or incineration.

Sorting of waste is steadily increasing in all of Landsvirkjun's operations, therefore reducing the amount of unsorted waste sent to landfill or for incineration. The decrease has been significant in the last five years.

Figure 31 shows the results achieved in the sorting of waste from Landsvirkjun's Headquarters in Reykjavík. This includes waste from offices which has decreased substantially in 2012. More detailed information on the quantity of waste from Landsvirkjun's operational areas in 2008–2012 can be found in the Annex.

Figure 30 — Quantity of waste from Landsvirkjun's operations between 2008 and 2012; divided according to waste category.

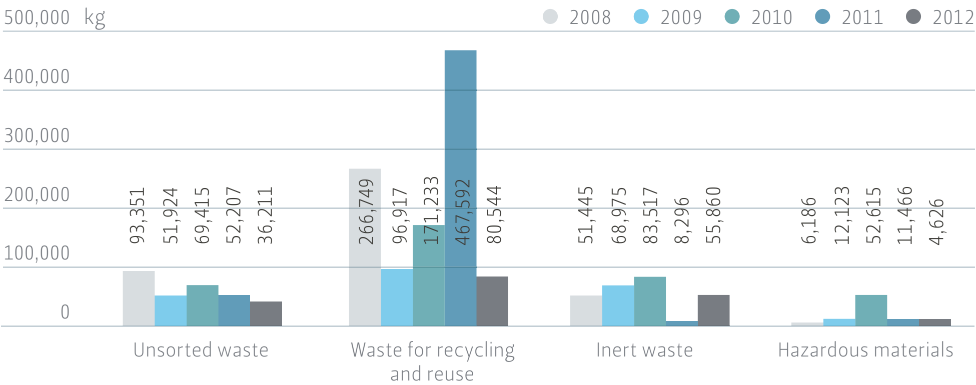
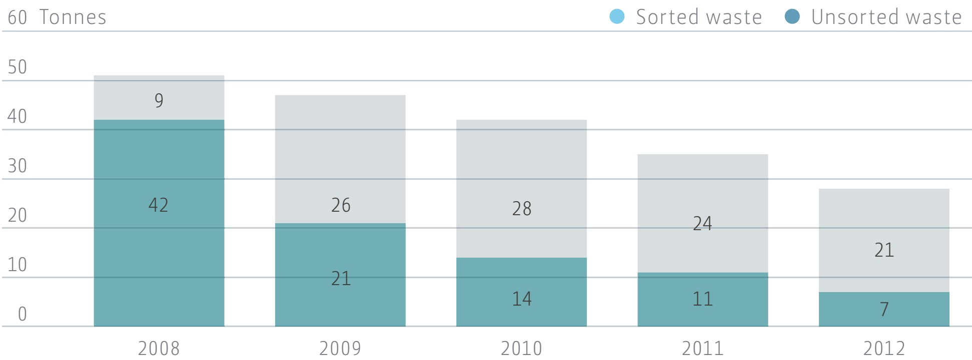


Figure 31 — Quantity of sorted and unsorted waste from Landsvirkjun's Headquarters at Háaleitisbraut 68 in Reykjavík between 2008 and 2012. Efforts to sort waste materials for recycling have been successful.

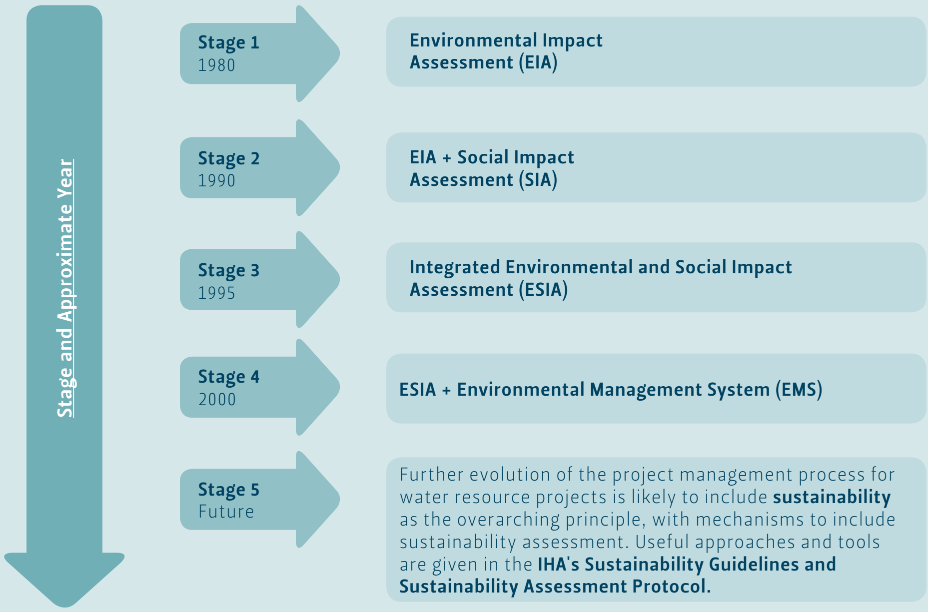


The Hydropower Sustainability Assessment Protocol

In the last few decades, preparation measures for new hydropower projects worldwide have made tremendous advancements with regard to environmental and societal issues. This is mainly due to legislation on environmental and societal issues. The international development of these issues since 1980 can be seen in Figure 32. The Intergovernmental Panel on Climate Change (IPCC) estimates that the main focus in the near future will be on the sustainability of hydropower projects (Kumar et al. 2011).

A Hydropower Sustainability Assessment Protocol has been developed on the initiative of the International Hydropower Association (IHA). A diverse group of stakeholders were involved in the development of the Protocol including international associations involved in societal and environmental issues (Oxfam, Transparency International, World Wide Fund for Nature (WWF) and The Nature Conservancy), the World Bank and the governments of a number of countries (including Iceland and the Director of the National Energy Authority, Gudni Jóhannesson). The Protocol is based upon standards within 20 categories and is designed to assess the sustainability of hydropower projects. There are four assessment tools for the different stages of the projects life cycle: Early Stage, Preparation Stage, Implementation Stage and the Operation Stage. The first assessment took place in May of 2012 and was an assessment of the Landsvirkjun's preparation work for the Hvammsvirkjun project in the lower regions of Thjórsá.

Figure 32: The international development of these issues since 1980 (Kumar et al. 2011).



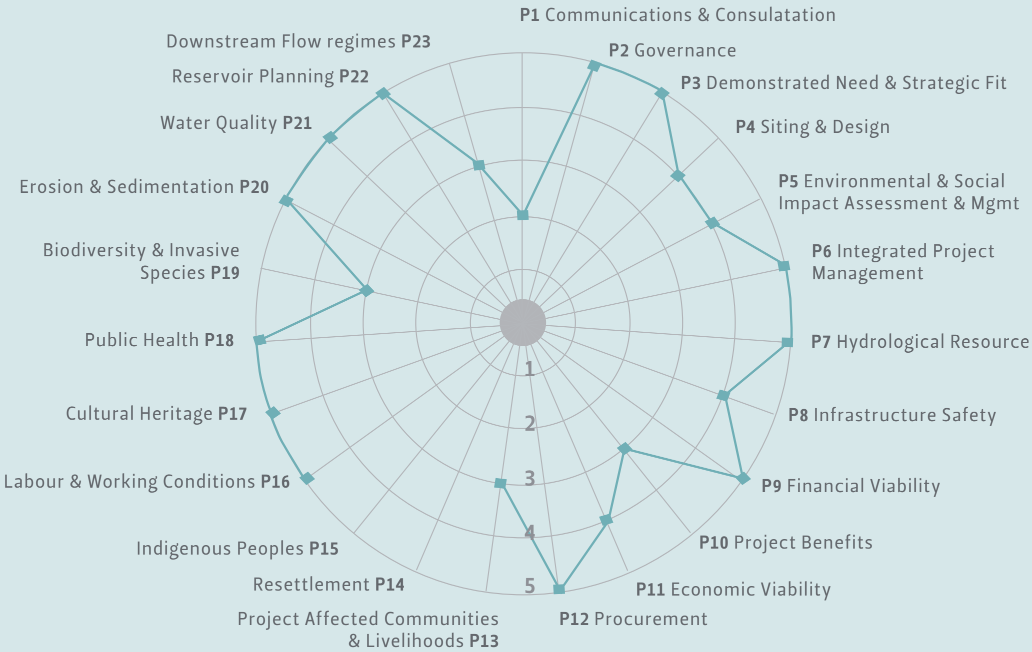
The Results of the Assessment on Preparation Work at Hvammsvirkjun
A team of six international assessors were responsible for the large-scale assessment and they interviewed 60 individuals; from stakeholders to institutions, municipalities, companies and social organisations.

The assessment involved the detailed assessment of 21 diverse topics pertaining to the preparation of the proposed power station to indicate how successfully these preparation measures have adhered to the international criteria for sustainable development. The results of the assessment can be seen in Figure 33. Landsvirkjun fulfils the requirements for "good practice" in 20 out of the 21 topics assessed (3-5 points). In 12 topics the project met a score of 5: Proven best practice and only one topic: Communications & Consultation did not fulfil the requirements for best proven practise, receiving only 2 points. According to the standard there must be a written plan based upon stakeholder analysis with regard to communication and consultation at all levels of implementation (Rydgren, 2012).

Landsvirkjun has taken all the recommendations put forward by the assessors into serious consideration and is in the process of reviewing and improving practices where needed.

Figure 33: Results from the assessment on the sustainability of Hvammsvirkjun.

1 Point: Not good practice **2 Points:** One gap form basic good practice **3 Points:** Basic good practice
4 Points: One gap from best proven practice **5 Points:** Proven best practice



Noise

The areas at Krafla and Bjarnarflag, where geothermal electricity generation takes place, are zoned as industrial areas. The Icelandic regulation on noise specifies a reference limit for industrial zones of 70 dB(A) at site boundary. There are popular tourist destinations within the industrial zones at Lake Mývatn; these include Námaskard, Jardbödin nature baths and Víti. Landsvirkjun has therefore set stronger reference limits for these areas, and is proactive in ensuring that sound levels do not exceed 50 dB(A) in these areas, which is the reference equivalent sound level value for residential areas. No reference values exist for recreational areas.

At geothermal power stations, turbine generator units and the release of steam during the capacity evaluations of the boreholes are the main source of noise. The sound level at each time therefore depends upon the number of boreholes being flow tested, the number of turbine generator units in operation, as well as weather conditions. Annual measurements of the sound level from the geothermal power stations are conducted at defined measurement locations. Additionally, measurements are made at boreholes when capacity evaluations take place, but silencers are installed in all boreholes. Each assessment takes four minutes, and car traffic can affect the sound level measurements.

It should be noted that the measurements are single measurements, which give an indication of the sound level in the area, but do not exclude the possibility of higher or lower sound levels at other times. An overview is shown on **Figure 34**.

Figure 34: Overview of the Mývatn area. The shaded area shows the limits of the industrial zones at Krafla and Bjarnarflag.

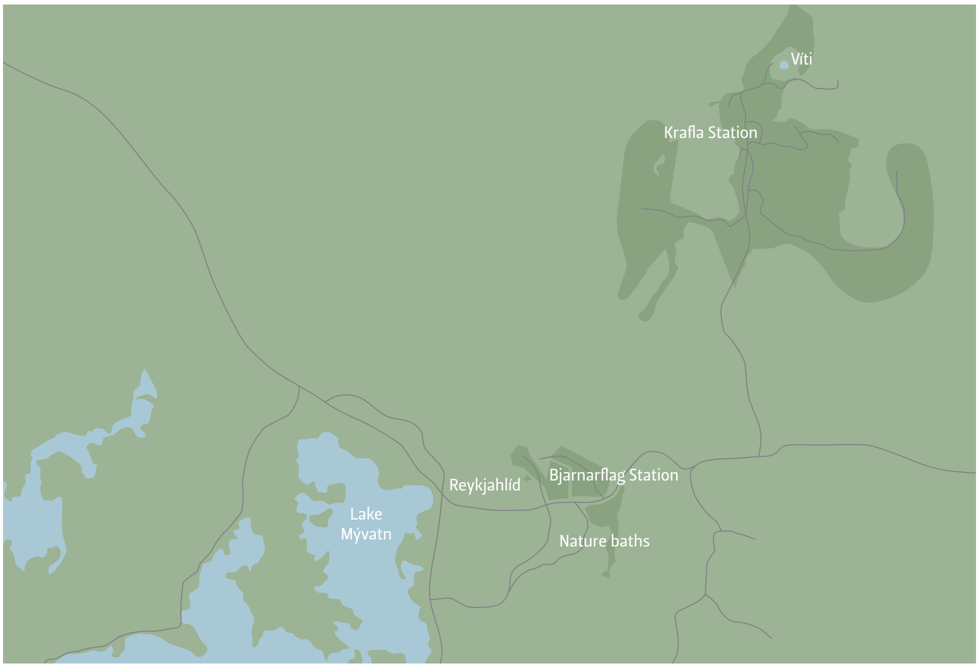
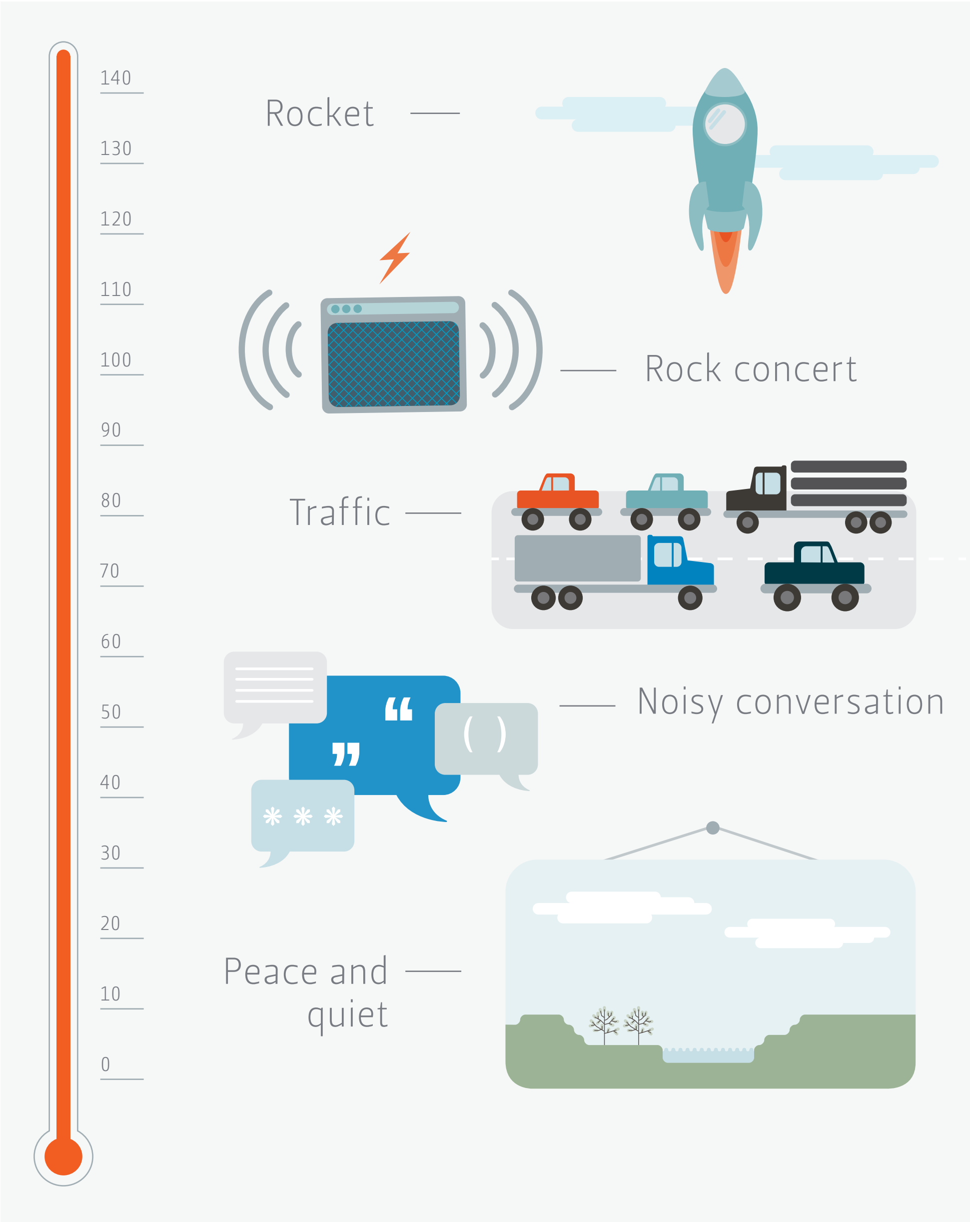
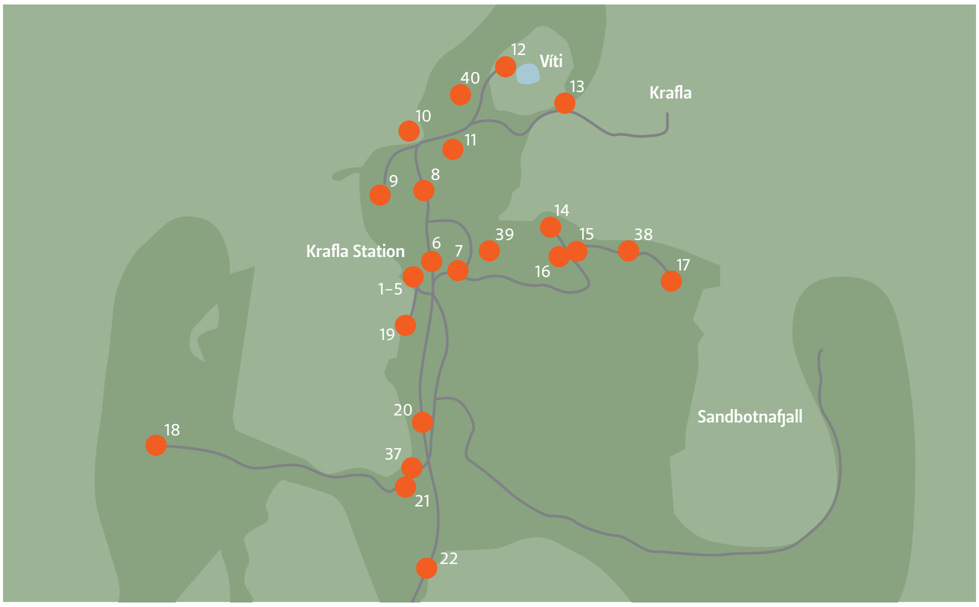


Figure 35 — Sound levels (dB) from various activities.



Noise is defined as an undesirable sound from e.g. anthropogenic sources, traffic or industrial activities. Sound intensity is measured in decibels (dB) or decibels A (dB(A)) which simulates the sense of the human ear. **Figure 35** shows the sound level from different activities on the decibel scale.

Figure 36 — The location of the noise monitoring stations at Krafla Station. Shaded areas show the industrial area for energy generation. Red dots show the location of annual monitoring.



Krafla Station

Figure 36 provides an overview of locations for sound level measurements in the vicinity of Krafla Power Station. The shaded areas represent the industrial area and red dots show measuring locations where sound levels are measured annually.

In 2012 sound level measurements at Krafla station were conducted on the 21st and 22nd of August. The weather was favourable on the 21st and winds from the east were approx. 6-8 m/sec. Measurements went ahead on the west side of Krafla on the 22nd during light rain and a northern wind direction of 6-8 m/sec. External factors affected the measurements and raised figures in some instances. More details on measurements between 2008 and 2012 and information on special circumstances pertaining to the measurement process in 2012 can be found in the Annex.

The noise levels outside the industrial site; more specifically at the viewing platform in Dalbrún (by borehole 10) and by the car park at Vítisbarmi (monitoring stations 11 and 12) were found to be over the 50 dB(A) reference levels set out by Landsvirkjun. There were a substantial number of tourists in the car park when measurements were conducted and this could have affected the outcome. The viewing platform noise levels have been above the reference levels for the last four years. This is mainly due to the fact that measuring takes place in an area where noise from the vicinity carries up to the measuring point. Wind speed and active boreholes in the area have also affected measurements in the last few years.

Figure 37 — The location of the noise monitoring stations at Bjarnarflag Station. Shaded areas show the industrial area for energy generation. Red dots show the location of annual monitoring.

Bjarnarflag Station

Figure 37 provides an overview of locations for sound level measurements at Bjarnarflag Station. The shaded area represents the industrial area. Red dots show measuring points where sound levels are measured annually.

In 2012, sound level measurements at Bjarnarflag Station were conducted on the 22nd of August, 2012 and the station's steam generator units were in operation. The wind came in from the north measuring at 4–6 m/sec and there was complete cloud cover. Noise levels at monitoring station 34 were significantly higher than that of the previous year but this could be attributed to the fact that a crawler was completing ground work at the station as measurements were being conducted. At separating station 2 (monitoring station 33) an air compressor was in use as measurements were conducted. Outside the industrial site the noise levels were measured at 50 dB(A); the reference level The levels were measured by the information centre close to the old bathing lagoon (monitoring station 26) and the figures were comparable to the last two years.

More detailed information on measured sound levels, as well as any special circumstances, at Bjarnarflag station between 2008 and 2012 can be found in the Annex.

Environmental Mishaps

Landsvirkjun's objective is to operate without environmental mishaps.

An environmental mishap is defined as an incident, which according to the Company's operation permit has to be reported to the environmental authorities, or an incident in the operation that violates the law, regulations, or the Company's work regulations. In 2012 there were two environmental incidents in Landsvirkjun's operations and both were in connection with the steering of flow rates in the Sogid area. The first incident saw the flow rate of the Sogid (from the Írafoss Station) rise temporarily to 167 m^3/sec, which is above the benchmark of 150 m^3/sec set out by Landsvirkjun. The reason for this increase was a substantial amount of rain falling onto frozen earth and therefore dispersing rapidly into the river. The second incident occurred during extreme weather conditions, causing extensive disturbances to the energy system, resulting in the Sogid area losing power. The water flow therefore needed hand steering temporarily and this resulted in the level decreasing to 60 m^3/sec, well below the benchmark of 70 m^3/sec set out by Landsvirkjun.

Subsequently, the working methods were reviewed in order to prevent a repeat of these incidents. Specialists reviewed any possible effects upon the ecosystem in the Sogid area and assessed the need for any necessary action.

The total number of incidents since 2006 are 12 in total. Most of them occurred in connection with the steering of water flow, i.e. when control of the flow rate in hydropower stations was unsuccessful according to the company's objectives (**Table 1**)

Table 1 — Environmental mishaps at Landsvirkjun between 2006 and 2012.

	2006	2007	2008	2009	2010	2011	2012	Number of mishaps
Water steering	3	–	2	–	–	–	2	**7**
SF_6 emissions	1	1	–	–	–	–	–	**2**
Violation of weight limitations	–	–	–	1	–	–	–	**1**
Noise	–	–	–	–	1	–	–	**1**
Oil leaks	–	–	–	–	1	–	–	**1**
Number of environmental mishaps per year	**4**	**1**	**2**	**1**	**2**	**0**	**2**	**12**

Landsvirkjun's Monitoring Project on High Temperature Fields in the Northeast of Iceland

Photo: ÍSOR

Vegetation and birdlife

The East Iceland Natural History Institute will be responsible for the monitoring and research of vegetation in the affected area, pertaining to the proposed power projects at Þeistareykir and Bjarnarflag, as well as the Krafla area. Vegetation monitoring began during the summer of 2012 with the basic mapping of vegetated areas and their exposure levels.

The cover of certain species and sub species in vegetated areas by Þeistareykir and Krafla will be monitored as well as the distribution of rare high temperature species at Bjarnarflag.

The Institute will also be responsible for the monitoring of heathland bird species and falcons in the Þeistareykir area. Density measurements on heathland birds began in 2009 and increased substantially by the summer of 2012, with the cooperation of Landsvirkjun. Subsequently the density of heathland birds will be measured annually, as well as the occupation and juvenile survival rates of the falcon. The results will be published in annual reports; the first will be published in 2013.

Hydrogen sulphide

Hydrogen sulphide (H_2S) is a naturally occurring compound in volcanic areas. Its origins can be found in the interaction between water and rock deep in the geothermal system along with the gases from the cooling thermal source at the base of the geothermal system. The concentration of hydrogen sulphide can vary between geothermal areas but in Iceland these areas have relatively low concentrations of gases.

Measurements conducted on hydrogen sulphide from Bjarnarflag and the steam from research boreholes in Bjarnarflag have been on-going since February, 2011 when a specialised monitoring station was installed by Helluhraun in Reykjahlíd to measure hydrogen sulphide levels in the atmosphere. More monitoring stations are due to be installed in the area in an effort to research the effects of geothermal utilisation on air quality by Mývatn and on the natural emission of hydrogen sulphide.

The results of measurements conducted at Reykjahíd show that the concentration of hydrogen sulphide in the atmosphere has never surpassed the limits set out by the regulations on hydrogen sulphide concentrations in the atmosphere or 50 µg/m³ mean value per 24 hours.

In most instances the concentration of hydrogen sulphide is rather low but can increase under certain weather conditions (usually when there is an easterly breeze and the temperature is low). Under these weather conditions a warm front forms above Bjarnarflag and the gas cannot rise above the front, causing an increase in the concentration of hydrogen sulphide. The highest rate recorded was 47 ug/m³ (compared with the 24-hour moving average).

Another monitoring station can be found at Eyvindarstadir in Kelduhverfi. The station is located in an area ahead of the prevailing wind direction from the Þeistareykjir area. Measurements have been on-going since December, 2011. There has not been any regular well testing at Þeistareykir and hydrogen sulphide levels have been barely traceable in the area.

If hydrogen sulphide levels were to rise above the regulated limits then Landsvirkjun would be obligated to implement the necessary mitigation measures. Landsvirkjun therefore works in co-operation with Reykjavík Energy and HS Orka in order to develop methods for reducing hydrogen sulphide concentrations in geothermal areas. Research is being conducted presently but is mainly focussed on the possibility of re- injecting gas back into the earth with water from the production process at the station; the same water that the gas originates from.

Groundwater

Large groundwater stream flows in from the south, from the highland areas and the Dyngjujökull Glacier and out to the sea at Öxarfjördur. Some of this water flows into Mývatn; a cold stream into the south bay and a warm stream into the outer bay. A cold stream which curves from the Búrfell lava field westward, warms up as it passes the Námafjall mountain area and merges with the stream in the Krafla highlands (Figure 25). The groundwater is warmest to the west of the Námafjall Mountain (closest to the mountain) and increases in temperature as it nears Mývatn. The stream is warmer in the lower areas of the Grjótagjá gorge and cools slightly as it nears the Hverfjall Mountain, until the cold stream from the south overwhelms it. This stream has been closely monitored since 1973. Figure 38 shows the development of the temperature in the Grjótagjá gorge since the Krafla Fires (1974-1984) up until 2012. A dramatic rise in temperature can be seen immediately after the volcanic activity and then a decrease after that.

The groundwater in Krafla, Bjarnarflag and the Þeistareykir area is monitored extensively and the research area reaches from the Búrfell lava field to the south and all the way northward to the Kelduhverfi area. The water levels and the temperature of the groundwater is monitored as well as the chemical composition of the water which is measured twice yearly in chosen areas and in cooperation with Iceland Geo Survey (ÍSOR). The scheduled monitoring of groundwater has been on-going for decades and was part of the overall monitoring carried out during the Krafla Fires (1975-1984). An agreement was reached between Landsvirkjun and the Environment Agency of Iceland in the summer of 2003 with regard to the monitoring.

Surface areas in geothermal areas

Surface changes in geothermal areas are monitored in Landsvirkjun's operational and research areas. Yearly monitoring and research on surface activity has been on-going in the Krafla area for the last four decades. Monitoring is comprised of the mapping of the area, photographic records, temperature measurements, assessments on heat distribution and heat generation, research and chemical studies on steam vents, spring activity and the flow of carbon dioxide in the soil. In newer areas an emphasis is placed upon researching the baseline data of areas and recognising and understanding natural changes that occur.

Society and tourism

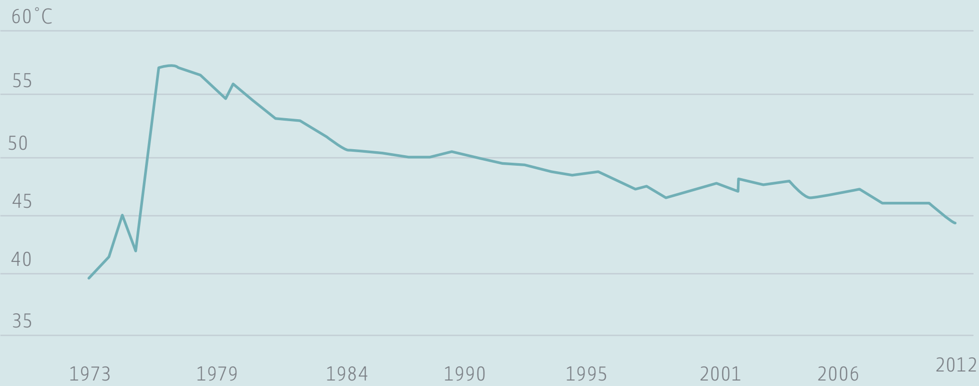
When the assessment on the environmental effects of the Þeistareykir station was developed recommendations were put forward with regard to the collection of data on land usage and tourism/outdoor recreation numbers in the Þeistareykir area; both during construction and after the onset of operations at the station. The Iceland Tourism Research Centre conducted a survey on tourism at Þeistareykir in the summer of 2012. Results show that traffic in the area is minimal and that locals mostly use the area. It could therefore be said that better road transport conditions would increase tourism activity in the area.

The number of tourists in Þeistareykir is relatively small when compared with the total number of tourists in other highland areas. It could therefore be said that the construction work currently underway has not had an effect on visitors to the area. They seem to be fully aware of the construction work, are not disturbed by them and actually visit the area in order to see the work being done. *See Landsvirkjun's report: LV-2013/045.*

Seismic activity

More emphasis has been placed on monitoring seismic activity in the area to the east of Mývatn in the last two decades. The Icelandic Met Office has steered the research on behalf of Landsvirkjun. The research includes an analysis of the size, distribution and depth of seismic activity. A summary report of this research was published at the end of 2011: *LV-2011/116.*

Figure 38 — Temperature developments in Grjótagjá before the Krafla Fires (1974–1984) and up to 2012.



Atmospheric Emissions and the Greenhouse Effect

This section contains information on greenhouse gas emissions, emissions of hydrogen sulphide from geothermal power stations and Landsvirkjun's carbon footprint.

GHGs are released into the atmosphere as a result of Landsvirkjun's electricity generation. This includes emissions from the burning of fossil fuels by vehicles and machines, air travel, incineration and landfilling of waste, as well as emissions directly related to electricity generation. Emissions that are directly related to electricity generation are e.g. GHG emissions from reservoirs and the release of steam from geothermal power stations.

The carbon footprint is a scale utilised to show the effects of human activity on climate change.

In this report the carbon footprint is expressed as the total set of annual GHG emissions from Landsvirkjun's operations subtracting the carbon sequestered, i.e. the carbon binding measures implemented by Landsvirkjun.

The Northern wheatear *(Oenanthe oenanthe)* is a small passerine bird. The bird's call sounds like two rocks being knocked against each other. The Travelling Guide by Eggert Ólafsson (1772) states that if the bird's nest is stepped on by sheep or cows the bird flies upward and bites the udder to seek revenge. The bite is poisonous.

Greenhouse gases and carbon footprint

The reduction of greenhouse gas emissions is one of Landsvirkjun's main objectives.

Global warming or climate change refers to the change in global temperature caused by the release of greenhouse gases (GHGs) by human activity, e.g. burning of fossil fuels and various land use. The consequences of climate change include a change to the earth's temperature. Evidence of this can be found in the 1°C rise in average temperature in Europe in the last 100 years (EEA, 2012). Iceland is a member of the United Nations Framework Convention on Climate Change (UNFCCC) and is therefore committed to taking action to limit GHG emissions and to increase carbon binding. Furthermore, Iceland is required to submit information on annual anthropogenic GHG emissions and carbon binding and inform on strategies and actions aimed to reduce these emissions. Countries are required to provide information on the emissions of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6). These six GHGs have a different radiative forcing and lifetime in the atmosphere and therefore the gases have a different Global Warming Potential (GWP). Total emissions of GHGs are calculated in carbon dioxide equivalents, expressed as CO_2-eq (**Table 2**).

The reduction of greenhouse gas emissions is one of Landsvirkjun's objectives

Table 2 — The global warming potential and the atmospheric lifetime of the greenhouse gases reported in the National Inventory Report (The Environment Agency of Iceland).

Greenhouse gases	Atmospheric lifetime (years)	Global warming potential (100 yrs)
Carbon dioxide (CO_2)	Variable	1
Nitrous oxide (N_2O)	120	310
Methane (CH_4)	12.2 (unsure 25%)	21
Hydrofluorocarbons (HFC)	2–250	140–11,700
Perfluorocarbons (PFC)	3,200–50,000	6,500–9,200
Sulphur hexafluoride (SF_6)	3,200	23,900

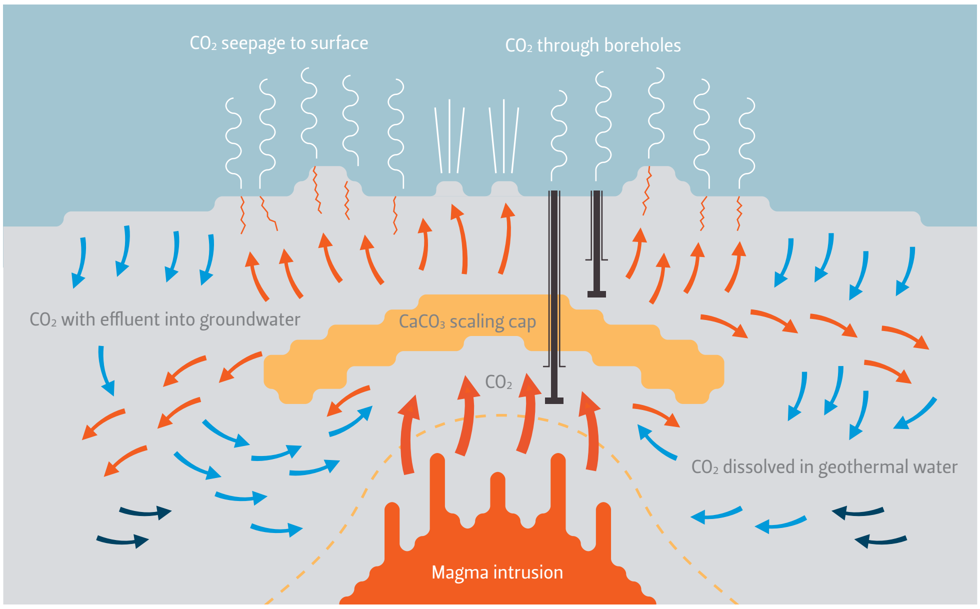
Greenhouse effect of geothermal power stations and atmospheric emissions

All high temperature fields in Iceland are connected to active volcanoes and heat fluxes into these areas have sources in shallow magma intrusions or magma chambers. Cooling magma intrusions release magmatic gases, most of which are lighter than water and steam and therefore move up to the surface. Many of these gases react with compounds in the geothermal fluid or rock and precipitate. The magma gas mainly consists of carbon dioxide, often around 60-95% by mass, and hydrogen sulphide (H_2S), 1-20% by mass.

Other gases are found in lower concentrations, including the GHG methane (CH_4). A concept model for the source and emissions of carbon dioxide from volcanic high temperature fields can be seen in **Figure 39**. It is debated whether GHG emissions from geothermal power stations should be considered as anthropogenic or as natural emissions from the area but no 'burning' takes place during the geothermal energy generation process (Goldstein et al. 2011). The inclusion of these emissions in 'GHG emissions accounting' as a result of the United Nations Framework Convention on Climate Change varies between countries but Iceland is includes this in its accounts.

The National Energy Authority has gathered information from energy companies with regard to CO_2 and H_2S emissions from geothermal stations in Iceland since 1991. At Landsvirkjun, the concentration of magma gases in steam is monitored regularly, because of how dependent the concentration of magma gases in the geothermal fluid is on the behaviour of the high temperature field and is an important part of process control. The concentration of magma gasses in Krafla increased dramatically during the Krafla Fires (1975-1984) but then decreased

Figure 39 — Concept model for the source and emissions of carbon dioxide from volcanic high temperature fields (Anette K. Mortensen et al. 2009).



when seismic activity ceased. Changes to gas concentration are an effective indicator of changes to the geothermal reservoir and consequently for changes in flow to the surface. The changes in the Krafla area show that the effects of the Krafla Fires (1976–1984) on the geothermal reservoir eventually diminish. Measurements are conducted on gas concentrations in steam and water from the boreholes and power stations on an annual basis. The GHG emissions accounting for Landsvirkjun's geothermal power plants are based on these measurements, alongside operational data.

Overall GHG emissions reduced in 2012 compared to previous years, mainly due to changes in the gas flow in the geothermal reservoir but production has also decreased slightly. This is the second year of increased GHG emissions as a result of exploratory drilling.

Emissions of hydrogen sulphide (H_2S) from Landsvirkjun's geothermal power plants are monitored.

Emissions of hydrogen sulphide (H_2S) from Landsvirkjun's geothermal power plants are monitored. Hydrogen sulphide is not a GHG but has a pollutant effect on humans and the ecosystem. The emission of hydrogen sulphide has until now been an inevitable part of utilising geothermal areas.

The emission of H_2S from exploratory boreholes has decreased considerably when compared with the previous year; 2012 was similar to 2009. Emissions from electricity generation remain almost stagnant between years.

Figure 40 — Concentration of magma gases, enthalpy and the flow rate of the geothermal fluid measured in one borehole in the Krafla area (KJ–15).

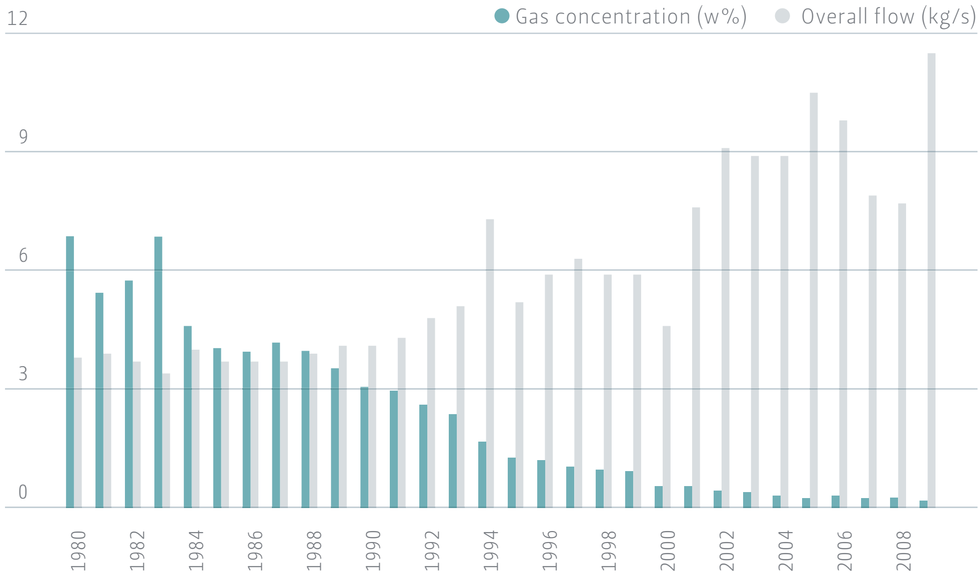


Figure 41 — GHG emissions as a result of Landsvirkjun's electricity generation and as a result of exploratory drilling 2008–2012.

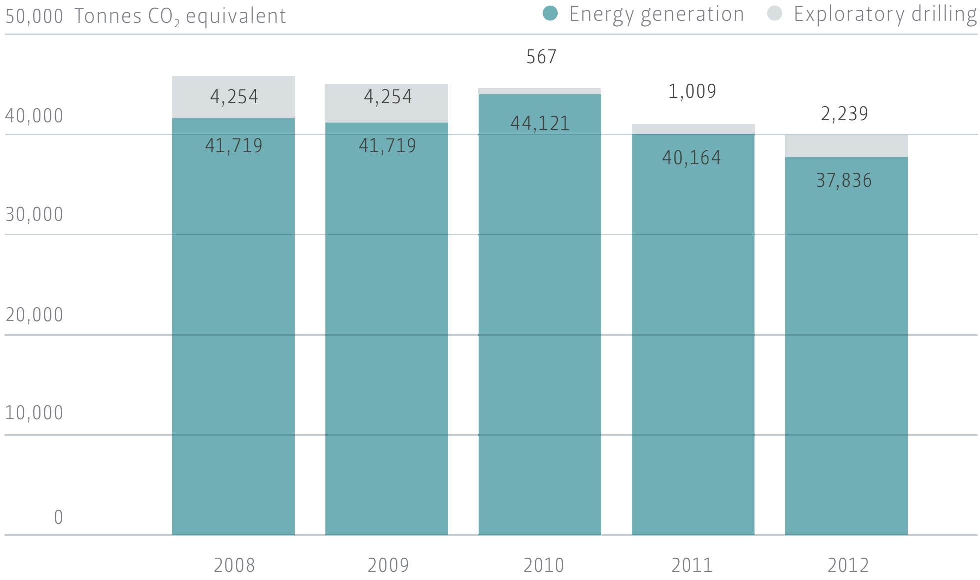
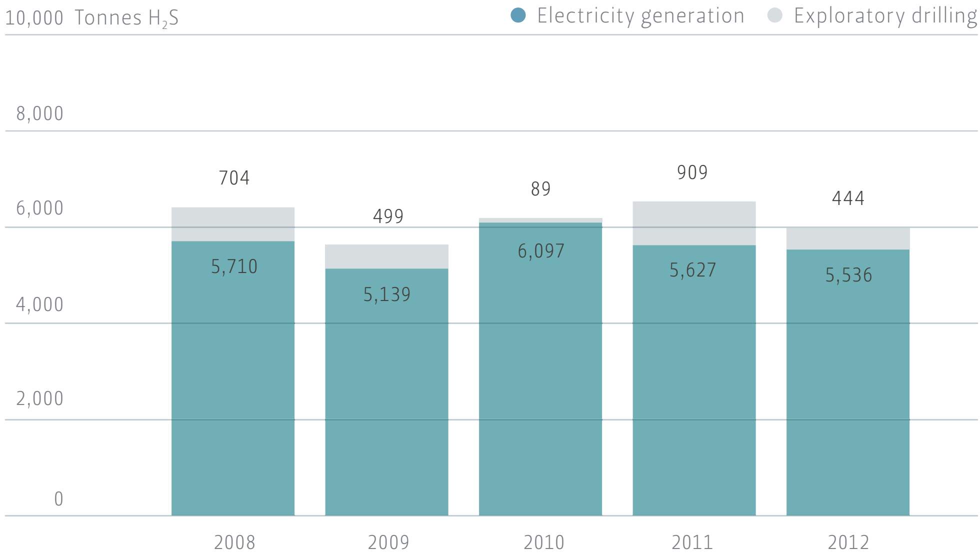


Figure 42 — GHG emissions as a result of Landsvirkjun's electricity generation and as a result of exploratory drilling 2008–2012.



Greenhouse effect of hydropower reservoirs

In reservoirs, carbon dioxide, methane and nitrous oxide are formed as a result of the decomposition of organic matter present in vegetation and submerged soil. **Figure 43** shows the main GHG processes for submerged land. **Figure 44** shows the amount of GHGs emitted from Landsvirkjun's hydropower reservoirs in 2008-2012.

Minimal amounts of GHGs are emitted from reservoirs when covered with ice. There are, however, negligible emissions of methane which are not reported separately, but calculated and reported as a part of the overall GHG emissions from the reservoirs. Landsvirkjun has recorded the number of days reservoirs are covered by an ice layer; when the release of GHG is at its highest. In 2012, there were 165 ice-free days in the Blöndulón Reservoir and 178 ice-free days at the Gilsárlón reservoir. Detailed information on the GHG emissions from Landsvirkjun's reservoirs in 2012 can be seen in the Annex.

Figure 43 — Main greenhouse gas processes for land that has been put under water. Adapted from: Gudmundsson, J. and Óskarsson, H., 2008.

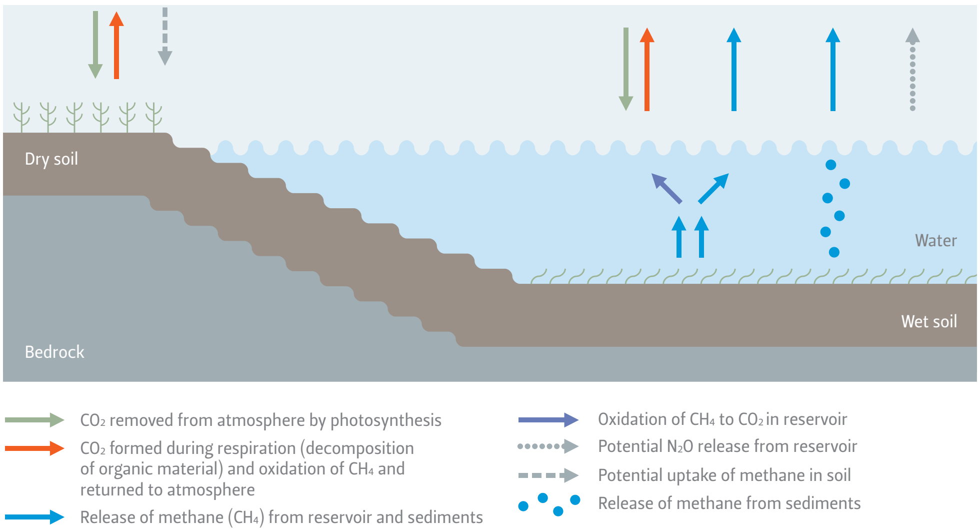
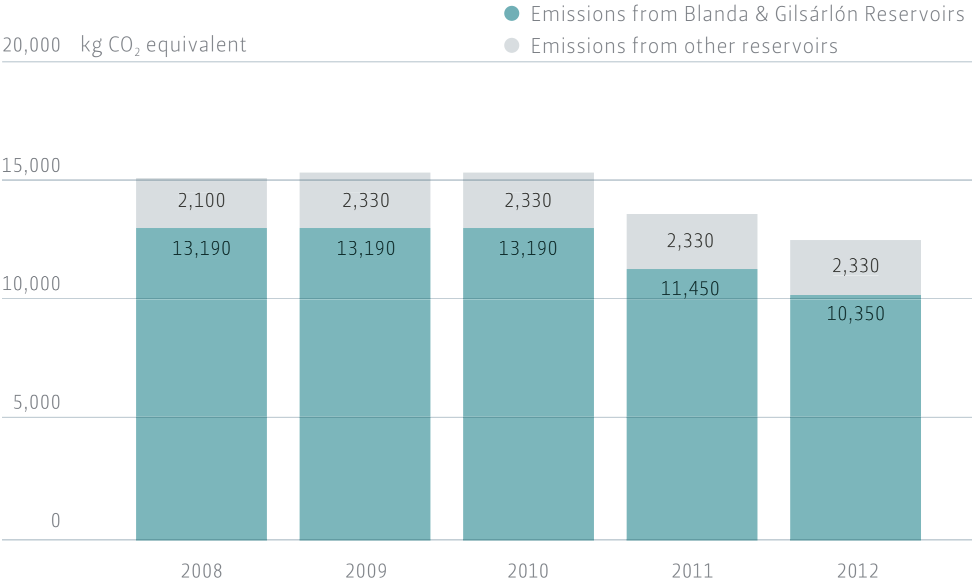


Figure 44 — GHG emissions from Landsvirkjun's hydropower reservoirs 2008–2012. Darker areas of columns represent Blanda and Gilsárlón Reservoirs. Lighter areas represent emissions from all other Landsvirkjun reservoirs.



Greenhouse effects due to burning of fossil fuels and emissions from electrical equipment

GHG emissions from the burning of fossil fuels are calculated based on the amount of fuel used. The emissions are then converted into CO_2-eq using the same coefficients used for Landsvirkjun's GHG emissions accounting.

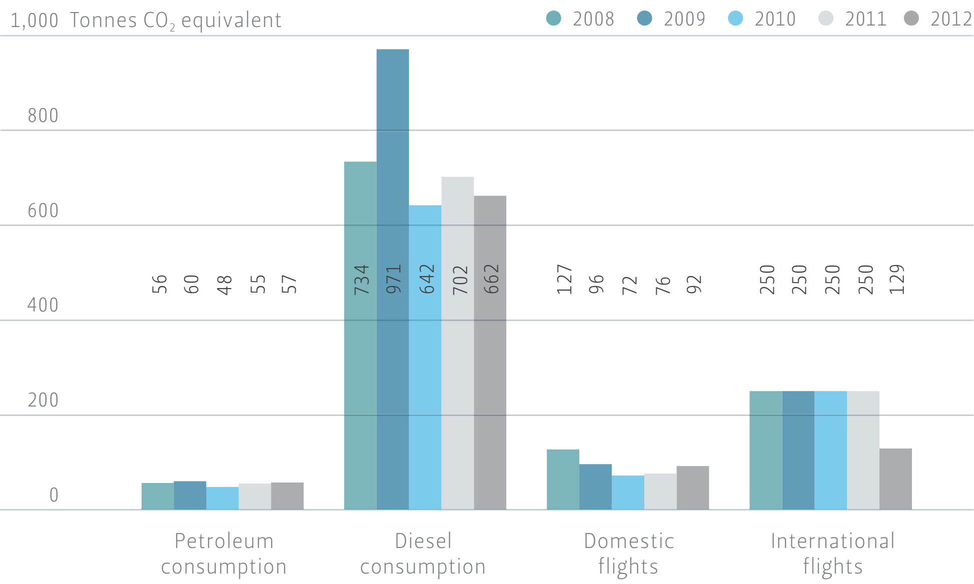
Information on the number of domestic flights is retrieved directly from the airlines. The corresponding GHG emissions are estimated based on the number of trips and information from e.g. The Icelandic Energy Forecast Committee and the airlines. GHG emissions from international flights have been assessed in the last few years and is estimated to be 250 tonnes CO_2-eq per year. In 2012, information on the actual number of international flights was made available and the GHG emissions were 129 tonnes CO_2-eq per year. The GHG emissions as a result of international travel have therefore decreased significantly.

SF_6 gas is used for insulation in high-voltage equipment in Fljótsdalur Station and in the Thjórsá area. Leakage or mishaps can cause the release of the gas to the atmosphere. The SF_6 gas is the most potent greenhouse gas, with a GWP of 23,900 times that of CO2. SF_6 emissions from electrical equipment have occurred once during the last four years, i.e. in 2009.

As in previous years, burning of diesel oil is the major source of GHGs from fossil fuels (65%).

In 2012, 504 kg of methane was used to power vehicles but no hydrogen run cars were used by Landsvirkjun that year. The use of methane as fuel saved emissions of approximately 2,000 kg CO_2-eq when compared to emissions from a petroleum car.

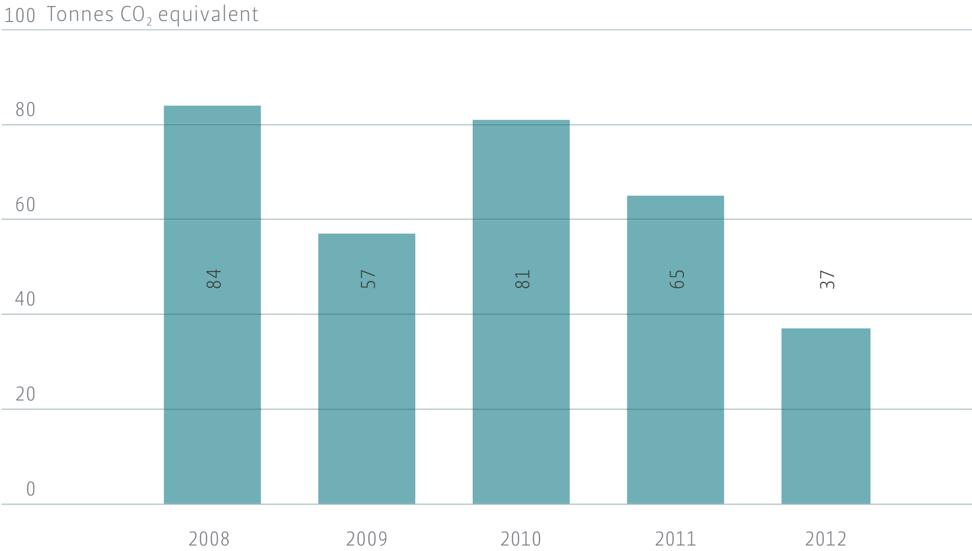
Figure 45 — GHG emissions due to the burning of fossil fuels in Landsvirkjun's operations between 2008 and 2012.



Greenhouse effect of landfill waste and incineration

Environmental impacts caused by landfilling of waste are mainly due to the formation of landfill gas as a result of decomposition of the organic waste fraction. Furthermore, contaminated leachate can pollute ground and surface waters. The landfill gas consists of methane and carbon dioxide, but the GWP of methane is 21 times that of carbon dioxide. **Figure 46** shows GHG emissions from the disposal of the unsorted waste fraction from Landsvirkjun between 2008 and 2012. There is a significant decrease in the amount of unsorted waste when compared with previous years and therefore a reduction in GHG emissions.

Figure 46 — GHG emissions as a result of Landsvirkjun's unsorted waste disposal 2008–2012.



Green Guarantees of Origin

Guarantees of origin are international certificates for electricity that is generated via renewable sources. The aim of the endeavour is to encourage Europe to support the generation and use of electricity from renewable sources.

The buyers are those whose interests are served by supporting the renewable generation of electricity. It could therefore be said that the "green" benefits of electricity represent two products. Customers are mostly working within markets where there is a high degree of environmental awareness and who list the Guarantees of Origin reports on social responsibility and emissions accounting.

Composition of electrical generation in Iceland and in Europe
In Iceland, almost all of the country's electricity is generated via renewable energy sources (99%) whereas in mainland Europe 7.8% of electricity is generated utilising renewable energy sources, 51.3% is produced from fossil fuels and 40.8% from nuclear energy. Iceland is a part of the electricity market in Europe and so the electricity generated in Iceland is counted as part of the overall electrical generation in Europe as a whole. When the company sells a guarantee of origin it sells its right to register that particular energy as renewable energy produced by the company. Instead, a similar amount of their production is registered as part of the average composition of electricity in Europe.

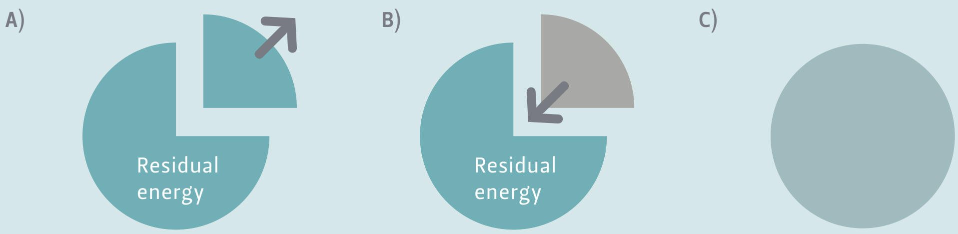
The National Energy Authority is responsible for registering Iceland's contribution to the overall composition of Europe's electricity production with a view to the export of guarantees of origin. Independent of how electricity is generated in Iceland; it is either certified with a guarantee of origin or not. Uncertified electricity is classified by the National Energy Authority as 'residual electricity' and the agency publishes this information annually.

The residual energy amount is calculated each year with a view to the overall composition of Europe's electricity production for the purpose of exporting guarantees of origin (Figure 47).

Business with guarantees of origins
Guarantees of origin are sold on the open European market and their market value is dependent upon demand and supply each time. Guarantees of origin are divided into categories including wind power, solar power and hydropower. Their market value depends on the demand within each category.

Landsvirkjun's average revenue for guarantees of origin for the period between 2006 and 2011 was between 30–38 million ISK and in 2012 they increased to 260 million ISK. Corporations and institutions in Germany, Austria, Switzerland, Belgium and Holland have all been involved in guarantees of origin transactions. Icelandic buyers are also able to buy Icelandic guarantees of origin and can receive their electricity purchases from Icelandic electricity sources certified in accordance with the European Standard (AIB–ECCS).

Figure 47 — Composition of electricity sale in Iceland, taking the export of guarantees of origin into consideration.



A) Renewable electrical energy generated in Iceland (green energy). Guarantees of origin are sold as a part of the production and what is left is the so called residual energy.

B) An equal amount of the energy sold with guarantees of origin is calculated as part of the Icelandic market just like the energy composition in Europe (grey energy).

C) The Icelandic electricity market is therefore considered to be grey-green and is composed of renewable energy (green) produced in Iceland and energy composition (grey) from Europe.

Summary of GHG emissions from Landsvirkjun's operations

The main source of GHG emissions from Landsvirkjun's operations is electricity generation utilising geothermal resources (i.e. emissions from geothermal power stations and exploration drilling) and emissions from hydropower reservoirs. **Figure 48** shows the relative contribution of GHG emissions from Landsvirkjun's operations in 2012, by source. Emissions from geothermal power stations contributed approximately 75% of the total GHG emissions and emissions from hydropower reservoirs 24%. Other GHG emissions (1%) can be traced to the burning of fossil fuel, air travel and waste disposal. There were no SF_6 emissions from electrical equipment this year. These percentages are similar to those of previous years.

Figure 49 shows the GHG emissions from Landsvirkjun's operations in 2008 to 2012, as well as carbon binding figures and the Company's net carbon footprint. GHG emissions from Company's operations amounted to 54,000 tonnes CO_2-eq and has been reduced by 4% compared to 2011 and 14% compared to 2008. However, the actual decrease is probably less for 2012 as information on the actual number of international flights was made available whereas these figures had been estimated previously (2008-2011). The results from these figures indicate that estimates for the period 2008-2011 were too high and these estimates have not been updated. Taking into account the carbon binding the carbon footprint for 2012 is 32,000 tonnes CO_2-eq and has decreased by 7% compared to 2011 and 25% compared to 2008. This is mainly due to the reduction of emissions from geothermal stations.

Figure 50 shows a summary of GHG emissions from Landsvirkjun's operations in 2008 to 2012. The figure shows that emissions from geothermal electricity generation and reservoirs are the main factors in terms of GHG emissions. Changes in operation of the geothermal power stations, reduced exploration drilling and emissions from reservoirs therefore have the greatest potential to decrease Landsvirkjun's overall carbon footprint. Currently, there is not a consensus whether emissions from geothermal electricity generation should be regarded as anthropogenic or natural emissions. Other emissions are dependent upon the scale of operations at any given time and have a minimal effect on the overall carbon footprint of the Company.

The total GHG emissions from Landsvirkjun's operations in 2012 per generated GWh of electricity were 4.2 tonnes CO_2-eq/GWh when carbon binding is not taken into consideration.

If carbon binding via land reclamation and re-forestation is taken into account then the GHG emissions per GWh were 2.4 tonnes CO_2-eq/GWh.

The carbon footprint decreases by 10% compared to 2011 and 30% compared to 2008. It must be noted that emissions from reservoirs in 2008 are based on an estimated number of ice-free days and the emissions for international air travel are estimated between 2008 and 2011. It is therefore likely that the actual decrease is in fact lower. Calculations of GHG emissions per generated GWh emissions related to exploration drilling are not included as these are not directly related to the annual electricity generation.

It is interesting to compare the emissions from the different energy sources utilised by Landsvirkjun: geothermal and hydropower. When calculating the greenhouse

Figure 48 — GHG emissions in Landsvirkun's operations by source 2012.

	Tonnes CO_2 equivalent	%
Geothermal electricity generation	40,075	75
Hydropower reservoirs	12,680	24
Other		
Diesel consumption	662	1
Flights	55	< 1
Petroleum consumption	326	< 1
Waste	65	< 1

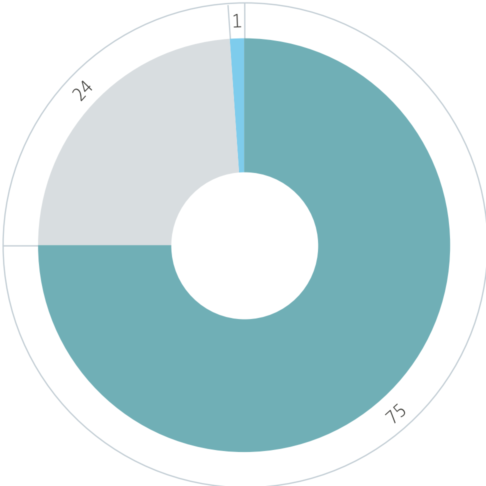
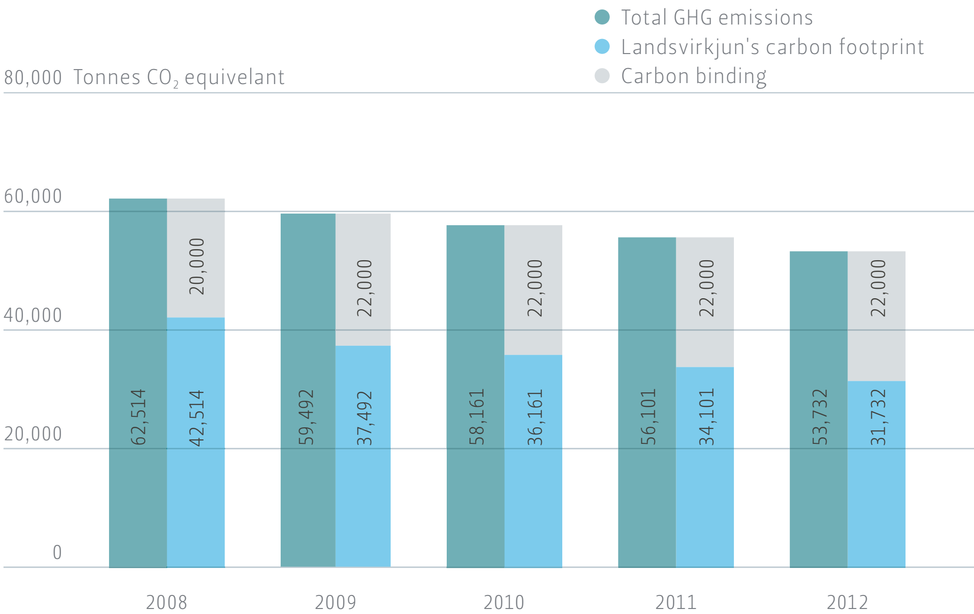


Figure 49 — Total GHG emissions from Landsvirkjun's operations 2008–2012.



effect by energy source, the emissions not directly related to the energy source itself are allocated between the different sources using the amount of electricity generated by the respective source. This is the case for GHG emissions related to flights, waste disposal and carbon binding. As mentioned above, emissions due to exploration drilling are not included in the calculations for GHG emissions per generated GWh. The comparison reveals a significant difference between the amount of GHGs emitted by geothermal and hydropower stations. GHG emissions for geothermal power stations were 77.5 tonnes CO_2-eq/GWh, excluding carbon binding and 75.7 tonnes CO_2-eq/GWh when carbon binding is taken into account. Landsvirkjun's geothermal stations will probably emit less GHG per GWh. This is mainly due to the fact that the emission of GHGs from Krafla Station is more than that of other geothermal areas in Iceland (Bjarni Pálsson et al. 2011).

GHG emissions for electricity generated at hydropower stations were 1.13 tonnes CO_2-eq/GWh when carbon binding is not taken into account and -0.65 tonnes CO_2-eq/GWh when carbon binding is included (**Figure 51**). The results show that Landsvirkjun binds around 0.65 tonnes CO_2-eq for each GWh generated using hydroelectric power. Detailed information on GHG emissions in Landsvirkjun's operations can be found in the Annex.

It is important to note that when this comparison is made it is not clear if GHG emissions from geothermal power stations are an addition to natural GHG emissions from geothermal areas or if these emissions are entirely or partly only a transfer of natural emissions.

Each area must be evaluated individually when GHG emissions are estimated, as behaviour of geothermal areas varies.

GHG emissions from electricity generation in Iceland are low compared to most other countries as the major part of the generation is from hydropower and geothermal energy resources. Landsvirkjun has assessed environmental impact factors for electricity generation at its stations using Life Cycle Analysis. The first analysis (for Fljótsdalur Station) is now complete. Landsvirkjun intends to continue this work in an effort to assess the overall environmental effects of electricity generation at its power stations.

Figure 50 — GHG emissions from Landsvirkjun's operations 2008–2012.

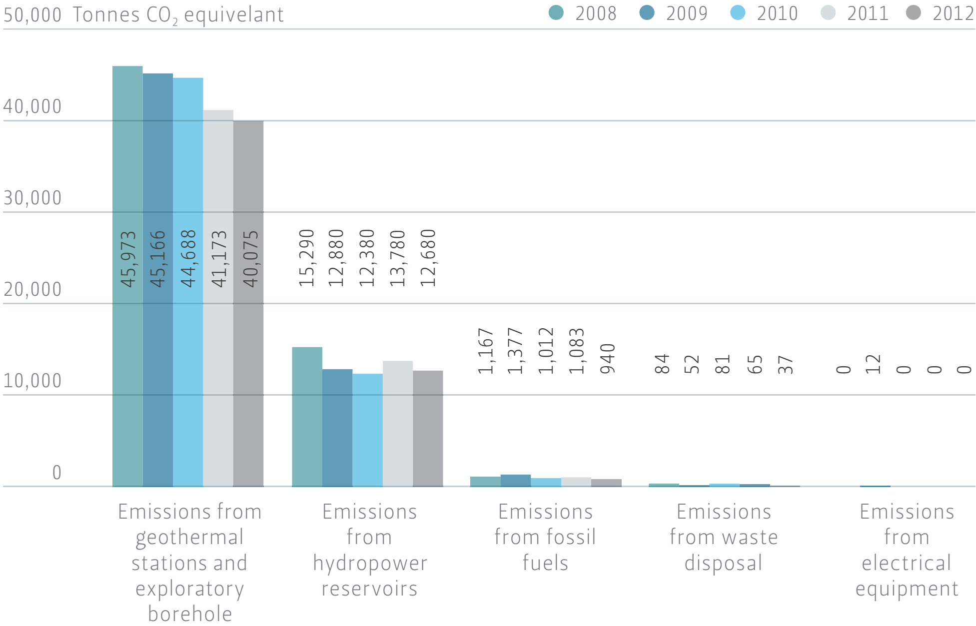
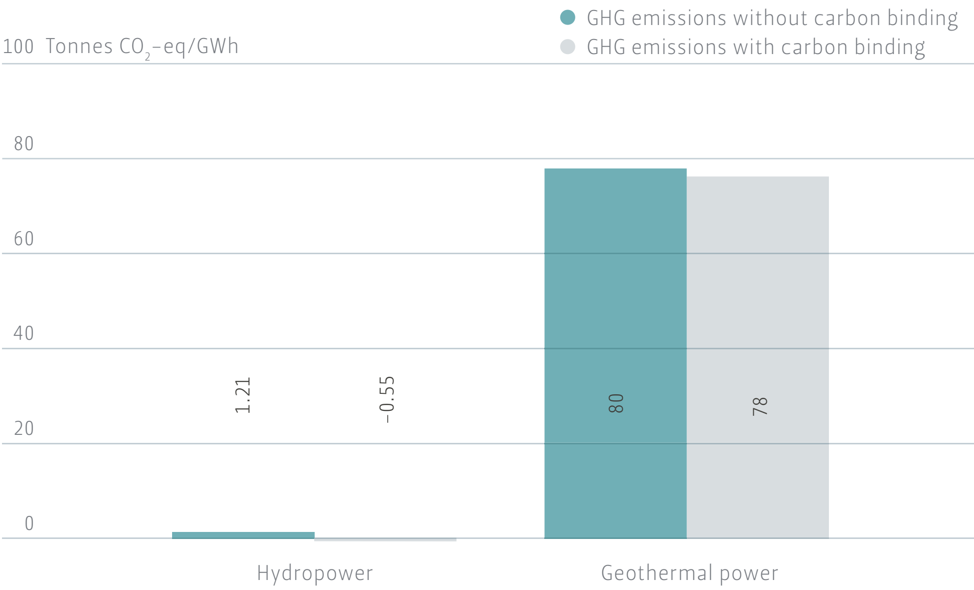


Figure 51 — GHG emissions by energy generation category; hydropower and geothermal, with and without carbon binding measures calculated from the operational year 2012.



Annex
Tables and numerical data

The Annex presents tables and detailed numerical data on issues discussed in previous chapters of this report.

The numerical environmental data is compiled from Landsvirkjun's accounting records, DynamicsAX, GB (green accounting), a human resource system, the geothermal database ViewData managed by Kemía sf., Landsnet's database on electricity generation and records on land-use, land-use change and forestry (LULUCF) from the Agricultural University of Iceland. The data published are either actual figures or calculated based on measured values and have been reviewed by EFLA Consulting Engineers. The information in this report is given to the best of knowledge and is considered accurate.


The Long-tailed Duck or Oldsquaw *(Clangula hyemalis)* is a northern sea duck and a commonly found breeding bird in Iceland. During the summers the male bird is mostly dark brown on top but has a lightly coloured chest and face. During the winters he becomes white with a few dark patches on his wings, chest and neck. The female bird does not change colour and is generally a light brown colour.

Electricity generation

In **Tables 1 and 2** a summary of Landsvirkjun's electricity generation is given. **Table 1** shows Landsvirkjun electricity generation, not taking into account energy losses as well as Landsvirkjun's energy consumption in the power stations, which in total accounts for 128 GWh in 2012. **Table 1** also shows the total number of employees and **Table 2** shows Landsvirkjun's total electricity generation in Iceland in 2008–2012.

Annex-Table 1 — Summary of Landsvirkjun electricity generation by operational area and number of employees in 2012.

	Energy source	Number of employees *	Capacity (MW)	Electricity generation (GWh)	Percentage of overall electricity generation (%)
Headquarters in Reykjavík and Akureyri	–	142	–	–	–
Power stations					
Blanda Station	Hydropower	14	150	849	7
Fljótsdalur Station	Hydropower	13	690	4,818	39
Mývatn area	Hydropower & geothermal power	25	91	660	5
– Krafla & Bjarnarflag Stations	Geothermal	(20)	(63)	(489)	(4)
– Laxá Station	Hydropower	(5)	(28)	(171)	(1)
Sogid area	Hydropower	14	90	542	4
Thjórsá area	Hydropower	39	840	5,443	44
Energy losses and own use					
Landsvirkjun total – 2012		**247**	**1,021**	**12,312**	**100**
Landsvirkjun total – 2011		**233**	**1,861**	**12,485**	**100**
Landsvirkjun total – 2010		**227**	**1,861**	**12,625**	**100**
Landsvirkjun total – 2009		**229**	**1,861**	**12,242**	**100**
Landsvirkjun total – 2008		**228**	**1,861**	**12,435**	**100**

* Number of permanent employees at the end of 2012.

Annex-Table 2 — Landsvirkjun's electricity generation and the total electricity generation in Iceland 2012 (Information retrieved from Annual Reports of the National Energy Authority 2008–2012).

		Landsvirkjun					Iceland total				
		2012	2011	2010	2009	2008	2012	2011	2010	2009	2008
Hydropower stations	GWh	11,822	11,982	12,110	11,772	11,954	12,337	12,507	12,592	12,279	12,427
Geothermal stations	GWh	490	503	515	470	481	5,210	4,701	4,465	4,553	4,038
Fuel	GWh	0	0	0	0	0	3	2	2	3	3
Total	GWh	**12,312**	**12,485**	**12,625**	**12,242**	**12,435**	**17,550**	**17,210**	**17,059**	**16,835**	**16,468**
Hydropower stations	%	96	96	96	96	98	70	73	73	73	73
Geothermal stations	%	4	4	4	4	4	30	27	26	27	27
Fuel	%	0	0	0	0	0	<1	<1	<1	<1	<1
Total	%	100	100	100	100	102	100	100	99	100	100

Utilisation of geothermal resources

Table 3 shows information on the utilisation of geothermal resources for Landsvirkjun's electricity generation, the utilisation per energy unit in 2008 to 2012 and the change between years.

In **Table 4** the utilisation of water and steam for exploration drilling in 2008 to 2012 is shown along with the change between years.

Annex-Table 3 — Utilisation of energy sources during Landsvirkjun's electricity generation.

		2012	2011	2010	2009	2008	Changes compared with 2011	Changes compared with 2008
Utilisation in thousand tonnes:								
Steam	thousand tonnes	5,857	6,123	6,496	5,724	5,939	-4%	-1%
Water	thousand tonnes	5,230	5,170	5,142	4,861	5,545	+1%	-6%
Re-injection	thousand tonnes	2,563	2,530	2,792	2,572	1,778	+1%	+44%
Utilisation per GWh generated								
Steam	thousand tonnes/GWh	12.0	12.2	12.6	12.2	12.6	-2%	-2%
Water	thousand tonnes/GWh	10.7	10.3	10.0	10.3	11.8	+4%	-7%
Re-injection	thousand tonnes/GWh	5.2	5.0	5.4	5.5	3.8	+4%	+41%

Annex-Table 4 — Utilisation of geothermal sources during exploratory drilling.

		2012	2011	2010	2009	2008	Change from 2011	Change from 2008
Amount; thousand tonnes:								
Steam	thousand tonnes	824	1,163	284	535	567	-29%	+45%
Water	thousand tonnes	210	1,095	0	171	408	-81%	-49%

Fuel – purchased quantity

Table 5 shows the total amount of electricity generation in Landsvirkjun's power stations in 2012 as well as the quantity of fuel used at each operational area and Landsvirkjun's total fuel use. **Table 6** shows Landsvirkjun's total fuel usage during the period 2008 to 2012 with comparison between years.

Annex-Table 5 — Fuel consumption in Landsvirkjun's operations 2012.

			Electricity generation						
		LV total 2012	Blanda Station	Fljótsdalur Station	Mývatn area	Sogid area	Thjórsá area	Research & Development Division & Project Planning & Construction Division	Other LV operations
Electricity generation	GWh	**12,312**	849	4,818	660	542	5,443	–	–
Petroleum	Litres	**22,943**	–	488	3,067	269	4,376	9,678	5,065
Diesel oil	Litres	**243,006**	17,863	19,212	43,152	20,511	67,001	56,102	19,165
Methane	kg	**504**	–	–	–	–	–		504
Hydrogen	kg	**–**	–	–	–	–	–	–	–

Annex-Table 6 — Fuel consumption 2008–2012.

		LV total 2012	LV total 2011	LV total 2010	LV total 2009	LV total 2008	Change from 2011	Change from 2008
Petroleum	Litres	22,943	21,891	19,430	24,216	22,392	+5%	2%
Diesel oil	Litres	243,006	257,572	235,759	356,407	269,260	-6%	-10%
Methane	kg	504	339	–	–	–	+49%	+100%
Hydrogen	kg	–	122	202	217	241	-100%	-100%

Land reclamation and carbon binding

Table 7 summarises the amount of fertiliser and the number of plants planted in 2008 to 2012 in the vicinity of power stations. **Table 8** shows the number of plants planted in the environmental project "Many hands Lighten the Load" during the same period. In **Table 9** the major quantities for the summer projects in Reykjavík Capital Area are shown. A list of the main projects are shown in **Table 9**.

Annex-Table 7 — Distribution of commercial fertiliser and number of plants planted under the auspices of Landsvirkjun 2008–2012.

		2012	2011	2010	2009	2008
Fertiliser distribution: commercial fertiliser*	Tonnes	482	456*	495	505	361
Plants planted in vicinity of power stations	Number	5,480	72,150	106,658	60,452*	41,410

* Quantity have been updated from last years Environmental Report.

Annex-Table 8 — Number of plants planted by the "Many hands Lighten the Load" cooperative project 2008–2012.

		2012	2011	2010	2009	2008
Plants planted by "Many hands Lighten the Load" project	pcs.	30,450	73,690	96,535	111,488	116,835

Annex-Table 9 — Overview of the "Many hands Lighten the Load" project.

Project	Amount
Planting	30,450 plants
Trails repairs	5.5 km
New trails	3 km
Fertiliser for plants	1000 kg
Fertiliser for grass	160 kg
Grass seeds	500 kg
Gravel for trails	100 tons

Releases into water and soil from geothermal power stations

Table 10 shows the amount released into water and soil, of condensed and separation water, heavy metals and nutrients from Krafla and Bjarnarflag power stations. The amount of heavy metals is calculated based on measured concentrations in condensed and separation water. The table shows that the percentage of heavy metals re-injected does not follow the percentage of volume of water re-injected. This can, to some extent, be explained by the fact that specific amounts of heavy metals are released with the corrosion of machinery. Furthermore, the table shows the amount of hydrogen sulphide and carbon dioxide released to surface waters or re-injected, but reinjection reduces the emissions of these gases into the atmosphere.

Limit values for release of these compounds are not defined in the operation permit, except that the concentration in the receiver must be below environmental group I, in accordance with regulation on mitigation measures against water contanimation No. 796/1999.

Table 10 also shows the amount of heavy metals and nutrients released into surface waters as a result of exploration drilling in the Mývatn area. The extent of research decreased during 2011 and the release of heavy metals and nutrients to surface waters has therefore decreased accordingly. No re-injection is done in exploration drilling.

Annex-Table 10 — Quantity of chemicals in condensed and separation water (heavy metals, nutrients and gases) reinjected into soil and released into surface waters.

		Electricity generation and researc														
		Electricity generation										Research				
		Release into surface waters					Re-injection					Release into surface waters				
		2012	2011	2010	2009	2008	2012	2011	2010	2009	2008	2012	2011	2010	2009	2008
Water																
- Water from geo-thermal stations	Thous. tonnes	4,640	4,693	4,507	4,223	5,745	2,563	2,530	2,792	2,572	1,778	-	-	-	-	-
Heavy metals																
- Arsenic	kg	173	190	167	157	115	10	7	28	33	23	5	27	0	1	3
- Copper	kg	4	3	2	1	2	-	1	-	-	1	0	0	0	0	1
- Chromium	kg	4	4	3	6	2	0	0	0	0	0	0	0	0	0	3
- Nickel	kg	1	3	2	12	2	-	-	1	-	1	0	0	0	0	1
- Zinc	kg	5	12	15	8	8	1	2	2	2	3	0	2	0	0	1
Nutrients																
- Phosphorus	kg	9	9	11	10	29	3	3	3	3	2	0	1	0	0	19
Other																
- Hydrogen sulphide	kg	108,215	128,000	117,000	64,000	186,000	120,363	119,000	131,000	121,000	84,000	-	-	-	-	-
- Carbon dioxide	kg	306,510	263,000	225,000	212,000	328,000	163,511	149,000	137,000	139,000	53,000	-	-	-	-	-

Waste

Table 11 shows the quantity of waste generated in Landsvirkjun's operations by category and disposal in 2008 to 2012. **Table 12** shows the quantity of waste generated in Landsvirkjun's operational areas in 2012 by waste categories and disposal method. **Table 13** shows the quantity of hazardous materials generated from the overall operation in 2008-2012, by category. The quantity of hazardous materials generated in different operational areas in 2012 can be seen in **Table 14**.

Annex–Table 11 — Quantity of waste by category and disposal method 2008–2012.

		LV Total 2012	LV Total 2011	LV Total 2010	LV Total 2009	LV Total 2008
Unsorted waste:	kg	**36,211**	**52,207**	**69,415**	**51,924**	**93,351**
Landfill	kg	29,464	41,997	59,378	41,899	80,760
Incineration	kg	6,747	10,210	10,037	10,025	12,591
Waste for recycling and reuse:	kg	**80,554**	**467,592**	**171,233**	**96,917**	**266,749**
Tyres	kg	1,900	1,155	270	100	0
Household equipment	kg	35	0	0	0	0
Organic waste	kg	12,221	13,830	13,132	8,148	5,359
Metals and various equipment	kg	36,943	225,034	82,807	39,795	62,671
Paper, cardboard and packaging	kg	12,514	16,560	12,045	7,423	7,696
Plastic	kg	451	379	4,858	3,779	110
Print cartridges	kg	140	181	95	100	7
Timber*	kg	**16,351**	**210,454**	**58,027**	**37,572**	**190,908**
Inert waste* **	kg	55,860	8,296	83,517	68,975	51,445
Earth and minerals, glass and porcelain	kg	**55,860**	**8,296**	**83,517**	**68,975**	**51,445**
Hazardous material	kg	**4,626**	**11,466**	**52,615**	**12,123**	**6,186**
Total wastes	kg	**177,251**	**539,561**	**376,780**	**229,939**	**417,731**

* Plastic and timber is sorted and sent to Húsavík for incinerationwhere there are plans to utilise this for electricity generation and heating purposes. As a result of equipment failure; only heating has been produced in the last year.

** Corrected amount from previous year.

*** Inactive waste is sent to landfill for inert waste.

Annex-Table 12 — Quantity of waste from Landsvirkjun's operational areas in 2012 by category and treatment/disposal.

		LV Total 2012	Blanda Station	Fljótsdalur Station	Mývatn area Krafla St.	Mývatn area Laxá St.	Sogid area	Thjórsá area	LV other operations
Unsorted waste:	kg	**36,211**	**2,700**	**10,160**	**5,892**	**855**	**3,340**	**6,190**	**7,074**
Landfilled	kg	**29,464**	2,700	10,160	–	–	3,340*	6,190	7,074
Incinerated	kg	**6,747**	–	–	5,892	855	–	–	–
Waste for re-cycling or reuse:	kg	**80,554**	**11,801**	**1,578**	**11,752**	**1,576**	**709**	**30,704**	**16,136**
Tyres	kg	**1,900**	–	–	180	60	–	1,660	–
Household equipment	kg	**35**				35			
Organic waste	kg	**12,221**	825	1,340	1,053	–	–	2,670	6,333
Metals and various equipment	kg	**36,943**	6,420	25	5,250	845	122	23,560	721
Paper, cardboard and packaging	kg	**12,514**	1,141	150	350	41	579	2,806	7,447
Plastic	kg	**451**	295	53	80	20			4
Print cartridges	kg	**140**		10	4	5	8	8	106
Timber**	kg	**16,351**	**3,120**	**–**	**4,835**	**570**	**–**	**–**	**1,526**
Inert waste* **	kg	**55,860**	–	80	–	51,050	–	–	4,730
Earth and minerals, glass and porcelain	kg	**55,860**	**–**	**80**	**–**	**51,050**	**–**	**–**	**4,730**
Hazardous materials	kg	**4,626**	**950**	**160**	**549**	**1,196**	**421**	**1,264**	**86**
Total waste	kg	**177,251**	**15,451**	**11,978**	**18,193**	**54,677**	**4,470**	**38,158**	**28,025**

* Measurements on the quantity of unsorted waste were inactive for a part of the year, it is therefore assumed that the amount of unsorted waste for Sogid is the same as that of 2011.

** Plastic and timber is sorted and sent to Húsavík for incineration where there are plans to utilise this for electricity generation and heating purposes. As a result of equipment failure; only heating has been produced in the last year .

*** Sent to landfill for inert waste.

Annex–Table 13 — Quantity of hazardous waste by category 2008–2012.

		LV Total 2012	LV Total 2011	LV Total 2010	LV Total 2009	LV Total 2008
Hazardous waste for disposal:	kg	**2,395**	**2,763**	**3,265**	**4,697**	**974**
Asbestos	kg	0	0	0	960	0
Toxins	kg	12	0	31	0	0
Organic waste	kg	259	117	310	1,669	232
Coal slack	kg	0	21	0	20	0
Batteries	kg	1,181	1,255	2,002	1,078	540
Hazardous material containers	kg	233	50	210	935	0
Inert waste	kg	57	611	79	10	14
Various hazardous materials	kg	654	709	633	25	188
Oil waste:	kg	**2,231**	**8,703**	**49,350**	**7,426**	**5,212**
Hazardous waste total	kg	**4,626**	**11,466**	**52,615**	**12,123**	**6,186**

Annex-Table 14 — Quantity and type of hazardous materials from Landsvirkjun's operations in 2012.

		LV Total 2012	Blanda Station	Fljótsdalur Station	Mývatn area Krafla St.	Mývatn area Laxá St.	Sogid area	Thjórsá area	Other LV operations
Hazarodus materials for disposal:	kg	**2,395**	**510**	**108**	**177**	**168**	**197**	**1,149**	**86**
Toxins	kg	12	0	12	0	0	0	0	0
Organic hazardous waste	kg	259	200	0	0	0	23	0	36
Coal slack	kg	0	0	0	0	0	0	0	0
Batteries	kg	1,181	270	63	0	120	56	647	25
Hazardous material containers	kg	233	40	27	113	20	0	33	0
Inorganic hazardous waste	kg	57	0	0	0	0	0	57	0
Various hazardous materials	kg	654	0	6	64	28	118	412	25
Oil waste:	kg	**2,231**	**440**	**52**	**372**	**1,028**	**224**	**115**	**0**
Hazardous materials and oil waste total	kg	**4,626**	**950**	**160**	**549**	**1,196**	**421**	**1,264**	**86**

Noise

The measured equivalent sound levels at Krafla and Bjarnarflag Stations 2008-2012 are shown in **Tables 15 and 16**. Blue coloured lines represent areas where measurements are done in popular tourist areas, within or outside of the industrial area. Values in red represent measured sound levels exceeding 50 dB(A) in such areas. Grey represents additional measurement locations, but no measurements have been conducted in these locations since 2010.

Annex-Table 15 — Equivalent sound levels at Krafla 2008–2012. Blue coloured lines represent measurement locations in popular tourist areas, within or outside the industrial area. Values in red represent measured sound levels exceeding 50 dB(A) in such areas. Grey represents additional measurement locations.

Monitoring location	Krafla	21. and 22.08 2012 LAeq[dB(A)]	21.02. 2011 LAeq[dB(A)]	08.and 11.02. 2010 LAeq[dB(A)]	31.07. 2009 LAeq[dB(A)]	05.08. 2008 LAeq[dB(A)]
1	Krafla control room	46.1	56.5	56	53.9	51.6
2	East of turbine 1	83.7	88.7	89.1	89.1	88.2
3	East of turbine 2	90	90.1	89.5	89.9	90.8
4	Powerhouse	79.8 [i]	67.9	73.4	72	73.3
5	Storehouse 1a	70.3	60.8	71.5	67.6	67.2
6	Residence at Sigurbogi	71.9 [ii]	56.3	79.9	50	49.7
7	By hole 6	74.9 [ii]	52.3	81.8	55.5	51.8
8	By hole 26	56.1	45.4	62.2	50	48
9	By hole 35	–	–	–	–	30.8
13	By hole 34	79.5 [iii]	74.9	73.3	75	63.8
14	By hole 19	65.8	60.2	61.9	68	66
15	By hole 31	45.2	51.5	44.9	57	45.5
16	By hole 14	51.5	43.4	48	52	42.9
17	By hole 18	33.3	41.2	41.2	52	30.3
18	By hole 1: SW area	34.9	43.1	38.6	42	31.9
19	Parking lot at power station's cafeteria	65	53.3	46.7	48	44.2
21	By hole 21	47.2	54	41.7	48	42.2
37	Borehole 22	–	–	–	Flow test	–
38	Borehole 37	–	–	–	Flow test	–
39	Borehole 39	–	–	101		–
40	IDDP deep drilling hole	–	–	117	–	–
10	By hole 8 in parking lot at Saurbær	46.5	39.7	48	50	32
11	By hole 10 – viewing platform	57.6 [iv]	51.1	73.5	64	47.8
12	Parking lot at Vítisbarmur	59.8 [v]	48.4	39	50	30
20	By a sign in Kröfluvegur – near waterhole house	49.7	53	37.8	51	37
22	Parking lot at Skardssel	41.1	47.5	35.9	44	42

[i] Substantial noise from traffic which effects masurements (bleeding from Þeisastation 1).
[ii] Steam released by silencer, measured noise higher than usual.
[iii] Hole KJ-38 in flow test which effects noise measurements (increase).
[iv] Tourist traffic within range of testing.

Annex–Table 16 — Equivalent sound levels at Bjarnarflag 2008–2012. Blue coloured lines represent measurement locations in popular tourist areas, within or outside the industrial area. Values in red represent measured sound levels exceeding 50 dB(A) in such areas.

Monitoring location	Bjarnarflag	21. and 22.08 2012 LAeq[dB(A)]	15. and 18.02. 2011 LAeq[dB(A)]	08.and 11.02. 2010 LAeq[dB(A)]	31.07.2009 LAeq[dB(A)]	05.08.2008 LAeq[dB(A)]
24	By hole 11	44.1	58.6	100.1	40	62.4
25	By hole 12	56.9	71.1	77.2	90	84.7
27	At steam station	82.8	85.7	84.8	48	81.8
28	By hole 9	65.3	71.2	82.6	36	51
29	Heat exchange station – electr. Room	83.3 [i]	84.5	77.1	66	62.5
32	Separation station 1	87.1	84.1	84.1	69	61
33	Separation station 2	82.0 [ii]	73.5	83	56.7	70.8
34	Parking lot at Grænar lausnir	72.6 [iii]	45.9	47	40	
35	On embankment	46.1	56.6	34.9	40	45.1
23	Viewing platform at Námaskard	48.9	47.6	48.5	43	54.2
26	6 Information lot – close to old bathing area	57.7	57.7	63	34	50.3
30	Parking lot for the bathing area entrance	39	52.3	46.7	43	48.3
31	At the new nature baths	38.5	44.9	47.7	35	47.3
36	Skútahraun 6	35.6	43.7	35.5	40	38.5

[i] The door to the computer room was open during measurement period and increased the reading.
[ii] An air compressor was on when measurements were conducted which increased the reading.
[iii] A crawler was working in the area when measurements were conducted which increased the reading.

Atmospheric emissions and the greenhouse effect

Table 17 shows GHG emissions from Landsvirkjun's operations 2008 to 2012. **Table 18** shows atmospheric GHG emissions and greenhouse effect from Landsvirkjun's operations in 2012 by source. **Table 19** shows GHG emissions calculated per generated GWh, excluding emissions from exploration drilling. Emissions due to exploration drilling are not included as these are not directly related to the electricity generation. **Table 20** summarises greenhouse effects from Landsvirkjun's electricity generation, hydropower and geothermal, in 2012. The GHG emissions are presented as emissions in CO_2-eq and CO_2-eq/GWh. Finally, **Table 21** shows GHG emissions from Landsvirkjun's hydropower reservoirs in 2012.

Annex-Table 17 — Greenhouse gas emissions from Landsvirkjun's operations 2008–2012.

		2012 LV Total	2011 LV Total	2010 LV Total	2009 LV Total	2008 LV Total	Changes compared to 2011	Changes compared to 2008
Geothermal stations: total emissions	tonnes CO_2-eq	**40,075**	**41,173**	**44,688**	**45,166**	**45,973**	**-3%**	**-13%**
Energy generation	tonnes CO_2-eq	37,836	40,164	44,121	41,292	41,719	-6%	-9%
Exploratory drilling	tonnes CO_2-eq	2,239	1,009	567	3,874	4,254	122%	-47%
Hydropower reservoirs	tonnes CO_2-eq	**12,680**	**13,780**	**12,380**	**12,880**	**15,290**	**-8%**	**-17%**
Burning of fossil fuels	tonnes CO_2-eq	**940**	**1,083**	**1,012**	**1,377**	**1,167**	**-13%**	**-19%**
Petroleum for equipment and vehicles	tonnes CO_2-eq	57	55	48	60	56	4%	2%
Diesel oil for equipment and vehicles	tonnes CO_2-eq	662	702	642	971	734	-6%	-10%
Flights: total emissions	tonnes CO_2-eq	221	326	322	346	377	-32%	-41%
- Domestic flights	tonnes CO_2-eq	92	76	72	96	127	21%	-28%
- International flights	tonnes CO_2-eq	129	250	250	250	250	-48%	-48%
Waste	tonnes CO_2-eq	**37**	**65**	**81**	**57**	**84**	**-43%**	**-56%**
Emissions from electrical equipment	tonnes CO_2-eq	**0**	**0**	**0**	**12**	**0**	**0%**	**0%**
GHG emissions	tonnes CO_2-eq	53,732	56,101	58,161	59,492	62,514	-4%	-14%
Carbon binding	tonnes CO_2-eq	-22,000	-22,000	-22,000	-22,000	-20,000	0%	10%
Landsvirkjun's carbon footprint	tonnes CO_2-eq	**31,732**	**34,101**	**36,161**	**37,492**	**42,514**	**-7%**	**-25%**

Annex–Table 18 — Greenhouse gas emissions and greenhouse effect from Landsvirkjun's operations in 2012.

Source of emissions	Use	Atmospheric emissions	
	Quantity	Quantity [tonnes]	Greenhouse effect kg CO_2-eq
Emissions from geothermal stations			
Steam from geothermal stations*	5,857,335 tonnes	3,883,724	
– Carbon dioxide emissions		37,387	37,386,684
– Methane emissions		21	449,158
– Hydrogen sulphide emissions		5,536	0
Exploratory borehole emissions			
Steam from exploratory boreholes	824,206 tonnes	824,206	
– Carbon dioxide emissions		2,173	2,173,115
– Methane emissions		3	65,529
– Hydrogen sulphide emissions		444	0
Emissions from hydropower reservoirs	339 km²		
– Carbon dioxide emissions		6820	6,820,000
– Methane emissions		279	5,860,000
Emissions from fossil fuel consumption: petrol for vehicles and machinery	22,943 litres		
– Carbon dioxide emissions		53	52,826
– Methane emissions		0.005	108
– Nitrous oxide emissions		0.014	4,267
Emissions from fuel consumption: Diesel for vehicles and machinery	243,006 litres		
– Carbon dioxide emissions		649	649,118
– Methane emissions		0.016	343
– Nitrous oxide emissions		0.041	12,656
Emissions from flights			
– Domestic flights		91.9	91,868
– International flights		129.3	129,283
Emissions from waste disposal			
– Landfill	29 tonnes		21,067
– Incineration	12 tonnes		15,449
Electrical equipment emissions		0	
– SF_6 emissions			0
Difference between the use and quantity released is due to reinjection			53,731,471

* Difference between the use and quantity released is due to reinjection.

Annex–Table 19 — Greenhouse gas emissions per GWh, excluding emissions from exploration drilling.

		LV Total 2012	LV Total 2011	LV Total 2010	LV Total 2009	LV Total 2008	Changes compared to 2011	Changes compared to 2008
Geothermal stations: energy generation*	tonnes CO_2-eq/Gwh	3,073	3,217	3,495	3,373	3,355	-4%	-8%
Hydropower reservoirs	tonnes CO_2-eq/Gwh	1,030	1,104	0,981	1,052	1,230	-7%	-16%
Fossil fuel burning								
Petroleum for vehicles and machinery	tonnes CO_2-eq/Gwh	0.005	0.004	0.004	0.005	0.005	25%	0%
Diesel oil for vehicles and machinery	tonnes CO_2-eq/Gwh	0.054	0.056	0.051	0.079	0.059	-4%	-8%
Flights total emissions	tonnes CO_2-eq/Gwh	0.017	0.026	0.026	0.028	0.030	-35%	-43%
– Domestic flights	tonnes CO_2-eq/Gwh	0.007	0.006	0.006	0.008	0.010	17%	-30%
– International flights	tonnes CO_2-eq/Gwh	0.010	0.020	0.020	0.020	0.020	-50%	-50%
Waste	tonnes CO_2-eq/Gwh	0.003	0.005	0.006	0.005	0.007	-40%	-57%
Electrical equipment emissions	tonnes CO_2-eq/Gwh	0.000	0.000	0.000	0.001	0.000	0%	0%
GHG emissions: exploratory drilling excluded	tonnes CO_2-eq/Gwh	4,182	4,413	4,562	4,543	5,027	-5%	-17%
Carbon binding	tonnes CO_2-eq/Gwh	-1,787	-1,762	-1,743	-1,797	-1,608	1%	11%
Landsvirkjun's carbon footprint: excluding exploratory drilling and including carbon binding	tonnes CO_2-eq/Gwh	**2,395**	**2,651**	**2,819**	**2,746**	**3,419**	**-10%**	**-30%**

* Emissions from production boreholes are included as these are part of the electricity generation, emissions from exploration boreholes are however not included as these are not part of the annual electricity generation.

Annex–Table 20 — Summary of greenhouse effects due to electricity generation in Landsvirkjun's hydropower stations and geothermal power stations in 2012, excluding emissions from exploration drilling.

		Hydropower station	Geothermal station		Hydropower station	Geothermal station
Petroleum consumption	tons CO_2–eq	48	9	tons CO_2–eq/GWh	0.004	0.018
Diesel oil consumption	tons CO_2–eq	390	120	tons CO_2–eq/GWh	0.033	0.245
Geothermal stations	tons CO_2–eq	0	37,836	tons CO_2–eq/GWh	–	77,216
Hydropower reservoirs	tons CO_2–eq	12,680	0	tons CO_2–eq/GWh	1,073	0
Flights	tons CO_2–eq	212	9	tons CO_2–eq/GWh	0.018	0.018
Waste	tons CO_2–eq	62	3	tons CO_2–eq/GWh	0.005	0.006
SF_6 from electrical equipment	tons CO_2–eq	0	0	tons CO_2–eq/GWh	–	0
GHG emissions from exploratory boreholes	tons CO_2–eq	13,392	37,977	tons CO_2–eq/GWh	1,133	77,504
Carbon binding	tons CO_2–eq	–21,124	–876	tons CO_2–eq/GWh	–1,787	–1,787
GHG emissions: excluding exploratory boreholes and including carbon binding	tons CO_2–eq	**–7,732**	**37,101**	tons CO_2–eq/GWh	**–0.654**	**75,717**

Annex-Table 21 — Calculated annual greenhouse gas emissions from Landsvirkjun's hydropower reservoirs in 2012.

Station/source	Reservoirs/Lakes	Total surface area [km^2]	Total surface area for calculation [km^2]	CO_2 Ice-free [tonnes CO_2]	CH_4 Ice-free [tonnes CO_2-eq]	GHG total [tonnes CO_2- eq]
Blanda Station		**70 (8)**	**62**	**5,550**	**4,800**	**10,350**
Blanda Station	Blanda Reservoir	57	57	4,400	3,800	8,200
Blanda Station	Gilsárlón Reservoir	5	5	1,150	1,000	2,150
Blanda Station	(Lakes along waterway)	(8.2)	0	0	0	0
Fljótsdalur Station		**70 (4)**	**66**	**620**	**520**	**1,140**
Fljótsdalur Station	Hálslón Reservoir	61 (2.6)	58	490	420	910
Fljótsdalur Station	Kelduárlón Reservoir	7.5 (1.1)	6	110	90	200
Fljótsdalur Station	Ufsárlón Reservoir	1.1 (0.14)	1	20	10	30
Fljótsdalur Station	Grjótárlón Reservoir	0.1 (0.02)	0	<1	<1	<1
Laxá Station		**38**	**0**			**0**
Laxá Station	(Mývatn)	(38.0)	0	0	0	0
Sogid area		**(86)**	**0**			**0**
Sogid Station	Úlfljótsvatn Lake	(3)	0			
Sogid Station	Þingvallavatn Lake	(83.0)	0	0	0	0
Þjórsá Area		**199 (70)**	**129**	**650**	**540**	**1,190**
Þórisvatn Reservoir	Þórisvatn Lake	85.2 (70)	15	50	40	90
Þórisvatn Reservoir	Saudafellslón Reservoir	4.5	5	20	10	30
Sigalda Station	Krókslón Reservoir	14	14	70	60	130
Hrauneyjafoss Station	Hrauneyjalón Reservoir	9	9	20	20	40
Búrfell Station	Bjarnalón Reservoir	1	1	<10	<10	<10
Hágöngumidlun area	Hágöngulón Reservoir	37	37	130	110	240
Kvíslaveita Diversion	Kvíslavatn Lake	22	22	270	230	500
Kvíslaveita Diversion	Dratthalavatn Lake	2	2	40	30	70
Kvíslaveita Diversion	Eyvindarlón Reservoir	0	0	<1	<1	<1
Kvíslaveita Diversion	Hreysislón Reservoir	0	0	<1	<1	<1
Kvíslaveita Diversion	Thjórsárlón Reservoir	4	4	10	10	20
Vatnsfell Station	Vatnsfellslón Reservoir	1	1	0	0	0
Sultartangi Station	Sultartangalón Reservoir	20	20	40	30	70
Total		**339 (82)**	**257**	**6,820**	**5,860**	**12,680**

Numbers in parentheses are lakes, and do not contribute to the corresponding power station's GHG emissions. These lakes are either lakes in diversion or natural lakes which have not been created by flooding land (Lake Thingvallavatn and Lake Mývatn). Lake Úlfljótsvatn was partly created by flooding land, but was created approximately 70 years ago and does therefore not contribute to GHG emissions.

Búdarháls – hydropower station under construction

The quantity of waste generated in the Búdarháls hydropower construction area and the use of diesel oil can be seen in **Table 23**. Additionally, the table shows the estimated amount of GHG emissions from the burning of diesel oil and disposal of waste.

Annex–Table 22 — Quantity of waste generated in the Búdarháls construction area, the fossil fuel use and the corresponding greenhouse gas emissions.

	Usage	GHG emissions
Diesel oil: Total	**2,248,981** Litres	
– Contractor	2,248,981 Litres	6,008 tonnes CO_2-eq
Unsorted waste: Total	**82,690** kg	
– Landfill	82,690 kg	59 tonnes CO_2-eq
Waste for recycling and reuse:	**388,576** kg	
– Organic waste	25,900 kg	
– Metals	108,060 kg	
– Paper	6,906 kg	
– Timber	247,710 kg	
– Other recyclable waste		
Inactive waste materials:	**265,010** kg	
– Bulky waste	265,010 kg	
Hazardous waste:	**9,580** kg	
– Waste oil	9,580 kg	
– Other hazardous materials	–	
GHG emissions: Total		**6,067** tonnes CO_2-eq

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Hreindýratalningar norðan Vatnajökuls með myndatöku úr flugvél 2012	LV–2012/115

References

Anette K. Mortensen, Ásgrímur Guðmundsson, Benedikt Steingrímsson, Freysteinn Sigmundsson, Guðni Axelsson, Halldór Ármannsson, Héðinn Björnsson, Kristján Ágústsson, Kristján Sæmundsson, Magnús Ólafsson, Ragna Karlsdóttir, Sæunn Halldórsdóttir og Trausti Hauksson (2009). *Jarðhitakerfið í Kröflu. Samantekt rannsókna á jarðhitakerfinu og endurskoðað hugmyndalíkan. Landsvirkjun, LV-2009/111.*

Arnór Snorrason (2011). *Prediction of Reference Level for the Period 2013-2020 for Forest Management in Iceland.* Skógrækt ríkisins, febrúar 2011.

Borgþór Magnússon og Hákon Aðalsteinsson (2012). *Blöndulón. Vöktun á strandrofi og áfoki. Áfangaskýrsla 2011. Landsvirkjun, LV-2012/049.*

Bjarni Pálsson, Hákon Aðalsteinsson, Hildur Ríkharðsdóttir, Ragnheiður Ólafsdóttir og Sigurður Óli Guðmundsson. (2011). *Loftslagsáhrif Landsvirkjunar – samantekt og tillögur að aðgerðum. Landsvirkjun, LV-2011-016.*

Edward H. Huijbens, Valtýr Sigurbjarnarson og Rögnvaldur Ólafsson (2012). *Rannsóknir á ferðamálum á virkjanasvæði við Þeistareyki. Niðurstöður umferðartalningar og könnunar á Þeistareykjum sumarið 2012. Rannsóknarmiðstöð ferðamála. Landsvirkjun, LV-2012/045.*

EEA (2012). Environmental Indicator Report 2012. *Ecosystem resilience and resource efficiency in a green economy in Europe. Umhverfisstofnun Evrópu, Kaupmannahöfn, Danmörk.*

Goldstein B, Hiriart G, Bertani R, Bromley C, Gutiérrez-Negrín L, Huenges E, Muraoka H, Ragnarsson A, Tester J, Zui V (2011). *Geothermal Energy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)].* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Hákon Aðalsteinsson, Arnór Snorrason og Björn Traustason (2012). *Úttekt á kolefnisbindingu skógræktar á svæðum í eigu Landsvirkjunar. Landsvirkjun, LV-2012/062.*

Hákon Aðalsteinsson, Magnús Jóhannesson og Benóný Jónsson (2012). *Fiskrannsóknir á vatnasvæði Þjórsár árið 2011. Landsvirkun, LV-2012/047.*

Hákon Aðalsteinsson og Kolbeinn Árnason (2012). *Hreindýratalningar norðan Vatnajökuls. Landsvirkjun, LV-2012/115 .*

Halldór Ármannsson og Magnús Ólafsson (2002). *Efnarannsóknir á vatni úr holum, lindum og gjám í Búrfellshrauni og nágrenni: undirstöður vöktunar vegna affalls frá jarðhitavirkjunum, Kröflu og Námafjalli. Orkustofnun, OS-2002/076.*

Helgi Bjarnason, Hákon Aðalsteinsson, Helgi Jóhannesson (2012). *Áhrif fyrirhugaðra virkjana í neðri hluta Þjórsár á fiskistofna í Þjórsá. Landsvirkjun, LV-2012/014.*

Hugrún Gunnarsdóttir (2009). *Vistheimt Landsvirkjunar og umhverfislegur ávinningur í kjölfar virkjana. Landsvirkjun, LV-2009/109.*

Kumar A, Schei T, Ahenkorah A, Caceres Rodriguez R, Devernay J-M, Freitas M, Hall D, Killingtveit Å, Liu Z (2011). *Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)].* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jónas Ketilsson, Axel Björnsson, Árný Erla Sveinbjörnsdóttir, Bjarni Pálsson, Grímur Björnsson, Guðni Axelsson og Kristján Sæmundsson (2010). *Eðli jarðhitans og sjálfbær nýting hans. Álitsgerð faghóps um sjálfbæra nýtingu jarðhita. Orkustofnun, skýrsla nr. OS-2010/05*

Orkustofnun (2013). *Ársskýrsla Orkustofnunar 2012.* Orkustofnun.

Pétur Ingólfsson (2012). *Hálslón 2011. Kortlagning strandsvæða. Landsvirkjun, LV-2012/007.*

Pétur Ingólfsson, Björn Stefánsson, Þorsteinn V. Baldvinsson og Svanhildur Arnmundsdóttir (2012). *Kárahnjúkavirkjun. Frágangur vinnusvæða. Landsvirkjun, LV-2012/011.*

Pétur Ingólfsson og Björn Jóhann Björnsson (2012). *Hálslón 2011. Jarðvegsbinding, gróðurstyrking og vöktun strandsvæða. Landsvirkjun, LV-2012/006.*

Rán Þórarinsdóttir og Hákon Aðalsteinsson (2012). *Kortlagning burðarsvæða hreindýra á áhrifasvæðum Kárahnjúkavirkjunar vorið 2011. Landsvirkjun, LV-2012/033.*

Reglugerð um hávaða nr. 724/2008.

Reglugerð um varnir gegn mengun vatns nr. 796/1999 með síðari breytingum.

Rydgren, Dr. Bernt (2012). *Hydropower sustainability Assessment Protocol. Unofficial Assessment Landsvirkjun Hvammur, Iceland.* The International Hydropower Association.

Sigurður G. Kristinsson, Magnús Ólafsson, Sveinborg Hlíf Gunnarsdóttir og Steinþór Níelsson (2013). *Jarðhitasvæði á NA-landi. Vöktun á yfirborðsvirkni og grunnvatni.*

Sigurður H. Markússon, Sverrir Óskar Elefsen og Snjólaug Ólafsdóttir (2012). *Styrkur brennisteinsvetnis í andrúmslofti í Reykjahlíð. Landsvirkjun, LV-2012/095.*

Sigurlaug Hjaltadóttir og Kristín S. Vogfjörð (2011). *Sprungukortlagning við Þeistareyki og Bjarnarflag með háupplausnarstaðsetningu smáskjálfta. Landsvirkjun, LV-2011/116.*

Umhverfisstofnun. (e.d.). *Gróðurhúsalofttegundir.* Sótt þann 1. apríl 2011 á http://www.ust.is/einstaklingar/loftslagsbreytingar/grodurhusalofttegundir/.

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Háaleitisbraut 68
103 Reykjavík, Iceland
landsvirkjun.is

landsvirkjun@lv.is
Tel. +354 515 90 00