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19. Historical Aspects of Geothermal Utilization in Iceland

by
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Abstract: Volcanoes and hot springs were probably the only natural phenomena completely new to the first settlers when they came to Iceland in the 9th century A.D., as these were unknown in Northern Europe. The distribution of hot springs did not affect the location of farmhouses during the Age of Settlement, and the hot springs were gradually used for washing and bathing. The oldest known geothermal pipeline, a covered duct made of stone slabs, dates back to the 13th century. Space heating with geothermal water, however, did not begin until 1908. For several centuries, sulfur mined in geothermal fields was one of the main export products of Iceland. Hot springs were used at one locality for extracting salt from seawater between 1773-1793.

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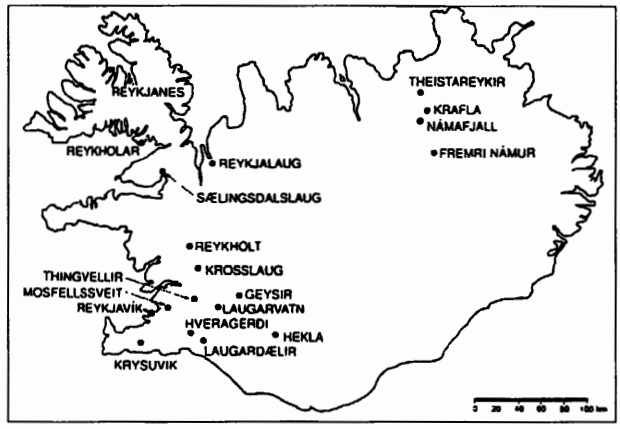
Location of Farms and Hot Springs

Warm springs and steaming ground probably were among the natural phenomena that were most surprising to the first settlers when they came to Iceland in the 9th century. It is unlikely that any of the settlers had seen hot springs or active volcanoes before. The novelty of the hot springs is reflected in numerous place names, including *reyk* ("smoke"), *laug* ("hot spring"), and *hver* ("boiling spring"), becoming Reykir, Reykjavik, Reykjadalur, Laugaland, Laugarvatn, Laugardalur, Hveravellir, and Hveradalir. It is likely that the settlers were suspicious of the hot springs and steam to begin with. But many of them were Vikings who claimed to fear nothing, and one can assume that they soon started using the hot springs for bathing and washing.

Iceland has more than 250 separate thermal areas with over 600 main hot springs. The majority of these are in lowland areas in the southern, western, and northern parts of the island.

The distribution of the hot springs does not appear to have had any significant influence on the location of farmhouses during the Age of Settlements (874-930). The *Landnáma* (*The Book of Settlements*), which was written in the 12th century and covers the entire island, includes stories of some 430 principal settlers, about 100 of whom obtained land within the lands of earlier settlers (commonly kinsmen of the first settlers). Stories are told of the land claims of each settler, his farmstead, his ancestors in the old country, and his descendants in the new. Researchers have tried to locate the exact positions of individual farmhouses from the text of *Landnáma*. In many cases, there is little doubt about these locations. A comparison of a map of the settlement farms in the edition of *Hið íslenska fornritafélag* (*The Book of Settlements, 1968)* and maps with the locations of the hot springs does not at all indicate that the first settlers wanted to build their farmhouses near the hot springs. On the contrary, Ingólfur Arnarson (considered to be the first Norse settler in Iceland) built his farmhouses about 3.5 km from the hot springs in Reykjavík. Apparently, he preferred to have his farm close to a good beach for landing boats rather than at hot springs suitable for washing clothes and bathing. Why not? The women would take care of the washing anyway!



Map of Iceland with the main geothermal localities mentioned in the text.

Use of Hot Springs through the Ages

It is not known with any certainty when the hot springs were generally used for washing and bathing. Reference is frequently made in the sagas, written in the 12th-13th centuries, to bathing in hot springs. The sagas have several romantic descriptions of people bathing in the hot springs, in particular in *Laxdæla Saga* (*Íslendingasögur, Sagas of the Icelanders*, 1981), where the beautiful but strong minded Guðrún Ósvífursdóttir meets her hero Kjartan Ólafsson in the *Sælingsdalslaug* ("hot pool") in the twilight. In addition to washing and bathing, the hot springs were also used widely for bending wood and bones and for softening materials. Apart from the elaborate bathing pool of the saga writer Snorri Sturluson, which will be described later, the bathing pools seem to have been rather primitive. Commonly, people would take a bath in brooks where hot water from the often-boiling springs would be mixed with cold

Women washing clothes in the hot springs at Laugardalur, Iceland, around the beginning of the 20th century. *Courtesy of Ljosmyndasafn Reykjavikur/Hitaveita Reykjavikur*

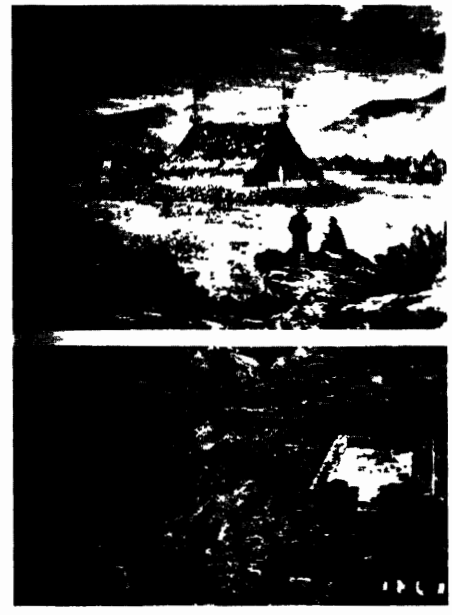
water. Eggert Ólafsson and Bjarni Pálsson, in their travel book from 1752-1757, described the bathing pools in Laugarnes (now the site of the main swimming pool of Reykjavík), where the people of Reykjavík brought clothes for washing and sailors and workers came in large groups on Saturday and Sunday nights to bathe (Ólafsson and Pálsson, 1943).

Boiling food (meat, fish, eggs, and milk) and baking bread were also common in the hot springs. Ólafsson and Pálsson also mentioned that people used the hot clay from mud pools in Ölfus (probably in the geothermal field of the present-day Hveragerði hot spring village) to make wooden barrels for airtight food storage. Furthermore, they wrote about dry-baths or steam baths (saunas) in Thingeyjarsýsla in Northern Iceland and in Árnessýsla in Southern Iceland. Thorvaldur Thoroddsen, who was traveling in Iceland a century later (1882-1892), mentioned a dry-bath at Sturlureykir near Snorri's Reykholt in Western Iceland. He also mentioned that people diverted hot water into fields where they grew potatoes and cabbage, significantly increasing the vegetable yield. Here we have the first documented examples of soil heating in Iceland.

Sulfur mining in geothermal areas was of significant interest from the 13th to the late 18th century, and geothermal springs were used for salt extraction from seawater during 1776-1792. These activities are described later.

Hot Springs of National Interest

The first time that geothermal energy was of national significance in the history of Iceland was associated with the adoption of Christianity as the formal religion of Iceland around the year 1000. After a decree by an arbitrator, the Parliament decided that the people should give up the pagan gods of the Vikings and become Christians. This was accepted with some grunting. But when it came to the ceremony of baptism, which involved every individual being submerged in water, real trouble arose. The people at the Parliament absolutely refused to be baptized in cold water. According to *Kristni Saga* (*Íslendingasögur, Sagas of the Icelanders*, 1981),

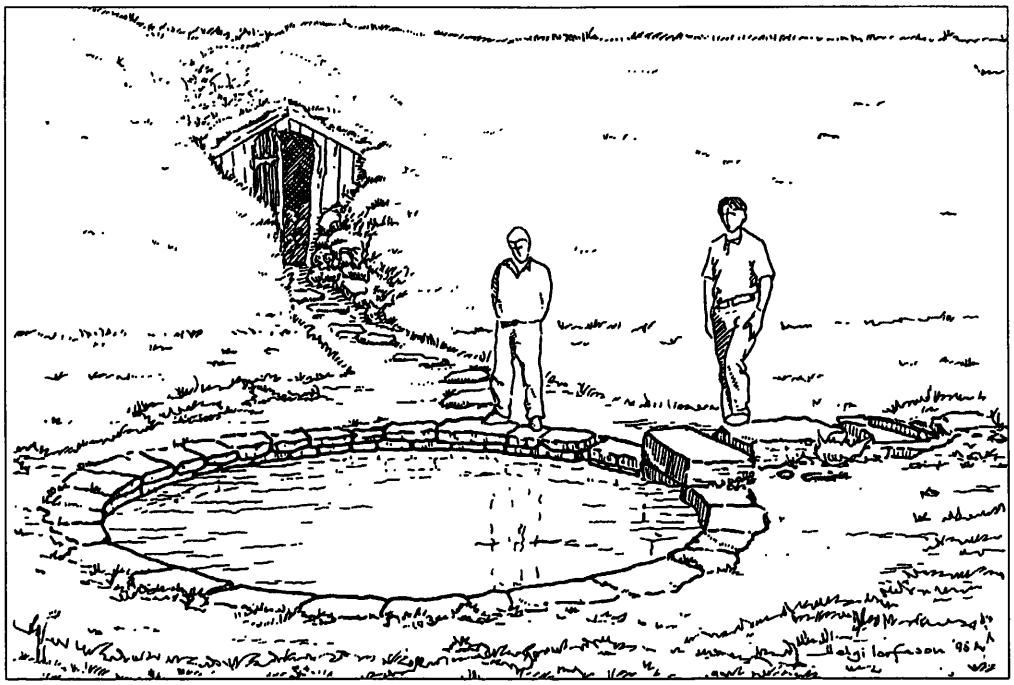


The sketch at top shows the old church at Reykjahlið near Lake Myvatn in Northern Iceland. A lava flow in 1729 engulfed several farms but encircled the church, which stood on a small hill—"divine intervention?" *Photo and text by Bárðarson, 1989. Reprinted with permission*

the Saga of Christianity originally written in the 12th century, the people from Northern and Southern Iceland were baptized in a hot spring named *Reykjalaug* (later called *Vígðalaug*, "the consecrated spring") at Laugarvatn, some 20 km east of the Parliament site at Thingvellir. The people from the western parts were baptized in *Reykjalaug* in Lundarreykjadalur (later called *Krosslaug*, "the spring of the cross") some 30 km north of Thingvellir. Both springs were considered to have healing powers from then on.

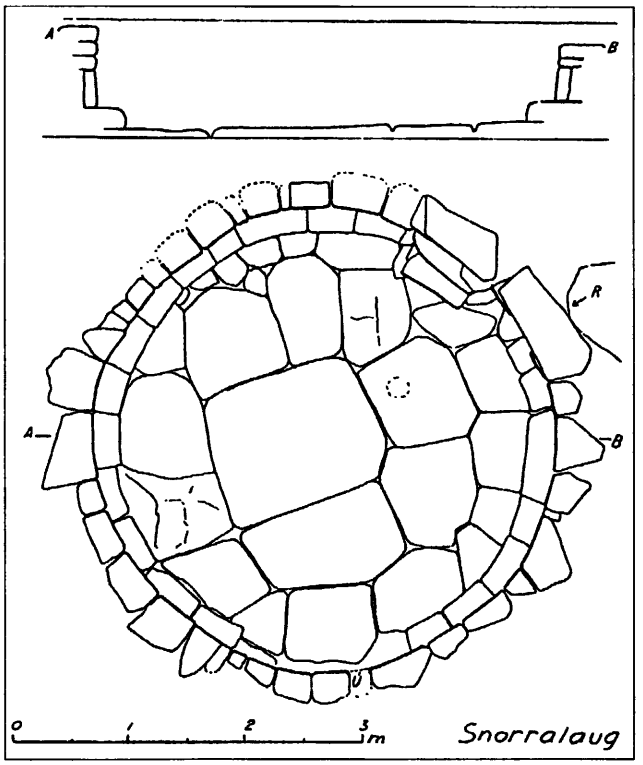
Snorri's Bath and Conduits for Water and Steam

The only man-made bath still remaining in Iceland from past centuries is *Snorralaug* ("Snorri's bath"), the bath of the famous historian and saga writer Snorri Sturluson (1178-1241) in Reykholt, Western Iceland. It is, in fact, one of the most remarkable archaeological monuments in Iceland. The pool is circular, slightly under 4 m in diameter, about 0.9 m deep, and made of hewn blocks of stone (silica sinter, which can be found about 2 km from Reykholt) that fit each other in the most exact manner. The floor is paved with the same stone, and a stone bench, capable of seating some 30 people, surrounds the inside of the bath. It is filled by hot water carried through an underground stone conduit from a boiling spring called Skrifla about 120 m away. In the olden days, it is said that the temperature of the water could be altered by the addition of cold water from a brook that now is dried up.



Snorralaug, in Reykholt. The hot water conduit is on the right. The entrance to a tunnel between the bath and the farmhouse is in the background. *Drawing by Helgi Torfason*

Archaeological excavations have revealed three conduits from the vicinity of Skrifla (Grímsson and Ólafsson, 1987). Two of these lead to Snorralaug and are considered to have been used for transporting water to the bath. The third goes from the morass of Skrifla up a slope to the farm site. This pipe is considered to have been used to transport steam from Skrifla to a place near the farm. It is not known whether the steam was used for a steam bath or for cooking and baking, or possibly for warming up a house. The three conduits are built in such a way that ditches were dug through the soil and humus layer (1-2 m deep), a narrow channel was made into the underlying clay at the bottom, and slabs of rock were used to cover the channel. In some cases, small slabs of rock were lined along the sides of the channel to support the larger slabs of rock used to cover the channel. The ditches were then filled with soil.



Plan and cross section of *Snorralaug* (Snorri's bath) before the restoration in 1959. R: Inflow of water from a 120 m underground conduit. Ú: Outlet for water. *From Grímsson, 1960. Reprinted with permission*

According to *Landnámabók* (*The Book of Settlements*) describing the situation late in the 10th century, there was no farm at Reykholt but only sheep sheds belonging to the settlement farm Breiðabólsstaður and a bath. As Tungu-Oddur took a bath there, this must have been before 960. Nothing is said about the position or nature of the bath, but this original bath in Reykholt must have been fed with hot water from either of the two boiling springs, Skrifla or Dynkur (Grímsson, 1960). Both springs are situated in a morass and exposed to winds on all sides. Both are far too hot for direct bathing. It is not known exactly when a ditch was first dug from Skrifla to bring the thermal water to the dry, solid ground sheltered from the northerly winds at the foot of the hill, which later became the Reykholt farm site. One can imagine that this happened in stages. The distance from the hot spring to Snorralaug is about 120 m.

In the latter part of the 12th century, Reykholt had become a rich church farm. Snorri Sturluson, a scholar and a powerful chieftain, moved there in 1206. According to *Sturlunga Saga*, he had

a defense wall built around his dwellings. Reference is made to two gates on this wall. One was on the northern side toward the church; the other was the doorway of a corridor or a tunnel leading to the bath. This bath is mentioned several times in *Sturlunga Saga* (*Íslendingasögur, Sagas of the Icelanders*, 1981), including a narration of an event in 1228 picturing Snorri himself in the bath one evening, chatting with friends. But no information is given on its age, size, or structure. The bath in Reykholt is mentioned in several books from the 18th century, including the travel book of Eggert Ólafsson and Bjarni Pálsson (Ólafsson and Pálsson, 1943) who visited Reykholt in 1757. Snorralaug was rebuilt in 1858 (Thorsteinsson, 1971) and again in 1959 (Grímsson, 1960). The walls of the underground passage nearest to Snorri's bath were also restored.

Although there is no absolute proof, it is considered very likely that the pool and the pipelines were built by Snorri Sturluson himself. At least the pool existed during Snorri's time. Snorri was not only the most remarkable writer and historian known in Iceland's history; he was also an ambitious builder, as reflected by the defense wall around his farmhouse described in *Sturlunga Saga*. The model for the construction of the wall around the farm could easily have been sought in Norway, where Snorri was a frequent visitor. But where did he get the idea of piping the geothermal water? During the 11th and 12th centuries, pilgrims went frequently from Iceland to Rome. It is even known that a young couple, who recently had inherited Reykholt, died on a pilgrimage to Rome in the late 12th century. It is tempting to speculate that some scholar visiting Snorri Sturluson on return from a pilgrimage told him how people in Italy constructed subterranean conduits to transport hot and cold water. Perhaps this is the first transfer of geothermal technology from Italy to Iceland. The sad fact is that this technology of piping hot water and steam seems not to have spread from Reykholt to other parts of Iceland. For 700 years, people at farms with boiling springs continued to suffer in cold, unheated houses.

Hot Springs as Barometers

Eggert Ólafsson and Bjarni Pálsson, who traveled around Iceland in the mid-18th century, mentioned that hot springs have been considered good indicators of changes in the weather (Ólafsson and Pálsson, 1943). Reykjalaug in Miðfjörður in Northern Iceland can be taken as an example. When the temperature in the spring rose, people said that rain would be coming soon, even if the sky was blue and cloudless. They also reported that people in the vicinity of the Great Geyser in Haukadalur in Southern Iceland could foresee rain and storm

from the height of the water column in the eruptions of the geyser. When the water column went as high as Laugafell in the background, then it was certain that a rainstorm was coming. With modern meteorology, people realize that the height is controlled by the air pressure. When a low depression goes over the country, the pressure on the surface of hot springs is reduced, and thus the hot aquifer pressure becomes relatively high. Additionally, depressions sweeping in from the ocean normally bring rain and storms. Our forefathers did not know this. Therefore it is understandable that people found hot springs mysterious and even magical.

The Nuisance of Hot Springs

The romantic aspect of the use of the hot springs reflected in the sagas appears to have dwindled with time, at least when it came to counting the perks of farms for the tax man. In *Jarðabók Árna Magnússonar and Páls Vídalíns* (*Description of the Farmsteads of Iceland*), written in 1703-1714, a description is given of every substantial farm in Iceland and the benefits and disadvantages associated with each farm listed (Magnússon and Vídalín, 1982). For all the farms with known geothermal activity that the present author looked up in the *Jarðabók*, the hot springs are considered a nuisance and a disadvantage. One must keep in mind, however, that the farmers describing the quality of their farmlands to the learned gentlemen at the beginning of the 18th century, probably had in mind that the descriptions might be used for assessing the taxation value of their farms.

It says of Laugardælir farm in Southern Iceland: "A part of the hay field is spoiled by a hot secretion which is caused by a nearby hot spring, and from this warm broth the grassroots are eaten up resulting in patches with no vegetation." This description was written on July 27, 1709. Presently this "hot secretion" area is the main production field of Hitaveita Selfoss (District Heating Service of Selfoss), with an installed capacity of 21 megawatts-thermal. The description of Hlaðgerðarkot in Mosfellssveit, which is now a part of the main production field of Hitaveita Reykjavíkur (Reykjavik District Heating Service), says: "The possibility of cutting turf (as building material) is limited. Peat resources for cooking fuel are both of bad quality and limited. The meadows are spoiled by scree. The land is small in size. Storms are fierce so that both houses and haystacks are in danger. The water is warm." There is a certain crescendo in this description, as the musicians would say. After describing all the bad qualities of the farmland, it is stated that even the water is not drinkable, as it is warm. At present, this area is to the Icelanders as oil

fields are to the Arabs. In 1908, a farmhouse at Reykir near Hlaðgerðarkot was the first in Iceland to be heated with geothermal water.

Sulfur Mining

Although the Icelanders did not make much use of the geothermal energy, at least not when asked by the tax man, the King of Denmark certainly made a lot of money during the Middle Ages from sulfur mining in Iceland. Sulfur deposits are common in the high temperature fields of the country. The main sulfur mines were in Krýsuvík in Southwestern Iceland and in Námafjall, Krafla, Fremri-Námur, and Theistareykir in Northern Iceland. At an early stage, sulfur was exported from Iceland as an expensive commodity.

Iceland lost its independence to the King of Norway in 1262 and together with Norway to the Queen of Denmark in 1388. Apparently, the Archbishop of Niðarós (now Trondheim) in Norway acquired some kind of exclusive right to transport or buy sulfur from Iceland during the latter part of the 13th century. What the sulfur was used for is not known, as gunpowder was not invented until about 1400. It has been suggested that perhaps the Catholic Church was exporting sulfur from Iceland so that people in churches in Europe could get acquainted with the smells of Hell (Lýður Björnsson, 1994). Iceland's most famous volcano, Hekla, was well known to the Church in Europe during the Middle Ages as one of the gateways to Hell.

Later the exclusive right to export sulfur was taken by the Danish King. At the beginning of the 16th century, sulfur was exported from Iceland by merchants from Hamburg, Germany, and the King of Denmark had to buy sulfur for powder production at an extremely high price. In 1561, the king forbade the Icelanders to sell sulfur to foreigners or to anyone except merchants appointed by him. After this, the Danish government controlled the export of sulfur from Iceland through the 16th century (Sigurjónsson, 1967). The export of sulfur was very lucrative during this period, and it is reported that the king earned some 6000 *ríkisdalir* from a single shipload. This is equivalent to the price of 1,500-2,000 dairy cows, which cost some $2-3 million US in Iceland today. The sulfur export was at this time the main source of income to the Danish Crown in Iceland. At the beginning of the 17th century, the price of sulfur fell on the European market and the Crown stopped exporting it. Mining was much reduced during the 17th and 18th centuries, and the license for mining and export was sold to various individuals. The king finally gave the Icelanders the right to sulfur mining as a part of an Industrialization Plan (*Innréttingar*) in the 1760s.

Salt Production with Geothermal Heat

The first experiments in producing salt from seawater by vaporization with geothermal heat were conducted by Eggert Ólafsson and Bjarni Pálsson in 1753 at Reykhólar in Western Iceland (Ólafsson and Pálsson, 1943). In 1773, a team sent by the Danish Crown started an experiment in producing salt from seawater using boiling geothermal springs on the beach at Reykjanes in Northwestern Iceland. The experiment resulted in commercial production of salt that lasted until 1793 (Björnsson, 1978). In 1776, salt was produced using 32 pans, each about 126 x 126 x 32 cm, made mostly of lead. The salt was thought to be of reasonable quality and was used for salting fish and meat. The annual production was up to 298 *tunnur* (equivalent to nearly 90 tonnes). The total production during 1773-1793 was 3,711 *tunnur* (equivalent to 1,113 tonnes), or about 53 tonnes/year. Commercial production continued until 1793, when it was stopped due to economic reasons. The salt did not sell well, as it was contaminated with lead from the drying pans and the lead gave a dark color to the fish. Experiments with salt production in a geothermal field in Iceland started again in the 1960s.

Initial Geothermal Drilling

The first geothermal drilling occurred in Laugarnes in Reykjavík in 1755 and in Krýsuvík in Southwestern Iceland a year later. Eggert Ólafsson and Bjarni Pálsson brought to Iceland a hand-driven drilling tool owned by the Danish Science Society. They drilled some 4 m down to the bedrock in Laugarnes but to about 10 m depth in the Krýsuvík high-temperature field. In the last drill hole in Krýsuvík, they got only to a depth of some 3 m, but according to Eggert Ólafsson "at that stage the soil started moving and in spite of the narrow well around the drilling rod, a thin soup started squirting out of the well with great force. We were forced to stop and pulled the drill out. But at that stage the heat came out in full force and squirted a boiling mixture of water and clay 2-3 m into the air. In a short while this restlessness stopped and we expected that the heat had become quiet. But after a short while the heat force increased again and the well started erupting and boiling again. We saw then that we had created a new boiling spring with our operations." After this episode, geothermal drilling did not resume until in 1928 and at that time also in Laugarnes in Reykjavík.

Discussion

In a country such as Iceland, with no coal deposits and very limited deposits of firewood and peat, the hot springs held significant potential value for washing wool and clothing, bathing, and boiling food at individual farms. But it is sad to think of all the thousands of people shivering in their houses for 10 centuries on farms with ample free-flowing water most suitable to heat the houses. The mean annual temperature in Iceland is about 4° C and the average temperature of July (the warmest month) about 11° C. Some heating is needed in the houses almost around the year. At many farms, it would have been very easy to heat the houses by constructing under the farmhouses a simple pipeline, such as the one at Reykholt, thus providing floor heating.

By all indications, the technique of piping the hot water came to Reykholt in the early 13th century. But it was not until in 1908 that a farmer at Reykir in Mosfellssveit, Stefán B. Jónsson (1861-1928), who had spent 12 years in the USA, constructed a 2.3 km pipeline (1 inch steel pipe) from a hot spring to heat radiators in his house (Thórðarson, 1993). The spring was at a higher elevation than the house, and thus no pumping was required. The achievement of the farmer and self-educated carpenter and blacksmith Erlendur Gunnarsson (1853-1919) was even greater. He lived at Sturlureykir in Western Iceland, 4 km west of Reykholt, and had a boiling spring by his farm at an elevation of 6 m below the farmhouse. After much experimenting, he invented a simple mechanism to separate the steam from the water. He piped the steam to his house in 1911 and used it both for cooking and for heating the house. Initially, the radiators were heated by steam, but later the steam was used to heat water for the radiators in a closed system (Finnbogason, 1943). It is an interesting coincidence that the world's longest geothermal pipeline, 63 km and constructed in 1980, transports boiling water from the Deildartunga hot spring some 2 km west of Sturlureykir.

The historical aspects of geothermal development during the 20th century are outside the scope of this chapter. Hopefully, the history of geothermal resources development after 1900 will be dealt with properly in the near future, as many of the pioneers of this development in the various countries are still alive. A few items of historical interest as regards Iceland will be mentioned here.

The first municipal district heating service to use geothermal water, Hitaveita Reykjavíkur, was

established in 1930. At present, about 86 percent of the Icelandic population lives in geothermally heated houses, and geothermal energy provides 46 percent of the total primary energy supply for the nation. Most school centers and villages established after 1930 are located near hot springs.

The first greenhouse was heated with geothermal water in 1924 at Reykir in Mosfellssveit. Most of the pioneering work for multipurpose use of geothermal energy, however, started in the Hveragerði hot spring village (Thorhallsson, 1988):

- 1930: the first dairy to pasteurize milk and produce cheese
- 1938: hay drying experiments
- 1939-1941: a plant to dry seaweed
- 1944: experimental electrical production
- 1946: a freezing plant for vegetables (using absorption refrigeration)
- 1947: commercial bread production, a wood-drying kiln
- 1955: a factory to cure concrete blocks and pipes
- 1975: a fish drying plant
- 1979: a candy factory

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Majestic Mt. Ararat, its volcanic peak shrouded in clouds, rises in Turkey just west of the Armenian border. At its base, nomad tents dot the plateau. ***Photo by Jeffrey Tayler, published with permission***