LV-2010/064

Landsvirkjun's Environmental Report and Carbon Footprint 2009

Landsvirkjun

August 2010

Landsvirkjun

Key page

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Authors/Company:	EFLA Consulting Engineers and Landsvirkjun
Project manager:	Ragnheiður Ólafsdóttir, Landsvirkjun
Prepared for:	Landsvirkjun, The National Power Company
Co operators:	Landsvirkjun's employees

Abstract: Landsvirkjun has a certified Environmental Management System in accordance with the international environmental standard ISO 14001. The report contains statistical information regarding Landsvirkjun's environmental management for the year 2009.
Since 2006 Landsvirkjun has actively participated in the Global Roundtable on Climate Change (GROCC).
One of Landsvirkjun's commitments by participating in GROCC is to report emissions from it's own operations and this report is a part of fulfilling that commitment.

Keywords: Environmental Management System (EMS), ISO 14001, green accounting, emission inventory report, carbon footprint, greenhouse effect.

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Ragnheiður Ólafsdóttir

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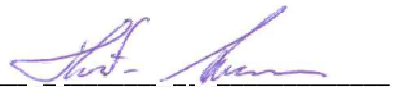
A Statement from the Managing Director

To the best of my knowledge, the information presented in this report is accurate. The values were recorded in Landsvirkjun's accounting program's, DynamicsAX, GB (green accounting), the Human Resources database, Kemía's View Data Geothermal Database and according to the Land Use, land-use change and forestry (LULUCF) accounting of the Agricultural University of Iceland.

The Managing Director of Landsvirkjun hereby approves the company's Environmental Report for the year 2009.

Reykjavik, August 30th 2010



Hörður Arnarson

Summary

Landsvirkjun has a certified environmental management system in accordance with the international environmental standard ISO 140001. Landsvirkjun has since 2006 published green accounting, covering the company's environmental management, significant environmental aspects and the company's environmental goals and objectives. Also Landsvirkjun has issued an independent report on the company's carbon footprint.

This report is simpler then the reports of previous years. It includes all relevant numerical information for the year 2009 and changes since 2007. The report also contains the company's carbon footprint.
Text has now been reduced, and all necessary information can be found in earlier publications.

A change in Landsvirkjun's operations affecting the green accounting is the beginning of the impoundment of the Kelduárlón and Ufsárlón reservoirs, which began mid year 2009. The reservoir is part of the Hraunaveita diversion scheme which is a part of Fljotsdalur station.

Landsvirkjun's energy production in 2009 was 12,237 GWh, which represents 73% of Iceland's total energy production. Just over 96% was produced with hydropower and 4% with geothermal from the Krafla area.

In Landsvirkjun's Environmental Report for 2009, a detailed discussion is provided on important environmental factors that relate to the company's operations. Better utilisation of natural resources and decreased greenhouse gas emissions are among Landsvirkjun's environmental objectives. To achieve these objectives, the use of the geothermal resource is monitored and its utilisation controlled to minimize the risk of overutilization. The arrangement of utilisation and distribution of the water resource is also well defined and controlled to avoid negative impact to soil, ecosystems and society.

In 2009, 5,436,000 tons of steam and 5,855,000 tons of water were used to produce 473 GWh. This is a considerable increase in water usage from previous year, but somewhat less when steam is considered. Primary reason lies in the fact that the enthalpy of boreholes has been decreasing which generates more separation water. Work continues in increasing reinjection of separation water into the geothermal reservoir in the Krafla area, but with reinjection it is possible to reduce the environmental impact associated with energy production. The percentage increase of reinjections has increased by 44% from previous year.

In Landsvirkjun's operations, fossil fuels are used for vehicles and various equipment. Oil is also used in the operation of several diesel generators. Total usage of fuel has increased between years. The increase can be explained works at the power stations and better recording of fuel use, e.g. recording of fuel used by Landsvirkjun Power (LVP) in research projects for Landsvirkjun.

Since 1968, Landsvirkjun has taken part in extensive land reclamation projects in the vicinity of its power stations and at other locations. Landsvirkjun's land reclamation involves fertilising, seeding of grass on sparsely vegetative land and planting of trees. Quantity of fertiliser and seeds used and number of planted trees varies between years. The land revegetated by Landsvirkjun so far has an area of approximately 140 km^2 (13,950 ha) and was in many cases initially often sparsely vegetated. The size of the revegetation area increased by 1,250 ha in 2009. Annual carbon binding of Landsvirkjun's revegetation and forest areas is estimated to be approximately 22,100 tons CO_2 in 2009, or approximately 10% than the year before.

Landsvirkjun's energy production causes specific amounts of chemicals to be released into the atmosphere. This refers to emissions due to the burning of fossil fuels, air travel and emissions that relate directly to the energy production, for example greenhouse gas emissions from reservoirs and release of steam from geothermal power stations. Approximately 56% of the total greenhouse gas emissions (measured as CO_2 eq) are due to geothermal power stations and 42% to reservoirs. Emissions due to the burning of fuel for air travel, vehicles and equipment represent 2% of total greenhouse gas emissions.

Landsvirkjun's carbon footprint for 2009 is 46.3 tons CO_2 eq or 3.8 tons CO_2/GWh. When the carbon footprint is compared to Landsvirkjun's total energy production we see it has decreased by little more than 17% from 2008. The most important factor is the fact that energy production from geothermal power stations, as part of Landsvirkjun's total energy production, has decreased by 18% as compared to the year 2008. Significant difference exists between the carbon footprint of geothermal power stations and hydropower stations. The carbon footprint of Landsvirkjun's geothermal power stations is little less than 79 tons CO_2/GWh while the carbon footprint of hydropower stations is approximately 1 ton CO_2/GWh when carbon binding is taken into account.

Summary

It should be kept in mind that greenhouse gas emissions from geothermal power stations are, to some extent, naturally occurring emissions because carbon dioxide and other greenhouse gases are not formed during the energy production but rather in the magma chamber under the harnessed area. When Landsvirkjun's carbon footprint is compared to the World Energy Council's reference values for greenhouse effect of energy production with fossil fuels, it can be seen that the greenhouse effect of burning coals is approximately 200 times greater than hydropower and 9 times greater than geothermal. Greenhouse effect of energy production with natural gas is estimated to be approximately 100 times greater than hydropower and 5 times greater than geothermal. Emissions from Landsvirkjun's geothermal power stations are similar to World Energy Council's values but considerably lower from hydropower stations. This is discussed in more detail in Landsvirkjun's emissions inventory report for the year 2008.

One of Landsvirkjun's environmental objectives is to reduce the generation of waste, increase the recycle rate and increase the percentage of waste that can be reused. Hazardous materials and general waste is sorted at Landsvirkjun's operation areas. The level of sorting varies between areas and is contingent upon the municipality's ability to receive and treat the waste. Hazardous materials are generated when toxic and dangerous materials become waste. At all operation areas, hazardous materials are collected in special containers and returned to authorized waste facility.

Total quantity of waste from Landsvirkjun's operations in 2009 was around 50% lower than in 2008. The primary reason is the fact that large renovation works are completed. Landsvirkjun has established a goal of increasing the recycling rate and the percentage of waste that can be reused. Figures from 2009 show that the rate of recycling is well above the established recycling goal at most power stations. The recycle rate at the power stations is in the range of 48-100% and the average recycle rate for all stations is 69% which is an decrease of 14% from 2008 because projects that produced large amounts of recyclable waste have been completed. Quantity of general waste for landfilling is reduced 39% from 2008. Total quantity of hazardous materials has increased by 46% as compared to 2008 and reduced by 10% when compared to 2007. The increase comes from diverse cleanup action at the power stations.

The main source of noise from Landsvirkjun's operations is geothermal energy production at Krafla and Bjarnarflag. This is noise from machines and equipment and release of steam into the atmosphere. The sound pressure level is, to some degree, contingent upon weather conditions and the operations of the power station at any given time, i.e. whether boreholes are being flow tested and the number of turbine generator units in operation. The entire operation area at Krafla and Bjarnarflag is defined as an industrial area, but in industrial areas the reference limit is 70 dB(A) according to Icelandic noise regulations. The sound pressure level at Krafla and Bjarnarflag is measured annually at specific locations. The sound pressure level exceeded the specified allowable limit at 5 measuring locations out of 36.It is Landsvirkjun's goal that the sound pressure level does not exceed 50 dB(A) at locations popular by tourists.

One environmental mishap was recorded in 2009. A road was damaged because weight limitations were disregarded.

Landsvirkjun's reports on environmental issues can be found under:

http://www.landsvirkjun.com/environment/environmental-management/

Landsvirkjun's environmental management

Landsvirkjun has established an environmental policy. Based on this policy, the company's environmental objectives have been defined. Based on these objectives, measurable goals are established for each Division and its operations. The company has also defined significant environmental factors in its operations that are monitored and controlled to ensure that negative environmental impact of the company's operations is kept at minimum.

Environmental policy

Landsvirkjun aims at being in the forefront environmentally and promotes sustainable development in Icelandic society.

Landsvirkjun puts emphasis on identifying the environmental impact of its operations and to minimize the impact. In order to continue its success in this area, the company monitors significant environmental aspects and makes systematic effort to improve them.

Landsvirkjun ensures that every legal requirement that relates to the environment is fulfilled and places stricter standards on itself if appropriate.

Landsvirkjun stresses that its employees, as well as others working for the company, have the capability and expertise to carry out this environmental policy.

Landsvirkjun presents its environmental policy to the public and reports on the company's success in environmental affairs, thus encouraging open and objective discussion.

Objective

Landsvirkjun's environmental objectives:

1. Operations without environmental accidents.
2. Conduct its operations in harmony with the natural ecosystem.
3. Better use of resources.
4. Reduce greenhouse gas emissions.
5. Reduce waste generation.

Monitoring and controlling of environmental factors

To achieve the set policy and objectives, factors in Landsvirkjun's operations, are measured and their controlling defined. Some of the environmental factors are dependent on the energy source, for example the release of CO_2 and CH_4 from hydropower reservoirs and gas from geothermal power stations. However, other factors are independent of the energy source, for example the use of fuel and toxic and dangerous materials and production of waste in the stations' operations. This report presents information on the monitoring of the following environmental factors in Landsvirkjun's operations in 2009:

- Percentage of separation water from the Krafla boreholes that is reinjected into the geothermal reservoir.
- Greenhouse gas emissions from geothermal power stations
- Use of fossil fuels.
- Carbon binding with land reclamation and reforestation.
- Recycling and reuse of waste as a percentage of landfilling.
- Release of chemicals into the environment from geothermal power stations. Greenhouse gas emissions from reservoirs.
- Total greenhouse gas emissions from Landsvirkjun's operations.
- Noise.
- Environmental accidents related to the company's operations.
- Deviations in reservoir management (none recorded in 2009).

Landsvirkjun's operation

Landsvirkjun's operations are divided into four main divisions; Energy Division, Finance Division, Information System Division and Human Resources Division as well as the Corporate Office. Landsvirkjun Power (LVP) is an independent company which is responsible for general research, preparatory work, design and construction of new power stations. This report on green accounting includes all of Landsvirkjun's Operations except those Operations of Landsvirkjun Power which don't relate to Landsvirkjun's environmental management system.

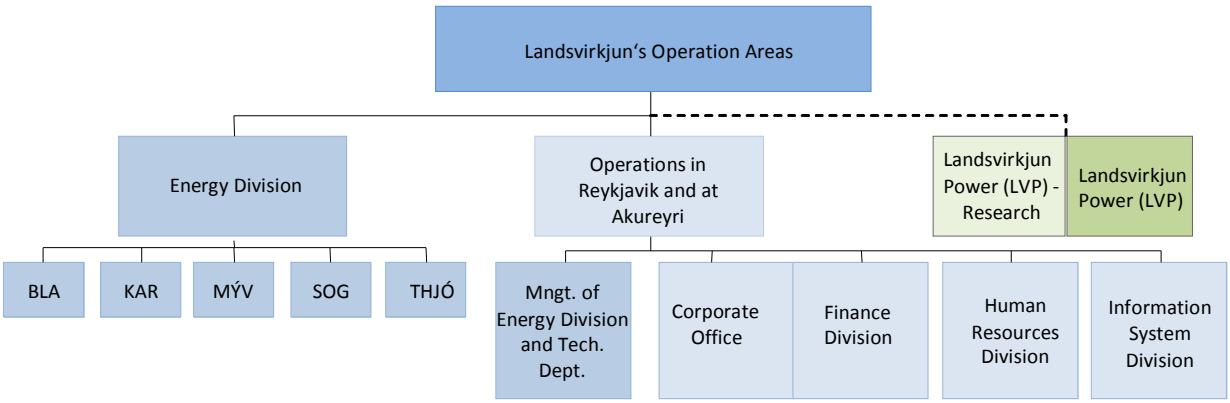


Figure 1. Landsvirkjun's operations as defined for the company's environmental management.

Landsvirkjun's Energy Division has a total of five operation areas; River Blanda station (BLA), Fljótsdalur station (KAR), River Sig station (SOG), Lake Mývatn stations (MÝV-KRA and MÝV-LAX) and River Thjórsá station (THJÓ).

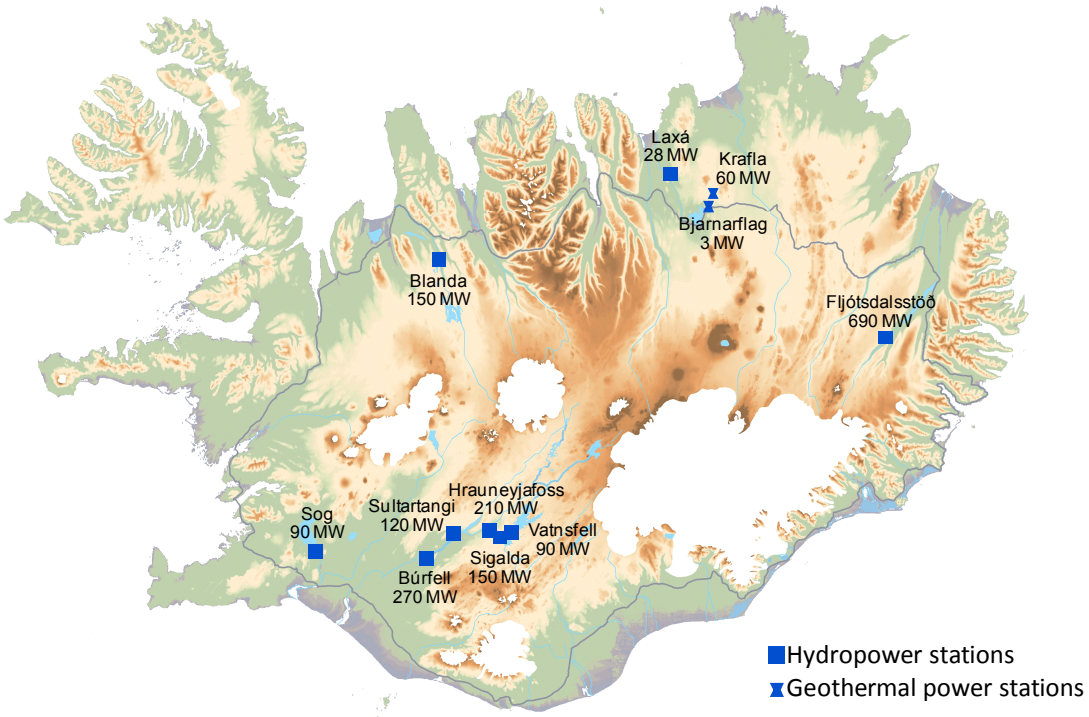


Figure 2. Location and capacity of Landsvirkjun's power stations.

Landsvirkjun's energy production

Landsvirkjun's total energy production was 12,237 GWh in 2009, which is a decrease of 0.9% from the year before. Approximately 96% of the total energy production came from hydropower and 4% from geothermal power. Figure 3 and tables 1 and 2 give an overview on the company's energy production.

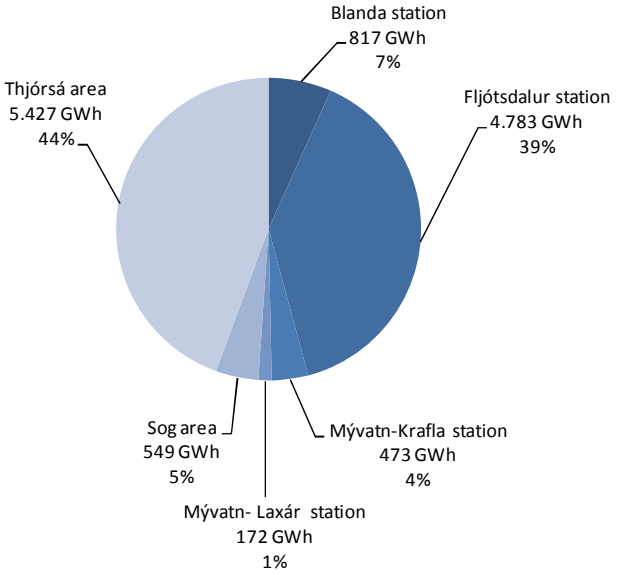


Figure 3. Landsvirkjun's energy production in 2009.

Table 1. A summary of Landsvirkjun's operation areas, number of employees and energy production in 2009.

	Identification	Energy source	Number of employees	Capacity (MW)	Energy production (GWh)	Percentage of total energy production (%)
Energy Division						
Blanda station	BLA	Hydropower	13	150	817	8
Fljótsdalur station	KAR	Hydropower	13	690	4,783	38
Mývatn area - total	MÝV	Hydropower and geothermal	25	91	661	5
- Mývatn-Krafla station	MÝV-KRA	Geothermal	(17)	(63)	(488)	(4)
- Mývatn-Laxár station	MÝV-LAX	Hydropower	(8)	(28)	(172)	(1)
Sog area	SOG	Hydropower	17	90	549	4
Thjórsá area	THJÓ	Hydropower	37	720	5,427	44
Energy Division mngt and technical dept.	-	-	24	-	-	-
Operation areas in Reykjavík and at Akureyri (w/ Energy Division's mngt and tech. dept.)	-	-	84	-	-	-
Landsvirkjun Power			40			
Landsvirkjun total – 2009			189	1,741	12,337	100
Landsvirkjun's Energy Division - total 2009			129	1,741	12,337	100
Landsvirkjun's Energy Division - total 2008			126	1,741	12,345	100
Landsvirkjun's Energy Division - total 2007			123	1,741	8,587	100

Table 2. Landsvirkjun's energy production and total energy production in Iceland (Source: Icelandic Energy Forecast Committee).

		Landsvirkjun			Iceland total		
		2009	**2008**	**2007**	**2009**	**2008**	**2007**
Hydropower	GWh	11,748	11,868	8,042	12,279	12,427	8,394
Geothermal	GWh	488	477	545	4.553	4,038	3,579
Fuel	GWh	0	0	0	3	3	3
Total	GWh	**12,237**	**12,345**	**8,587**	**16,835**	**16,467**	**11,976**
Hydropower	%	96	96	94	73	75	70
Geothermal	%	4	34	6	27	25	30
Fuel	%	0	0	0	0	0	0
Total	%	**100**	**100**	**100**	**100**	**100**	**100**

Utilisation of geothermal resource

Better utilization of the natural resources such as the geothermal resource is one of Landsvirkjun's environmental objectives. The use of geothermal fluid and steam is recorded and monitored and measurements for trace elements made in every borehole. Since 2002 part of the separation water has been reinjected into the geothermal reservoir and the amount of the reinjection monitored. Table 3 provides a summary of the utilisation of water and steam taken from the geothermal systems at the Krafla area and the amount of reinjected separation water.

Table 3. Utilisation of the geothermal resource for Landsvirkjun's energy production.

		2008	2008	2007	Change from the year 2008	Change from the year 2007
Utilisation in thousand tons:						
Steam	thousand tons	5,436	5,986	6,394	-9%	-15%
Water	thousand tons	5,855	5,805	5,466	+1%	+7%
Reinjection	thousand tons	2,718	1,892	1,665	+44%	+63%
Utilisation per GWh produced:						
Steam	thou. tons/GWh	11.5	12.5	11.7	-8%	-1.8%
Water	thou. tons/GWh	12.4	12.2	10.0	+2%	+24%
Reinjection	thou. tons/GWh	5.7	4.0	3.1	+43%	+84%

Figures of utilization of the geothermal resource apply to both energy production and research. Quantity of reinjection in 2009 is measured at Krafla. Values for reinjection have been updated from values presented in Environmental Report 2008.

Table 3 shows that the utilisation of steam is reduced by 9% from 2008, among other things due to a reduction in the energy production. Greater capacity of pumps used for reinjection increases the amount of reinjected separation water by 44% from 2008. Since 2006 reinjection has increased by 63%, thus reaching Landsvirkjun's goal to increase reinjection between 2006 and 2010 by 40%.

Figure 4 shows quantity of separation water that was reinjected into boreholes in the Krafla area in 2007, 2008 and 2009.

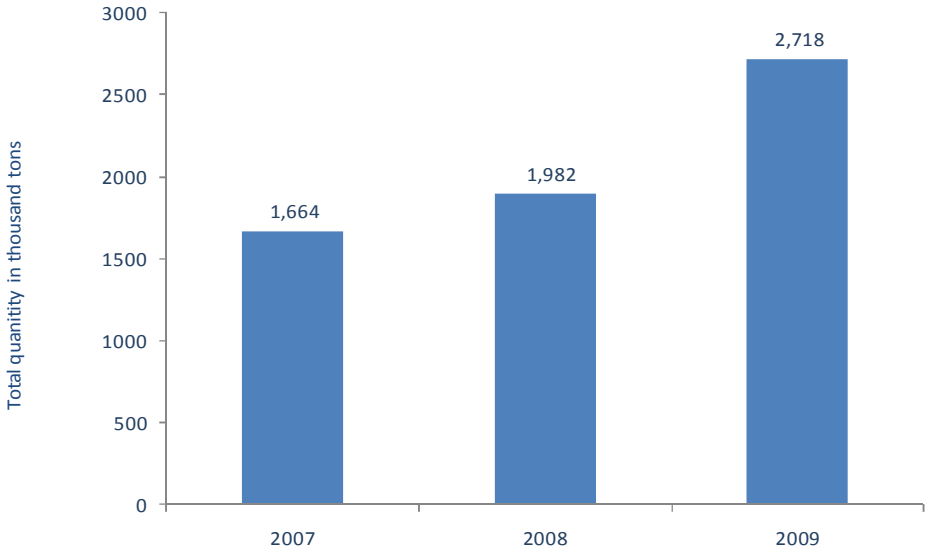


Figure 4. Quantity of separation water (in tons) that was reinjected into boreholes at Krafla during the period 2007-2009.

Releases into water and soil from geothermal power stations

Table 4 shows the release of condensed and separation water and heavy metals and nutrients from the Krafla area into water and soil. The table shows that the volume of water released into surface water was higher in 2009 than in 2008, but lower than was released in 2007. Reinjection increases between the years 2009 and 2008 and is now 34%.

Table 4. Quantity of chemicals in condensed and separation water reinjected into soil and released into surface waters from the Krafla area.

		Releases into surface waters			Reinjection into soil		
		2009	2008	2007	2009	2008	2007
Water							
- Water from geothermal power stations	Thousand tons	5,003	4,111	5,796	2,718	1,892	1,664
Heavy metals							
- Arsenic	kg	291	206	284	33	48	70
- Cupper	kg	1	2	3	0	0	1
- Chromium	kg	6	3	3			
- Nickel	kg	10	3	3			
- Zinc	kg	9	10	11	2	3	2
Nutrients							
- Phosphorus	kg	15	83	25	3	2	2
Other							
Hydrogen sulphide	kg	42,000	209,000	55,000	75,000	97,000	13,000
Carbon dioxide	kg	242,000	276,000	271,000	139,000	53,000	93,000

Fuel – purchased quantity

Table 5 shows the quantity of fuel used at each station and total use for Landsvirkjun's entire operations. Fuel usage is recorded for all operations such as power stations, but also for research and preparatory work done by LVP for Landsvirkjun. Other LVP fuel usage is not included. It is Landsvirkjun's goal to reduce the usage of fuel.

Table 5. Fuel usage in Landsvirkjun's energy production in 2009.

			Energy Division							
			Energy production					Division Mngt and tech. dept.	LV's operation in RVK	LV total and LVP's projects
Operation areas		LV total	BLA	KAR	MÝV	SOG	THJÓ			
Energy production	GWh	12,222	817	4,783	642	549	5,427	-	-	12,222
Gasoline	Liters	24,216	400	489	3280	245	6,658	7,414	3,644	2,086
Diesel oil total	Liters	356,407	18,075	18,596	58,335	30,537	99,912	13,453	37,411	80,088
- vehicles	Liters	269,676	15,449	17,726	55,264	20,531	49,914	13,453	35,640	61,699
- machines	Liters	86,731	2,626	870	3,071	10,006	49,998	0	1,771	18,389
- engines	Liters	10,006	0	0	0	10,006	0	0	0	0
Hydrogen	kg	217	0	0	0	0	0	0	217	217

Figure 5 shows the usage of fuel per unit energy produced, i.e. liters fuel and oil per GWh produced. Average usage of fuel and oil is almost 31 l/GWh of which diesel oil is mostly used. When comparison is made between Landsvirkjun's operation areas, a significant difference in usage can be noticed, which can primarily be explained by very different circumstances between power stations, when it comes to energy production vs. location and need for vehicle fleet and equipment. Also when diesel oil tanks are filled late one year, it can lead to reduced amount of fillings the next year.

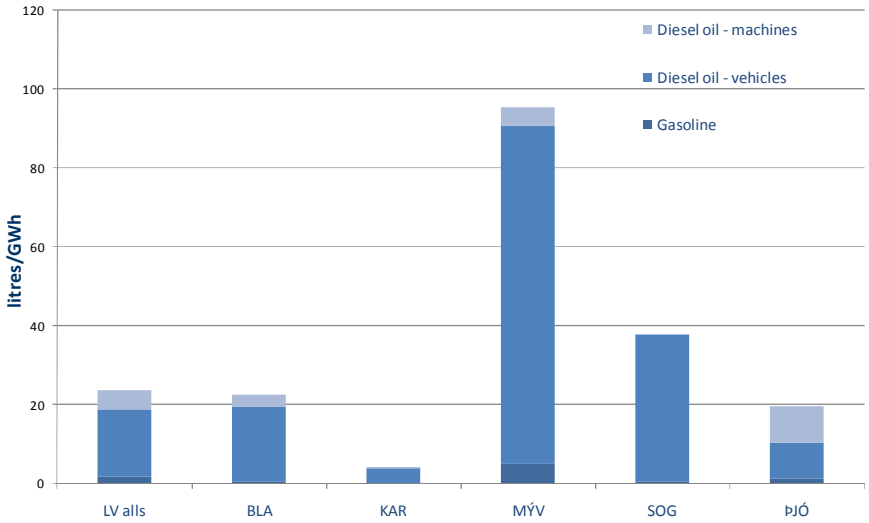


Figure 5. Fuel usage per unit energy produced (use of diesel oil by a stand-by diesel generator at an aluminum smelter in Straumsvik is excluded).

Table 6 shows Landsvirkjun's total fuel usage in 2008 and fuel used by the Energy Division and power stations during the period 2007-2009 as well as comparison between years. The Energy Division's total usage of gasoline has increased by 54% from the year before and by 12% when compared to 2007. The usage of disel oil for vehicles increased by 18% from the year before and by 20% by 2007. The increase in gasoline usage can primarily be led to better recording of fuel usage for vehicles owned or leased by Landsvirkjun, rental cars and vehicles used by LVP in research projects for Landsvirkjun. Most of the company's diesel oil tanks were filled this year, but some of the tanks don't need to be filled yearly. In the Thjórsá area eight diesel powered engines are located around Búrfell station. Three of the eight engines are in constant operation and five serve as reserve, and therefore are rarely in operation. The oil tanks of the reserve machines are not filled every year.

Table 6. Total fuel usage in 2007-2009 and comparison between years.

		2009 Landsvirkjun total	2009 Energy Division and power stations	2008 Energy Division and power stations	2007 Energy Division and power stations	Energy Div. 2009: Change from 2008	Energy Div. 2009: Change from 2007
Gasoline	Liters	24,216	18,486	12,037	16,482	+54%	+12%
Diesel oil total	Liters	356,407	238,908	202,102	198,628	+18%	+20%
- vehicles	Liters	269,676	172,337	146,225	123,437	+18%	+40%
- machines	Liters	86,731	66,571	45,239	65,049	+47%	+2%
- engine in Straumsvík	Liters	10,006	10,006	10,638	10,142	-6%	-1%
Hydrogen	Kg	217	0	0	0	0%	0%

Table 7 shows fuel usage per unit of energy produced for the period 2007 to 2009 and comparison of usage between years. An increase is evident between the years 2008 and 2009, but the decrease from 2007 is to a large extent due to the addition of the Fljótsdalur power station with high production of energy (38%) with very little usage of fossil fuels.

Table 7. Fuel usage per unit energy produced in 2007-2009 and comparison between years.

		2009 Landsvirkjun total	2009 Energy Division and power stations	2008 Energy Division and power stations	2007 Energy Division and power stations	Energy Div. 2009: Change from 2008	Energy Div. 2009: Change from 2007
Gasoline	Liters/GWh	1.98	1.51	0.98	1.92	+54%	-21%
Diesel oil total	Liters/GWh	29.16	19.55	16.50	23.13	+18%	-15%
- vehicles	Liters/GWh	22.07	14.10	11.80	14.37	+19%	-2%
- machines	Liters/GWh	6.28	4.63	3.74	8.76	+24%	-47%
- generator in Straumsvik	Liters/GWh	0.82	0.82	0.86	1.18	-5%	-31%
Hydrogen	Kg/GWh	0.02	0.00	0	0	0%	0%

Land reclamation and carbon binding

It is Landsvirkjun's goal to conduct its operations in harmony with the natural ecosystem. Table 8 provides summary of fertilising, seeding and planting of trees from 2007 through 2009 which was completed and/or funded by Landsvirkjun.

Table 8. Fertilising, seeding and planting.

		2009	2008	2007	Change from 2008	Change from 2007
Fertilising, commercial fertiliser*	t	494	365	455	+35%	+9%
Fertilising, manure fertiliser	t	0	6	253	-100%	-100%
Fertilising, total*	t	494	371	708	+35%	+9%
Seeding*	t	2.00	3.84	0.80	-48%	+150%
Planting in the vicinity of power stations (by LV)	pc	60,452	41,410	39,348	+46%	+54%
Planting by *„Many hands make light work"*	pc	111,488	116,835	65,000	-5%	+72%
Planting, total	pc	171,940	158,245	104,348	+9%	+65%

*including fertilizing and seeding by the Land Improvement Funds of Norður-Hérad and Fljótsdalshreppur.

The quantities of fertiliser and seeds that are spread and how much is generally planted vary considerably between years. In 2009, fertilising increased 33% to the year before and approximately 9% to 2007, but seeding decreased around half between years. Planting of trees has also increased in 2009 compared to the previous two years, mainly in the vicinity of power stations.

Carbon binding in revegetation and reforestation areas

Table 9 shows the land revegetated by Landsvirkjun in 2009 has an area of approximately 140 km^2 (13,950 ha). - It can be roughly estimated that the annual CO_2 binding in Landsvirkjun's revegetation and reforestation areas was approximately 20 thousand tons CO_2 in 2009 or about 2 thousand tons CO_2 more than the year before.

Table 9. Carbon binding in revegetation and reforestation areas.

		2009	2008	Change from 2008
Revegetation area	ha	13,950	12,700	+ 10%
Carbon binding	t CO_2	22,100	20,100	+ 10%

Waste

One of Landsvirkjun's environmental goals is to reduce the generation of waste, increase level of recycling and reduce the amount of waste to be landfilled. All general and hazardous waste is sorted at Landsvirkjun's operation areas.

Quantity and type of waste

Table 10 shows the quantity of waste generated in Landsvirkjun's operation areas. Figures 6 and 7 show the percentage size of waste categories, figure 6 for all categories and figure 7 when the biggest waste categories, timber, earth materials, glass and porcelain are excluded.

Table 10. Quantity of waste by category and treatment.

		LV total	BLA	KAR	MÝV-KRA	MÝV-LAX	SOG	THJÓ	Operations in RVK and AKU
General unsorted waste, landfilled	kg	40,531	4,131	2,702	0	0	4,140	10,104	19,454
General unsorted waste, incinerated	kg	6,098	0	0	5,190	908	0	0	0
Waste for recycling and incineration:									
Tires	kg	100	100	0	0	0	0	0	0
Furnishings	kg	0	0	0	0	0	0	0	0
Earth materials, glass and porcelain	kg	65,276	2,888	0	0	30,625	128	30,892	1,142
Organic waste	kg	8,148	0	188	0	0	0	0	7,960
Metals and various equipment	kg	39,763	6,524	2,480	9,350	1,375	1,844	18,130	92
Paper, cartons and cardboard packaging	kg	6,375	579	211	1,100	27	396	65	5,049
Plastics	kg	1,919	0	88	1,800	0	0	0	31
Timber	kg	29,892	1,410	1,540	6,700*	1,250*	1,602	17,390	0
Hazardous materials	kg	11,945	371	222	916	2,285	447	7,633	71
Total waste	kg	210,047	16,003	7,431	25,056	36,470	8,557	84,214	33,799

* Timber is sorted and incinerated at Húsavík where plans are to use it for electricity production and house heating. Due to equipment failures, the thermal energy has only been utilised for reheating in previous years.

The total quantity of waste was approximately 210 tons in 2009. Substantial success has been made in decreasing the amount of general unsorted waste for landfilling, or by 39% between years. Earth materials, glass and porcelains were the biggest waste category. An increase was in that category because of earth materials from the Thjorsá area and from sandblasting of pipes in Sigalda station, but a decrease at Krafla. Renovations of the roof of a cooling tower and the powerhouse at Krafla generated 1,800 kg of plastics that were recycled.

In 2008 sorting of waste begun at Landsvirkjun's operations in Reykjavík and at Akureyri. Success has been achieved in reducing waste from those operations or by approx. 53% between years. Over the same time period an increase of waste sent to recycling can be observed or an increase of around 142% for organic waste and 187% for cardboard packaging. The increased recycling at the operations in Reykjavík and at Akureyri decreases the release of greenhouse gas emissions from landfills by around 2,500 CO_2 and applied to Landsvirkjun's total operations increased recycling decreases the release by around 9,800 kg CO_2.

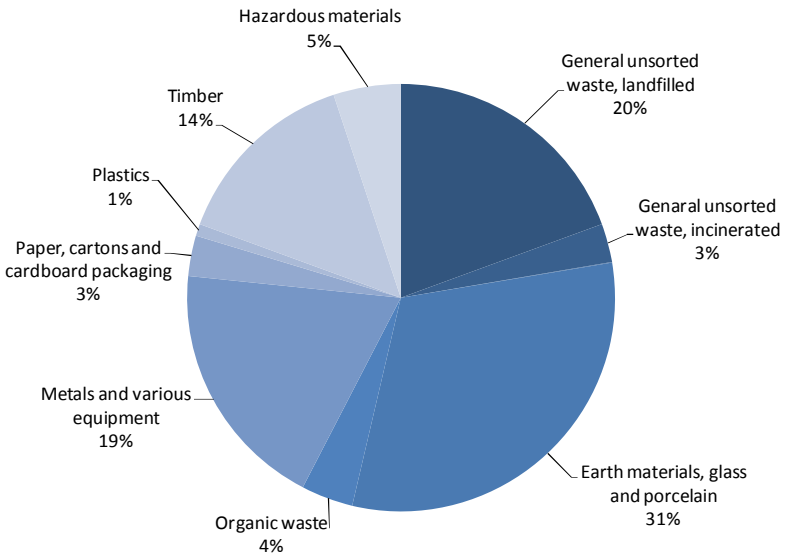


Figure 6. Type and composition of waste generated in Landsvirkjun's operation areas.

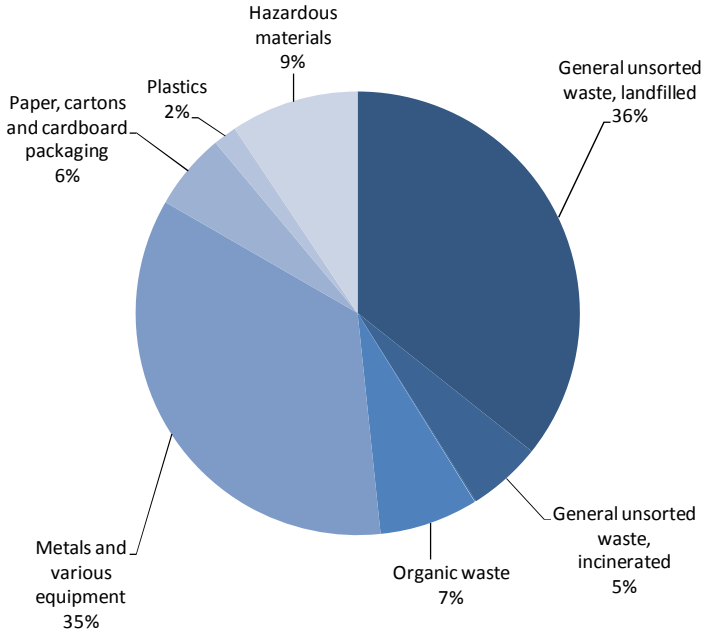


Figure 7. Type and composition of waste generated in Landsvirkjun's operation areas when the biggest categories, timber and earth materials are excluded.

Quantity and type of waste: Comparison between years

Table 11 shows a comparison of quantity and type of waste between the years 2009, 2008 and 2007. The table shows that total quantity of waste has decreased by approx 50% from 2008 and 42% from 2007. The generation of timber waste and metals is reduced mainly due to completion of large renovation works e.g. at Krafla station in 2008. The large increase in plastics in 2009 derives from a second phase of maintenance works at Krafla. A significant reduction is in unsorted landfilled and incinerated waste – or around 40 and 50% in each group. By reducing the amount unsorted waste for landfill reduces the atmospheric greenhouse gas emissions by 7.800 CO_2 eq from 2008.

Table 11. Comparison of total quantity of waste by category and treatment between the years 2008 and 2007.

		2009	2008*	2007	Change 2009 and 2008	Change 2009 and 2007
General unsorted waste, landfilled	kg	40,531	66,510	27,250	-39%	+49%
General unsorted waste, incinerated	kg	6,098	12,591	16,636	-52%	-63%
Tires	kg	100	0	340	+100%	-71%
Furnishings	kg	0	0	85	0.0%	-100%
Earth materials, glass and porcelain	kg	65,276	51,445	204,300	+27%	-68%
Organic waste	kg	5,362	4,218	1,757	+27%	+205%
Metals and various equipment	kg	39,763	62,301	31,586	+36%	+26%
Paper, cartons and cardboard packaging	kg	5,703	6,035	3,750	-6%	+52%
Plastics	kg	1,919	102	106	+1,781%	+1,710%
Timber	kg	29,892	190,908	47,283	-84%	-37%
Hazardous materials	kg	11,931	7,268	11,727	+64%	+2%
Waste total	kg	206,575	401,376	344,821	-49%	-42%

* First time all waste from Landsvirkjun's operations is recorded, therefore an increase from previous years.

Increased recycle – Success of 2008

Landsvirkjun has established measurable goals to increase the rate of recycle and percentage of reusable waste. The goal is that the recycle rate of specific waste categories be over 35%. At the power stations, the recycling of three waste categories is monitored, i.e. 1) metals and various equipment, 2) paper, cardboard and packaging materials, and 3) timber, and it compared to the quantity of unsorted general waste to be landfilled.

Table 12 shows that recycling is well over the recycling goal of 35%. The average recycling rate of all stations is 69% which is a decrease of approximately 14% from 2008, partly because large renovation projects that e.g. produce larger quantities of timber for recycling have been completed. This implies that the reference for establishing the goal needs to be reviewed.

Table 12. Landsvirkjun's recycling goal and landfilling at power stations.

			Waste generation and sorting in operation areas					
		LV total	BLA	KAR	MÝV-KRA	MÝV-LAX	SOG	THJÓ
Metals and various equipment	kg	39,763	6,524	2,480	9,350	1,375	1,844	18,130
Paper, cartons and cardboard packaging	kg	5,703	579	211	1,100	27	396	65
Timber	kg	29,892	1,410	1,540	6,700	1,250	1,602	17,390
Total quantity of waste pertaining to recycling goal,	kg	75,358	8,513	4,221	17,150	2,652	3,842	35,585
Quantity of general unsorted waste, incinerated	kg	6,098	0	0	5,190	908	0	0
Quantity of general unsorted waste, landfilled	kg	33,822	4,131	2,702	0	0	4,140	10,104
Recycling as compared to established goal	%	69	67	61	100*	100*	48	78

* Waste to be recycled that is generated in MÝV-KRA and MÝV-LAX has been sent for incineration and energy recovery. Only a part of the thermal energy has been utilised. To meet the company's goal regarding recycling, it may be required to review the pathway for recyclable wastes from these operation areas.

Quantity and type of hazardous materials

As can be seen in table 13 and figure 8, a total of 10.6 tons of hazardous materials were generated by Landsvirkjun's operations. Most of it was oil or around 70%.

Table 13. Quantity and type of hazardous materials.

		Total quantity	BLA	KAR	MÝV-KRA	MÝV-LAX	SOG	THJÓ	Other operations
Oil	kg	7.403	364	8	685	1.135	382	4.829	0
Asbestos	Kg	960	0	0	0	960	0	0	0
Organic hazardous	kg	201	7	49	63	0	65	17	0
Batteries	kg	1.062	0	163	161	80	0	587	71
Coal slack	kg	20	0	0	0	0	0	20	0
Packaging of hazardous materials	kg	935	0	0	0	110	0	825	0
Inorganic hazardous	kg	10	0	0	0	0	0	10	0
Various hazardous	kg	9	0	2	7	0	0	0	0
Hazardous total	kg	10.600	371	222	916	2.285	447	6.288	71

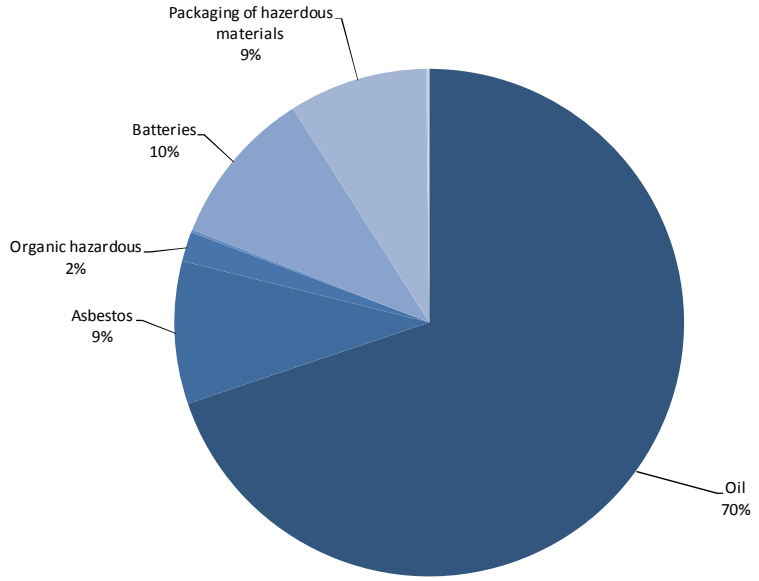


Figure 8. Type of hazardous materials generated from Landsvirkjun's energy production and sent for disposal.

Quantity and type of hazardous materials: Comparison between years

Table 14 shows the quantity and type of hazardous materials in 2009, 2008 and 2007 and comparison between years. The table shows that total quantity of hazardous materials has increase by 46% compared to 2008. This increase is partly because of projects that produce waste containing asbestos, but also there is an increase of contaminated waste and disposal of batteries and packaging of hazardous materials that arise from special cleanup actions.

Table 14: Comparison of quantity of hazardous materials by category and treatment, as quantity per unit energy produced, between the years 2009 and 2007.

		2009	2008	2007	Change 2009 and 2008	Change 2009 and 2007
Oil	kg	7,403	5,159	10,579	+44%	-30%
Asbestos	kg	960	0	0	+100%	-
Toxic materials	kg	0	0	94	-	-100%
Organic hazardous materials	Kg	201	1,381	112	-85%	+80%
Organic halogenic hazardous materials	Kg	0	0	713	-	-100%
Coal slack	kg	20	0	0	+100%	-
Batteries	kg	1,062	528	94	+101%	1,030%
Packaging of hazardous materials	kg	935	0	0	+100%	-
Inorganic hazardous materials	kg	10	14	146	-29%	-93%
Various hazardous materials	kg	9	187	0	-95%	+100%
Total hazardous materials	kg	10,600	7,268	11,730	+46%	-10%

Atmospheric emissions and greenhouse effect

It is Landsvirkjun's goal to reduce greenhouse gas emissions from its operations. This affects many of the company's environmental factors, such as usage of fossil fuels and emissions from geothermal power stations and hydropower reservoirs.

Greenhouse effect due to burning of fossil fuels and release from electrical equipment

Table 15 shows atmospheric greenhouse gas emissions due to burning of fuel, to air travel and release from electrical equipment. Table 16 shows calculated greenhouse effect based on values in table 10, for Landsvirkjun's energy production, both overall and in each operation area.

Table 15. Greenhouse gas emissions due to fuel usage and releases from electrical equipment.

			Energy Division							
			Power stations					Division Mngt and tech. dept.	LV's operation in RVK	LVP's projects for LV
		LV total	BLA	KAR	MÝV	SOG	THJÓ			
Gasoline for vehicles and equipment*	**tons**	**55,777**								
- carbon dioxide emissions	tons	55.757	0.921	1.126	7.552	0.564	15.330	17.071	8.390	4.803
- methane emissions	tons	0.005	0.000	0.000	0.001	0.000	0.001	0.002	0.001	0.000
- nitrous oxides emissions	tons	0.015	0.000	0.000	0.002	0.000	0.004	0.004	0.002	0.001
Diesel oil for vehicles and equipment	**tons**	**925,387**								
- carbon dioxide emissions	tons	925.306	48.282	49.674	155.824	54.842	266.885	35.936	99.932	213.931
- methane emissions	tons	0.023	0.001	0.001	0.004	0.001	0.007	0.001	0.003	0.005
- nitrous oxides emissions	tons	0.058	0.003	0.003	0.010	0.003	0.017	0.002	0.006	0.013
Release from electrical equipment										
SF_6 release* **	tons	<0.001		<0.001						
Air travel**										
- carbon dioxide emissions	tons	**284.9	+	+	+	+	+	+	+	58.0

* Emissions from vehicles include both emissions from private cars, rental cars and LVP cars in projects for Landsvirkjun.
** Emissions due to air travel (domestic and overseas) are not divided between operation units, but rather is one value calculated based on the total number of flights taken by Landsvirkjun employees. Domestic air travels are flights by both LV and LVP's projects for Landsvirkjun. Emissions on domestic air travel are calculated information of fuel usage from the Icelandic Energy Forecast Committee and distances from Air Iceland for an averaged weight passenger and the average number of seats filled. Emissions for overseas flight are taken from Kolviður, www.kolvidur.is. The emissions were recalculated for 2008 and 2007.
***sulfur hexafluoride

Table 16. Total greenhouse effect due to fuel usage.

	Total emissions		Emissions at power stations based on energy production					
	Landsvirkjun total			BLA	KAR	MÝV	SOG	THJÓ
Gasoline for vehicles and equipment	kg CO_2 eq	60,376	kg CO_2 eq/GWh	1.22	0.26	12.67	1.11	3.06
Diesel oil for vehicles and equipment	kg CO_2 eq	943,836	kg CO_2 eq/GWh	60.29	10.59	246.30	101.88	50.16
Air travel	kg CO_2 eq	284,887	-	-	-	-	-	-
SF_6 release *	kg CO_2 eq	11,950		-	2.5	-	-	-
Total greenhouse effect	**kg CO_2 eq**	**1,301,049**	**kg CO_2 eq/GWh**	**61.51**	**13.35**	**258.97**	**102.99**	**53.22**

* 1 kg of SF_6 equals to 23.900 kg carbon dioxide (CO_2)

Figure 9 shows greenhouse gas emissions due to burning of fossil fuels and release from electrical equipment.

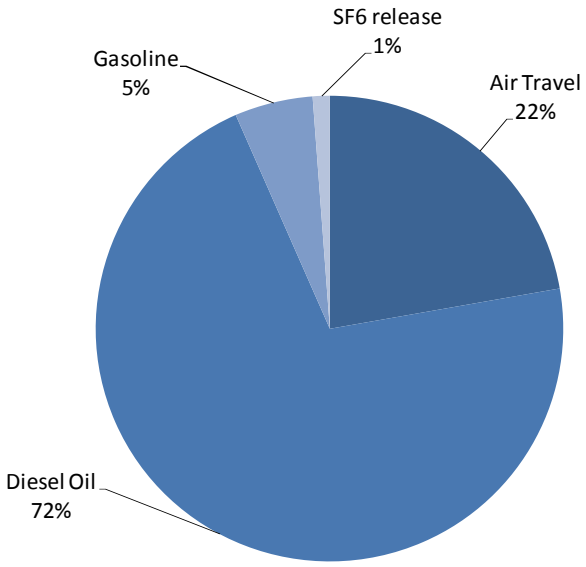


Figure 9. Greenhouse gas emissions due to burning of fossil fuels and release of SF_6.

In 2009, 217 kg of hydrogen were used to power compact cars. By using hydrogen cars, approximately 2,430 kg of CO_2 eq were saved when compared to average fuel consumption of gasoline compact car.

Greenhouse gas emissions between years

Table 17: Use of fuel for vehicles and equipment at the Energy Division's operation areas in 2009, 2008 and 2007 and change between years.

Operation area	2009 (liters)	2008 (liters)	2007* (liters)	Energy Div. 2009: Change from 2008	Energy Div. 2009: Change from 2007
BLA	18,475	18,219	13,015	+1%	+42%
KAR	19,085	13,499	-	+41%	-
MÝV	61,615	58,719	67,273	+5%	-8%
SOG	20,776	22,859	17,878	-9%	+16%
THJÓ	106,570	65,125	82,668	+64%	+29%
Total usage in the four operation areas	245,606	178,421	180,834	+38%	+36%

* Because of better recording values for 2007 been updated based on values presented in Environmental Report 2007.

Greenhouse effect of geothermal power stations

Table 18 shows the atmospheric gas emissions in 2009. The values include emissions from research borholes, which are not part of the energy production but still contribute to Landsvirkjun's total emissions.

Table 18: Atmospheric gas emissions and greenhouse effect of geothermal power stations in 2009.

	Use		Atmospheric emissions			
			Quantity		Use	
Steam from geothermal power stations[1]	5,436,000	tons	3,715,600	tons		
- total carbon dioxide emissions			37,426	tons	37,426,000	kg CO_2 eq
- total methane emissions[3]			26	tons	546,000	kg CO_2 eq
- total hydrogen sulphide emissions[4]			5,800	tons	0	kg CO_2 eq

Quantity of usage and emissions are from Kemia sf. Quantity of reinjection is from measured at Krafla.
1: The difference between usage and quantity of atmospheric emissions is due to reinjection.
2: Emissions from research borholes are included in Landsvirkjun's total emissions.
2: Release of 1 kg of methane is comparable to the release of 21 kg of carbon dioxide.
3: Not a greenhouse gas.

Greenhouse effect of hydropower reservoirs

In reservoirs, carbon dioxide (CO_2), methane (CH_4) and nitrious oxides (N_20) are formed when organic matter, present in vegetation and soil that goes under water, decomposes.

It's Landsvirkjun's objective to know, monitor and further investigate emissions from reservoirs

Results of a Landsvirkjun commenced study[1] on emission from the Gilsárlón are based on calculated values on emission from reservoirs. Number of days when the reservoirs were covered with ice was counted for the highest emitting reservoirs. No release is expected when the reservoir is covered with ice.
The results are shown in table 19 and are presented as emissions per ha reservoir per day in accordance with the IPCC terminology.

Table 19: Estimated CO_2 and CH_4 emissions from reservoirs based on quantity of organic carbon in reservoir area. Measured emissions from Gilsárlón reservoir and IPCC 2006 coefficients are shown for comparison.

Reservoir	Ice free days	kg carbon per m^2 reservoir area	kg CO_2/ha/day	kg CH_4/ha/day
Bjarnalón reservoir	215*	0.63	0.076	0.0030
Blöndulón reservoir	168	38.90	4.670	0.1870
Hálslón reservoir	175	0.12		
Hrauneyjalón reservoir	215*	0.88	0.106	0.0042
Keldárlón reservoir	215	0.07		
Krókslón reservoir	215*	1.92	0.230	0.0092
Sultartangalón reservoir	215*	0.68	0.082	0.0033
Ufsarlón reservoir	215	0.08		
Vatnsfellslón reservoir	215*	0.00	0.000	0.0000
Gilsárlón reservoir	187	108.70	12.900	0.5240
IPCC 2006 ice-free period			11.800	0.0860

The number of ice free days has been counted for the Blöndulón, Hálslón, Keldárlón and Ufsárlón reservoirs. Counting for other reservoirs remains.
* Number of ice free days unknown. Values are IPCC reference values.

[1] Oskarsson and Gudmundsson (2008). Gróðurhúsaáhrif uppistöðulóna. Rannsóknir við Gilsárlón 2003-2006, Landsvirkjun

Table 20 shows estimated greenhouse gas emissions from the Landsvirkjun's hydropower reservoirs. The table shows that total greenhouse gas emissions are approximately 29,000 tons CO_2 eq. Now values include the Kelduárlón and Ufsárlón reservoirs for the first time, increasing the emissions around 3.5%.

Table 20: Estimated annual greenhouse gas emissions from Landsvirkjun's hydropower reservoirs in 2009.

Station	Reservoir/Lake	Area [km^2]	CO_2 ice-free [kg CO_2]	CH_4 ice-free [kg CH_4]	CH_4 ice [kg CH_4]	Total greenhouse effect [kg CO_2 eq]
Blanda station		**62 (8,2)**	**7,100,000**	**286,000**	**4,320**	**13,600,000**
Blanda station	Blöndulón reservoir	57	5,700,000	230,000	3,420	11,000,000
Blanda station	Gilsárlón reservoir	5	1,400,000	56,000	900	2,600,000
Blanda station	(lakes in diversion)	(8.2)	0	0	0	0
Fljótsdalur station		**64.5**	**7,515,919**	**324,671**	**367**	**14,340,000**
Fljótsdalur station	Hálslón reservoir	56.6	6,900,000	300,000	0	13,200,000
Fljótsdalur station	Kelduárlón reservoir	6.8	525,000	21,030	313	970,000
Fljótsdalur station	Ufsárlón reservoir	1.1	90.919	3,641	54	170,000
Fljótsdalur station	(lakes in diversion)	(10.0)	0	0	0	0
Laxár stations		**(38.0)**	**0**	**0**	**0**	**0**
Laxár stations	(Lake Mývatn)	(38.0)	0	0	0	0
Sog area		**(83.0)**	**0**	**0**	**0**	**0**
Sog stations	Lake Thingvallavatn	(83.0)	0	0	0	0
Thjórsá area		**194 (2.6)**	**834,881**	**33,264**	**318**	**1,500,000**
Lake Thórisvatn reservoir	Lake Thórisvatn	83.4	38,000	1,500	0	70,000
Lake Thórisvatn reservoir	Sauðafellslón reservoir	4.5	9,600	380	0	18,000
Sigalda station	Krókslón reservoir	14	69,000	2,800	0	130,000
Hrauneyjafoss station	Hrauneyjalón reservoir	9	21,000	810	0	38,000
Búrfell station	Bjarnalón reservoir	1	1,600	65	0	3,000
Hágöngumiðlun area	Hágöngulón reservoir	37	79,000	3,100	0	140,000
Kvíslaveita diversion	Lake Kvíslavatn	22	500,000	20,000	276	920,000
Kvíslaveita diversion	Lake Dratthalavatn	2	73,000	2,900	42	130,000
Kvíslaveita diversion	Eyvindarlón reservoir	0.01	21	1	0	38
Kvíslaveita diversion	Hreysislón reservoir	0.1	210	9	0	390
Kvíslaveita diversion	Thjórsárlón reservoir	3.5 (2.6)	7,450	300	0	14,000
Vatnsfell station	Vatnsfellslón reservoir	0.6	0	0	0	0
Sultartangi station	Sultartangalón reservoir	20	36,000	1,400	0	65,000
Total		**312**	**15,000,000**	**620,000**	**4,600**	**29,000,000**
Total emissions based on IPCC reference values [kg CO_2 eq]						**94,000,000**

Numbers in brackets stand for the size of natural reservoirs like Lake Thingvallavatn or where a reservoir is partly natural.

Total greenhouse gas emissions

Table 21 and figure 10 show total greenhouse gas emissions from all of Landsvirkjun's operations. As can be seen, source of atmospheric greenhouse gas emissions are primarily from geothermal power stations (56%) and hydropower reservoirs (42%). Emissions due to burning of fuels for vehicles, machines, air travel, waste and release of electrical equipment (SF_6) account for approximately 2% of the total greenhouse gas emissions.

Table 21. Atmospheric gas emissions and greenhouse effect of Landsvirkjun's energy production in 2009.

	Use		Atmospheric emissions Quantity		Greenhouse effect	
Steam from geothermal power stations[1,2]	5,436,000	tons	3,715,600	**tons**		
- carbon dioxide emissions			37,426	tons	37,426,000	kg CO_2 eq
- methane emissions[3]			26	tons	546,000	kg CO_2 eq
- hydrogen sulphide emissions			5,800	tons	0	kg CO_2 eq
Emissions from hydropower reservoirs	320	km^2				
- carbon dioxide emissions			15,549	tons	15,459,099	kg CO_2 eq
- methane emissions			623	tons	13,618,040	kg CO_2 eq
Fuel: Gasoline for vehicles and equipment	24,216*	liters				
- carbon dioxide emissions			56	tons	55,757	kg CO2 eq
- methane emissions[3]			0.005	tons	114	kg CO2 eq
- nitrous oxides emissions[4]			0.015	tons	4,650	kg CO2 eq
Fuel: Diesel oil for vehicles and equipment	356,401*	liters				
- carbon dioxide emissions			925	tons	925,306	kg CO2 eq
- methane emissions[3]			0.023	tons	489	kg CO2 eq
- nitrous oxides emissions[4]			0.058	tons	18,041	kg CO2 eq
Air travel						
- carbon dioxide emissions			284.9	tons	284,887	kg CO2 eq
Waste disposal[6]						
- landfilling	41	tons			13,359	kg CO2 eq
- incineration	6	tons			610	kg CO2 eq
Release from electrical equipment						kg CO2 eq
SF_6 release			<0.001	tonn	11,950	kg CO2 eq
Total greenhouse effect					**68,422,302**	**kg CO2 eq**

1: The difference between usage and quantity of atmospheric emissions is due to reinjection
2. Total emissions from production and research.
3. Release of 1 kg of methane is comparable to the release of 21 kg of carbon dioxide.
4: Release of 1 kg of nitrous oxides is comparable to the release of 310 kg of carbon dioxide.
5: Release of 1 kg SF_6 is comparable to the release of 23,900 kg of carbon dioxide.
6: Greenhouse gas emissions from landfilling and incineration of waste are roughly estimated.
* Landvirkjun and LVP in projects for Landsvirkjun.

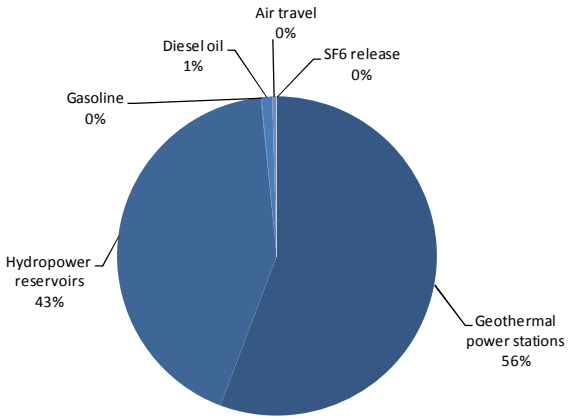


Figure 10. Total greenhouse gas emissions.

Greenhouse effect of energy production: Comparison between years

Emissions by type of energy production

Table 22 provides a summary of greenhouse gas emissions from Landsvirkjun's hydropower and geothermal power stations, both total and by type of energy production. Landsvirkjun's total energy production in 2009 was 12,237 GWh, of which 96 % was produced by hydropower stations and 4% by the Krafla station as in the year before. When evaluating greenhouse effect by type of energy production, emissions that are caused by factors that are not directly related to the respective hydropower and geothermal power stations are grouped based on the significance of the energy production. This applies, for example, to emissions due to air travel and treatment of waste. Emissions from geothermal power stations are much greater than emissions from hydropower stations. Table 22 also shows that greenhouse gas emissions due to the burning of fossil fuels by vehicles are insignificant hen total emissions from energy production are evaluated. Furthermore carbon binding reduces the greenhouse effect of energy production significantly.

Table 22. Summary of greenhouse effect of Landsvirkjun's hydropower and geothermal power stations in 2009, both total and according to type of energy production.

	Unit	Hydropower	Geothermal	Unit	Hydropower	Geothermal
Burning of gasoline	kg CO_2 eq	50,932	9,444	kg CO_2 eq/GWh	4	20
Burning of diesel oil	kg CO_2 eq	771,104	145,809	kg CO_2 eq/GWh	66	308
Geothermal power stations	kg CO_2 eq	0	37,972,000	kg CO_2 eq/GWh	0	80,292
Hydropower reservoirs	kg CO_2 eq	29,069,432	0	kg CO_2 eq/GWh	2,474	0
Air travel	kg CO_2 eq	273,879	11,008	kg CO_2 eq/GWh	23	23
Waste	kg CO_2 eq	13,429	540	kg CO_2 eq/GWh	1	1
SF_6 release	kg CO_2 eq	11,950	0	kg CO_2 eq/GWh	1	0
Total emissions	**kg CO_2 eq**	**30,190,726**	**38,138,801**	**kg CO_2 eq/GWh**	**2,570**	**80,645**
Carbon binding	kg CO_2 eq	-19,296,418	-775,582	kg CO_2 eq/GWh	-1,642	-1,640
Carbon footprint	**kg CO_2 eq**	10,894,308	37,363,219	**kg CO_2 eq/GWh**	927	79,005

Figure 11 shows greenhouse effect of various types of energy production based on life cycle assessment results, provided by information from the World Energy Council from 2007. For comparison, information on Landsvirkjun's energy production in 2009 is provided as well.

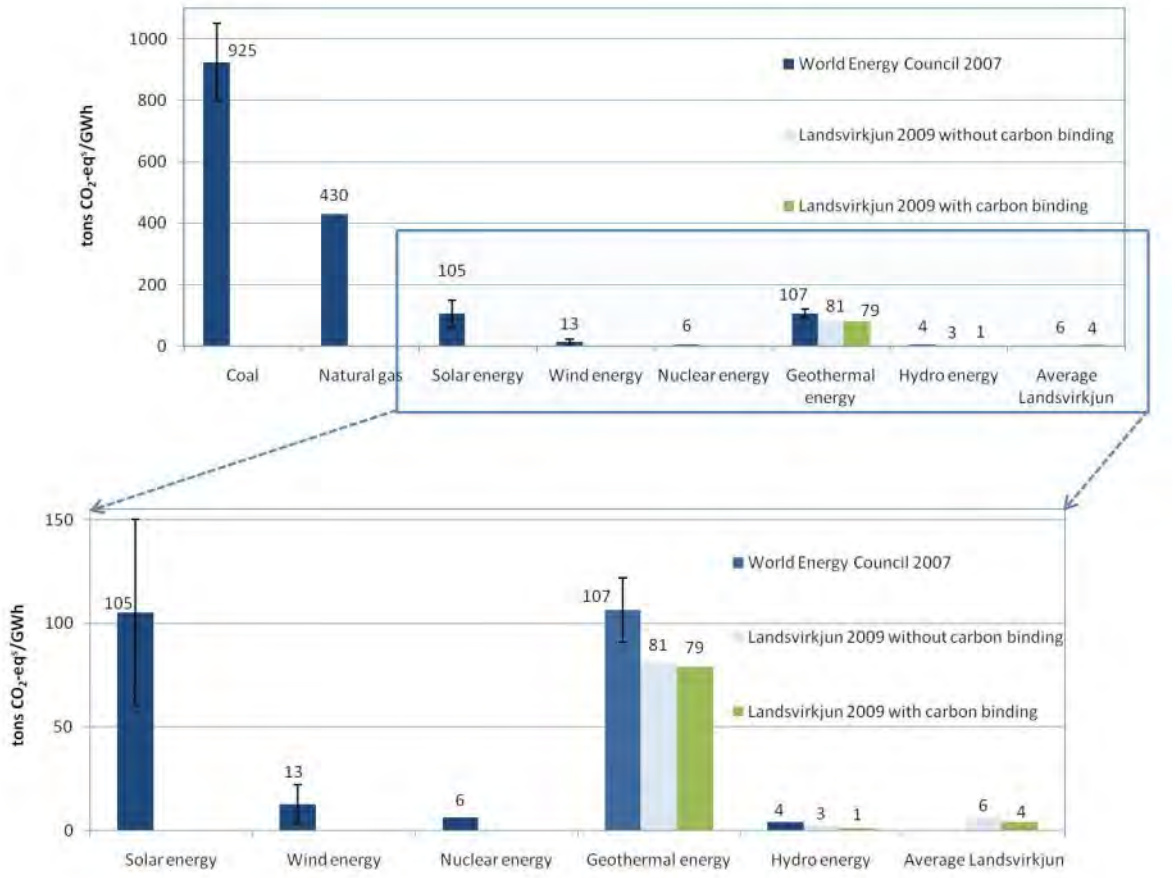


Figure 11. Greenhouse effect of various types of energy production (values rounded to the nearest ton)

Based on the information from the World Energy Council, greenhouse effect due to the burning of coals is estimated to be at least 200 times greater than hydropower and 9 times greater than geothermal. Greenhouse effect due to the burning of natural gas is estimated to be over 100 times greater than hydropower and 5 times greater than geothermal. Emissions from Landsvirkjun's geothermal power stations are similar to the values from the World Energy Council, but emissions from hydropower stations are considerably lower, both with and without carbon binding (1 with carbon binding and 3 without carbon binding).

Landsvirkjun's carbon footprint – Total greenhouse gas emissions

Table 23: Landsvirkjun's carbon footprint and comparison of the Energy Division's carbon footprint between years.

		2009 LV total	2009 Energy Division	2008 Energy Division	2007 Energy Division	Change 2009 & 2008	Change 2009 & 2007
Emissions – in kg CO_2 eq							
Geothermal power stations	kg CO_2 eq	37,972,000	37,972,000	46,388,000	51,093,000	-18%	-26%
Emissions from hydropower reservoirs	kg CO_2 eq	29,077,139	29,077,139	27,935,422	14,735,000	+4%	+97%
Fuel: Gasoline for vehicles and equipment	kg CO_2 eq	60,376	46,090	30,010	41,093	+54%	+12%
Fuel: Diesel oil for vehicles and equipment	kg CO_2 eq	943,836	623,680	521,680	513,566	+20%	+21%
Air travel*	kg CO_2 eq	284,887	284,887	239,280	126,400	+19%	+125%
Waste	kg CO_2 eq	13,969	6,933	12,875	9839	-46%	-30%
Release of SF_6	kg CO_2 eq	11,950	11,950	0	35,850	+100%	-67%
Total emissions	kg CO_2 eq	68,364,157	68,022,686	75,127,267	66,544,909	-9%	2%
Carbon binding with land reclamation and reforestation	kg CO_2 eq	-22,104,000	-22,104,000	-20,072,000	-18,600,000	+10%	+19%
Carbon footprint	**kg CO_2 eq**	**46,033,328**	**45,918,486**	**55,055,267**	**47,944,909**	**-17%**	**-4%**
Emissions per unit energy produced – in kg CO_2 eq/GWh							
Geothermal power stations**	kg CO_2 eq/GWh	3,107	3,107	3,758	5,950	-19%	-48%
Emissions from hydropower reservoirs***	kg CO_2 eq/GWh	2,379	2,379	2,263	1,716	+5%	+39%
Fuel: Gasoline for vehicles and equipment	kg CO_2 eq/GWh	5	4	2	5	100%	-10%
Fuel: Diesel oil for vehicles and equipment	kg CO_2 eq/GWh	77	51	42	60	+22%	-15%
Air travel*	kg CO_2 eq/GWh	23	23	19	15	+23%	+55%
Waste	kg CO_2 eq/GWh	1	1	1	1	-43%	-43%
Release of SF_6	kg CO_2 eq/GWh	1	1	0	4	+100%	-75%
Total emissions	kg CO_2 eq/GWh	5,594	5,565	6,086	7,751	-9%	-28%
Carbon binding with land reclamation and reforestation	kg CO_2 eq/GWh	-1,809	-1,809	-1,626	-2,166	+11%	-17%
Carbon footprint	**kg CO_2 eq/GWh**	**3,785**	**3,756**	**4,498**	**5,585**	**-16%**	**-33%**

* Recording of emissions due to air travel is lacking for the year 2007 and unavailable for the year 2006. Air travel emissions emitted in 2008 and 2007 have been updated in accordance with methods of the Icelandic Energy Forecast Committee.

** This table shows emissions from geothermal power stations as part of average total greenhouse gas emissions per GWh produced. These emissions were 80,627 kg CO_2 eq/GWh for the year 2009 without carbon binding and 78,987 kg CO_2 eq/GWh with carbon binding.

*** This table shows emissions from reservoirs as part of average total greenhouse gas emissions per GWh produced. Table 21 shows greenhouse gas emissions from reservoirs per GWh produced in hydropower stations, which were 2,551 kg CO_2 eq/GWh for the year 2009 without carbon binding and 909 kg CO_2 eq/GWh with carbon binding.

Noise

Sound pressure level at Krafla and Bjarnarflag is measured annually at specified locations and more frequently if needed. The entire operation area at Krafla and Bjarnarflag is defined as an industrial area but the reference limit for industrial areas is specified as 70 dB (A) in Icelandic noise regulations. The Krafla area is a popular tourist area. It is Landsvirkjun's goal that the sound pressure level does not exceed 50 dB(A) at locations where the number of tourists is the greatest. This goal was not reached in the year 2009 due to traffic at the measurement points.

Figure 12 shows the locations where sound pressure levels were measured at Krafla. Table 24 shows the equivalent sound pressure levels for 2007, 2008 and 2009 at Krafla's measurement locations. The main source of noise at Krafla are the station's turbine generator units, incidental releases of steam and traffic. Equivalent sound pressure levels at turbine 1 and 2 and powerhouse are above the reference limits. Both turbine generator units were in operation during the measurements.

The sound pressure level measured at some of the boreholes is higher in 2009 than in 2008. Boreholes 22 and 37 were being tested at Krafla when measurements were made in 2009, but when a hole is tested the sound pressure levels in its closest environment will increase.

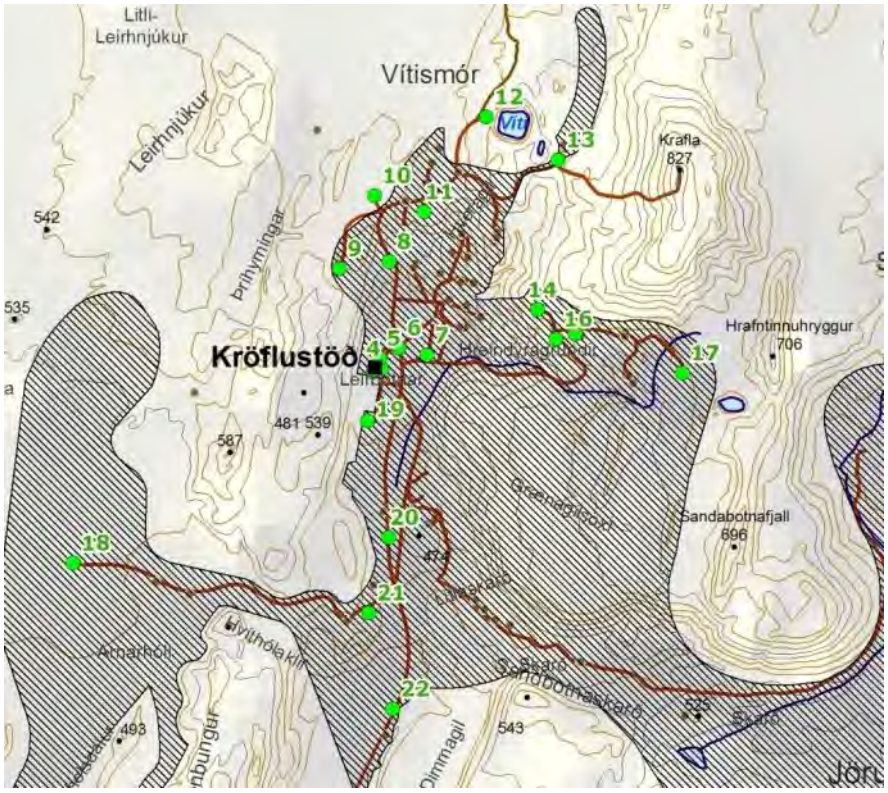


Figure 12. The locations of sound pressure level measurements at Krafla. The numbers indicate the applicable measurement in the table.

Table 24. Measured sound pressure level at Krafla area in 2007-2009. Green lines indicate measurements at popular tourist areas.

No.	Krafla	31.07.2009 L_{Aeq}[dB(A)]	05.08.2008 L_{Aeq} [dB(A)]	04.07.2007 L_{Aeq} [dB(A)]
1	Krafla control room	53.9	51.6	49.2
2	East of turbine 1	89.1	88.2	87.9
3	East of turbine 2	89.9	90.8	88.6
4	Powerhouse	72	73.3	74.2
5	Storehouse 1A	67.6	67.2	64.7
6	Residence at Sigurbogi	50	49.7	50.5
7	At hole 6	55.5	51.8	49.4
8	At hole 26	50	48.0	55.1
9	At hole 35	50	30.8	
10	At Saurbær (hole 8)	64	32.0	45.1
11	At hole 10 (Viewing platform)	50	47.8	42.2
12	Parking at Vítisbarmur	75	30.0	40.5
13	At hole 34	68	63.8	67.5
14	At hole 19	57	66.0	67.3
15	At hole 31	52	45.5	45.5
16	At hole 14	52	42.9	52.1
17	At hole 18	42	30.3	32.8
18	At hole 1 – in Leirhnjúkar Lava field	48	31.9	33.1
19	At power station's cafeteria parking lot	51	44.2	40.8
20	Near waterhole house	48	37.0	32.4
21	At hole 21	44	42.2	49.2
22	Parking at Skarðssel	53.9	42.0	30.8

* Abnormal measurement, a car may have driven by during the measurement.
** Flow testing at Víti

Table 25 shows the results of sound pressure level measurements in Bjarnarflag in 2007-2009. The main noise generators at Bjarnarflag are the station itself, separation stations and incidental releases of steam. No holes were being flow tested when measurements were made in 2009. The reference limit for an industrial area is 70 dB(A) and the sound pressure level exceeds that at borehole 12 (measurement 25). The nature baths in Mývatnssveit are located in an area that is defined as an industrial area. This area is a popular tourist attraction and it is therefore preferable that the sound pressure level not exceed 50 dB(A) at that location. This goal has been achieved according to measurements from 2009 and 2008. One measurement (nr. 36) was made in Reykjahlíð and the equivalent sound pressure level from the power station was well under the reference limit, even though the maximum sound pressure level is only slightly under the limit. Traffic increased the sound pressure level at nr. 23, 24 and 26 but didn't have a significant influence on the sound pressure level.

Figure 13. The locations of sound pressure level measurements in Bjarnarflag. The numbers indicate the applicable measurement in the table.

Table 25. Measured sound pressure level at Bjarnarflag in 2007-2009. Values in red indicate measurements that exceed the specified reference limit.

No.	Bjarnarflag	31.07.2009 L_{Aeq} [dB(A)]	05.08.2008 L_{Aeq} [dB(A)]	04.07.2007 L_{Aeq} [dB(A)]
23	Námaskarð viewing platform	43	54.2	52.0
24	At hole 11	40	62.4	42.8
25	At hole 12	90	84.7	57
26	Information lot – near old bathing area	34	50.3	59.5
27	At steam station	48	81.8	86.4
28	At hole 9	36	51	73.1
29	Heat exchange station – electr. room	66	62.5	65.1
30	Parking lot for the bathing area entrance	43	48.3	35.9
31	Near the new bathing areas	35	47.3	37.2
32	Separation station 1	69	61	86.1
33	Separation station 2	56.7	70.8	78.1
34	Parking lot for the office of Grænar Lausnir	40		39.1
35	At Varnargarðshryggur	40	45.1	
36	Skútahraun 6	40	38.5	

Wind strength and wind direction has major effect on sound measurements. When measurements were made in 2009 winds blew from the north at 5-8 m/sec and there was a slight rain.

Environmental mishaps

One environmental mishap was recorded in the year 2009. During earthworks at Fljotsdalur station contractors disregarded weight limitations, causing damage to the road in Nordurdalur and causing danger to people and environment. The mishap was reported to the authorities and the road repaired.

Landsvirkjun • Háaleitisbraut 68 • 103 Reykjavík • Iceland
Tel.: +354 515 9000 • Fax: +354 515 9007 • landsvirkjun@lv.is
www.lv.is