

Tourism and Geothermal Energy in Iceland

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ABSTRACT

Tourism's share of foreign exchange earnings in Iceland has grown from 26.4% to 42.0% between 2013-2017 according to measurements on the export of goods and services. Every year the Icelandic Tourist Board releases a report about the status of tourism and makes a survey to compare main activities. One of the results for last year that the report highlighted was that in winter, as in the summer, tourists were particularly interested in activities related to nature, health and well-being. Swimming was the activity that most tourists paid for during winter and summer.

Bathing in natural pools has been a part of human history for centuries. Swimming pools and spa might be a modern-day invention, but relaxing and enjoying the numerous health benefits of bathing in thermal baths is an Icelandic tradition dating back to the country's settlement some 1100 years ago. Tourist attraction and destinations that have evolved around geothermal energy and heat are spread around the country. They are often located in municipalities where fishing industry is or has been a dominant lifeline of the community. The increased tourism and development of destination such as geothermal pools and spas can now give small municipalities and community's a greater variety in jobs and derived jobs around these destinations.

Other forms of geothermal utilization also attract numerous visitors, with more and more visitors interested in the nation's clean energy production and various use of this energy form. Visitor centers located within the proximity of renewable energy production sites constantly grow in popularity and small businesses based on using geothermal energy flourish. A family-run geothermally heated greenhouse has evolved from mainly growing tomatoes in 2010 to be a popular stop for tourist interested in sustainable food production and now includes guided tours, a restaurant with tomato base cuisine and small shop.

1. INTRODUCTION

There are numerous locations related to the geothermal industry and tourism discussed in the paper. Figure 1 identifies these locations.



Figure 1: Overview of the locations discussed in the paper.

1.1 Iceland's history and geological context

Iceland has a vast geothermal potential based on the location of the country on the Mid-Atlantic Ridge. The population of Iceland is approximately 357.000 (Statistics Iceland, 2019) and the country is approximately 103.000 km² with much of the country uninhabited and parts of it untouched. In recent decades, there have been a significant evolution in the country's energy productions, with the country increasingly moving towards renewable energy sources. During the 20th century Iceland went from being one of Europe's poorest countries, to a country with a high standard of living (Ragnarsson, 2015). This economic progress can, at least partly, be related to the energy production transition. In that period the country went from being dependent upon peat and imported coal for its energy production to practically all stationary energy, and roughly 82% of the primary energy coming from indigenous renewable sources (62% geothermal, 20% hydropower) (National Energy Authority of Iceland, 2018a). The transition was, at least partly, a reaction by the national authorities to the oil crisis in the 1970s (Jónsson, Karlsson & Saemundsson, 2018). Today Iceland's energy use per capita is among the highest in the world and the proportion provided by renewable energy sources exceeds most other countries (Iceland Geothermal Cluster, 2015).

At a geological context Iceland is a young country located in the North Atlantic at the intersection of and the Greenland-Iceland-Faeroes ridge and the Mid-Atlantic Ridge. The Mid-Atlantic Ridge is the boundary between North American and Eurasian tectonic plates (Björnsson & Kristmannsdóttir, 2015). Due to the position geological and tectonic processes are extraordinary rapid and easily observed. Iceland is in fact one of the few places on Earth where an active ridge spreading can be seen above sea level (Iceland Geothermal, 2015). Some 20-30 volcanic eruptions occur every century on average, producing lava in the order of 45 km³ every 1000 year. Some 400 km are exposed of the Mid-Atlantic ridge which makes it possible to observe a variety of tectonic processes such as volcanism and associated features (Ragnarsson, 2015). Many volcanoes and hot springs are found in the country and earthquakes are frequent, a several dozen on average each day. Figure 2 gives an overview of the geological conditions of Iceland with focus on the geothermal resources. The volcanic zone runs from the southwest to the northeast, as highlighted on figure 2. More than 200 volcanoes are located within this zone and at least 30 of them have erupted since the country was settled over 1100 years ago. Associated with the volcanoes are numerous geothermal systems. At least 20 high temperature areas exist within the volcanic zone with temperatures reaching 200°C within 1000 m depth (The National Energy Authority of Iceland, 2019d). About 250 separate low temperature areas with temperatures not exceeding 150°C in the uppermost 1000 m are mostly in the areas flanking the active volcanic zone. Over 600 hot spring areas (temperature over 20°C) have been located (Ragnarsson, 2015). Additionally figure 2 highlights the vast potential of the country related to geothermal resources as high or low fields can be found in almost every region.

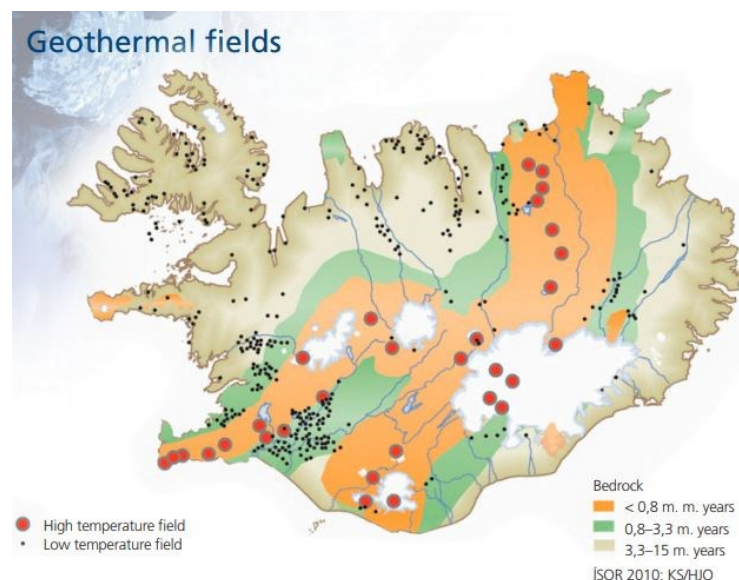


Figure 2: Overview of the geothermal fields in Iceland (National Energy Authority of Iceland, 2018b).

When observing the history of Iceland, there are many sources that demonstrate how closely it has been linked to its geothermal resources. For example, swimming pools and spas might be a modern-day invention, but relaxing and enjoying the numerous health benefits of bathing in thermal baths is an Icelandic tradition dating back to the country's settlement some 1100 years ago (Björnsson, 2005). Ancients' sources tell stories of constructions of pools which utilized local geothermal resources. Snorri Sturluson, a famous Icelandic historian, poet, and politician, is believed to have built one in Reykholt, called Snorralaug. It is estimated that it was built in 13th century (Sigurðardóttir, 2009). Interestingly, modern hot tubs, which are found at almost every swimming pool in Iceland are built in a similar manner to the one at Snorri built some hundreds of years ago. The historical design has therefore been kept throughout the centuries and is today a common thing among Icelanders.

The purpose of hot springs and pools today are mostly for bathing and well-being but that has not always been the case. In the early days of Reykjavik (and elsewhere in Iceland) the pools and springs played a vital role in the everyday life of Icelanders. Throughout the decades they served a crucial role regarding hygiene, especially for laundry purposes. People from the local neighborhood, mostly women at that time, would gather to take care of the family's laundry. The one located in Laugardalur, a central part of the capital area today, was used by the population in Reykjavik from the early days of the city until early 20th century (National Power Company of Iceland, 2012). The remains of the pool are now presented in Laugardalur, a popular recreational area among both local and tourists. Close by is one of the most visited swimming pools in Iceland, Laugardalslaug, which utilizes the geothermal resources in the area. On figure 3 (on right), the remains of the pool today can be observed.



Figure 3: *Left:* Women doing laundry in Laugardalur (Árbæjarsafn, unknown photographer). *Right:* Remains of the pool used for laundry in Laugardalur central Reykjavík (Haflíðadóttir, 2014).

1.2 Utilization of geothermal resources in Iceland

Throughout the history Iceland has used various ways to harness and benefit from the geothermal fields that the country is so rich of. One of the most common and known way is energy production. Iceland is one of the countries which produces most energy from geothermal sources (Think GeoEnergy, 2018). Additionally, there is a prolong tradition of heating homes with geothermal resources, steams and hot water from geysers have been used to heat homes ever since 1930 (Þórðarson & Jónasson, 2007). Other countries have been utilizing geothermal resources for energy production (including Italy, New Zealand and the United States), but it is not commonly used for house heating internationally, although it has been gaining momentum in the resent years. Figure 4 displays the utilization of geothermal energy in Iceland in 2017 (The National Energy Authority, 2018).

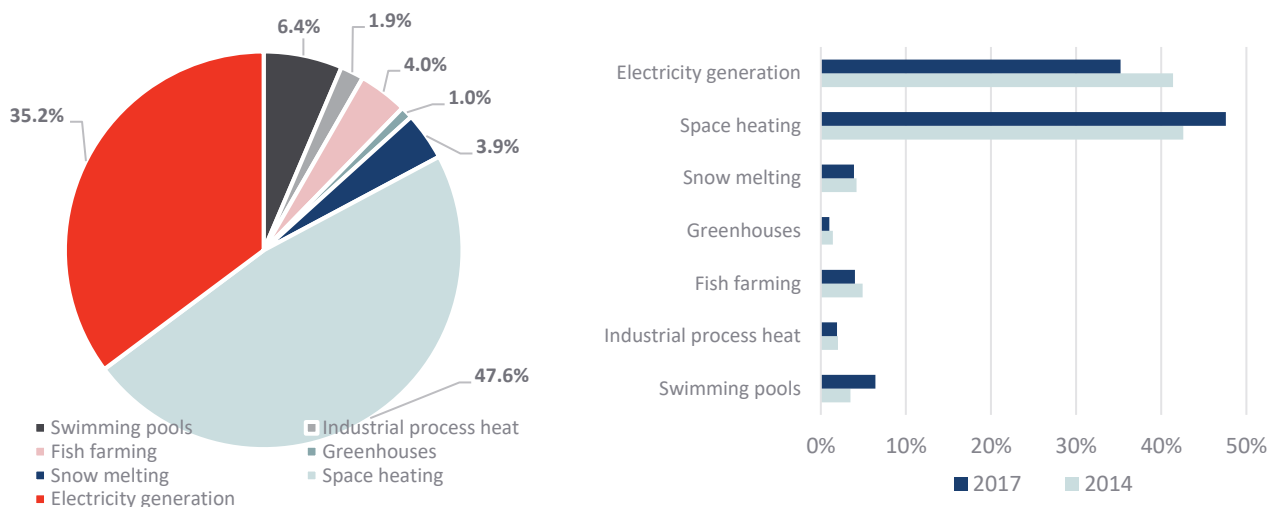


Figure 4: *Left:* Utilization of geothermal energy in Iceland 2017 (The National Energy Authority of Iceland, 2018c). *Right:* Comparison of the utilization of geothermal energy in Iceland in 2014 and 2017 (The National Energy Authority of Iceland, 2015 & 2018c).

As displayed in figure 4 most of the geothermal energy is used for electricity generation and space heating, the two combined correspond to nearly 83% of the utilization (Ragnarsson, Steingrímsson & Thorhallsson, 2018). Other categories include snow melting, a practical utilization in a country like Iceland where it snows regularly and for swimming pools which are popular among the local as well as tourists across the country.

Fish farming has been a growing industry in Iceland and geothermal areas have been played a key role in the development. In 2014 around 4% of geothermal energy was used by the fish farming industry. Hydrothermal water can be used in fish farming of most type of fish when they are growing as well as on coastal fish farming of salmon and similar types of fish. With the use of geothermal water, it is possible to speed up the development of the fish and increase the production. The importance and improvement of geothermal water in fish farming depends on the types of fish (National Energy Authority of Iceland, 2019a). Utilization of geothermal resources for fish farming is not unique for Iceland but it is one of the leading counties in the industry along e.g. China, Italy and US (Ragnarsson, 2014).

Greenhouses use only a 1% of the geothermal energy in Iceland. However, it has has a long history in Iceland, as it began in 1924. Weather conditions in Iceland can be unfavorable for growing food related plants outside and greenhouses play vital part minimizing the need for transportation of products. The greenhouses usually consist of controlled indoor climate, which makes it suitable to grow different kinds of crops (National Energy Authority of Iceland, 2019b).

Geothermal energy has been used for various industrial processes throughout the last decades and it counted for approximately 2% of the utilization of geothermal energy in 2017. One of the most known is the drying of fish, an Icelandic tradition. The indoor drying is practical when weather can be unexpected and unfavorable for drying fish outdoors. Other examples of industrial processes which rely on geothermal resources are seaweed manufacturer, salt production etc. (National Energy Authority of Iceland, 2019c). Further discussion of specific industrial processes which utilize geothermal resources will be discussed in section 3.4.3.

The National Energy Authority has published a forecast for geothermal utilization in Iceland. The latest one was published in 2003 and includes a forecast of the utilization over the period from the year 2003 to 2030 (Orkuspánefnd, 2003). There is an on-going work at the National Energy Authority as well as other institutions to update the forecast. It will be interesting to highlight the changes in the use of geothermal resources in Iceland as well as seeing if there are any footprints of the tourist industry once a new forecast will be published.

Most part of the utilization of geothermal energy is for everyday purpose and only small part of it can directly be related to the tourism industry. The tourism industry benefits from the current energy infrastructures in a similar way that any industry or operation does. As will be discussed later, there are numerous and, in some cases, not obvious ways to combine the everyday utilization of geothermal resources and tourism.

1.3 Tourism development in Iceland

The tourism growth in Iceland in recent years has been extensive, so extensive that few other countries have experienced as rapid growth as Iceland has experienced. The growth in number of tourists annually (columns) and daily (line) can be seen in figure 5. From 2014-2018, the increase has been rather consistent as well as the distribution of the tourists throughout the year. To emphasize the intensive growth, the number of tourists annually have more than doubled from 2014 to 2018 (Icelandic Tourist Board, 2019). The difference between visitor numbers by seasons is still obvious, but the tourism sector and the country as a destination has gradually been transitioning from being a seasonal tourist destination to being all around the year destination. As the number of visitors have been increasing over every month of the year, the differences between seasons are still present. To be able to operate throughout the year is important. Authorities have in recent years funded cooperative projects to encourage distribution of tourists across the country as well as throughout the year, e.g. a project called “Iceland the whole year” (Atvinnu- og nýsköpunarráðherra, 2012-2013). For a country with approximately 357.000 inhabitants, welcoming over 2.5 million visitors annually can both take its toll on existing infrastructure as well as greatly impact the country’s economy.

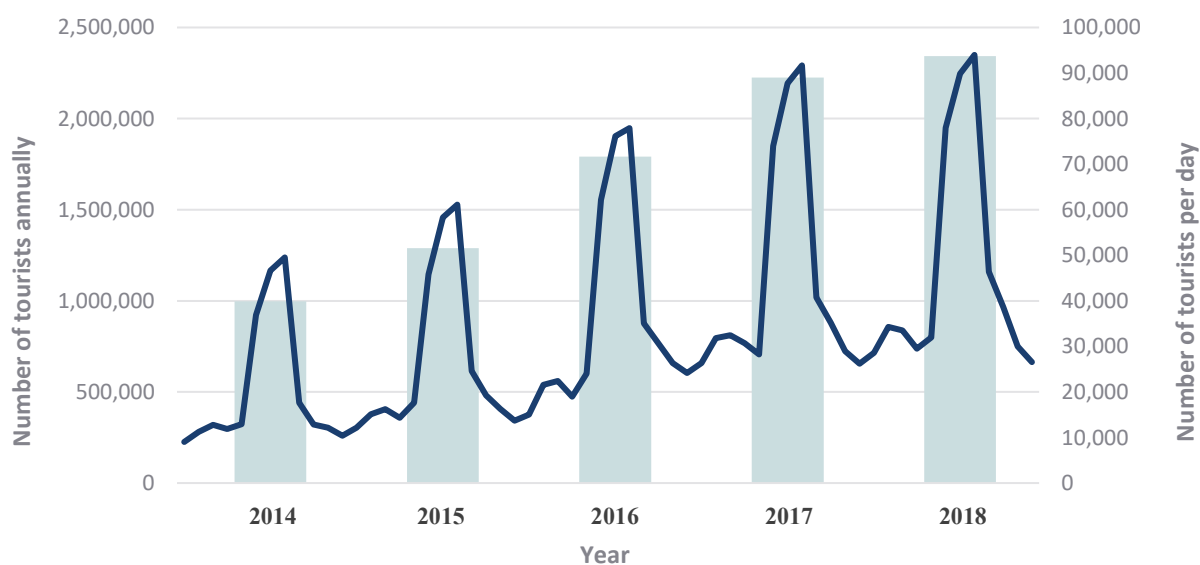


Figure 5: The development of tourists both annually (columns and left y-axis) and daily from 2017 to 2018 (line and right y-axis).

The tourism explosion in Iceland occurred at a favorable time for the country’s economy. With the financial crisis in 2008 the injection of tourism with their expenditure were one of the main components to recovery from the crisis. If not for the tourism explosion, the crisis and its impacts could have been much worse and prolonged (Greiningardeild Arion banka, 2018). Since then the tourism sector has been increasing its value and importance for the economy of the country. Now it is now recognized as one of the foundations of the economy, along with more traditional industries such as the fishery.

Tourism’s share of foreign exchange earnings in Iceland has grown from 26.4% to 42.0% between 2013-2017 according to measurements on the export of goods and services (Icelandic Tourism Board, 2017), the development presented on figure 6. Since 2013, the number of employees in tourism-related sectors has increased yearly by more than 68%. The total number of people employed in tourism-related sectors was 24.500 in January 2017, or the month the fewest were employed, and 31.700 in August 2017, when the most were employed. Due to this rapid development of the industry and the potential of the tourism sector the focus on the industry has evolved significantly.

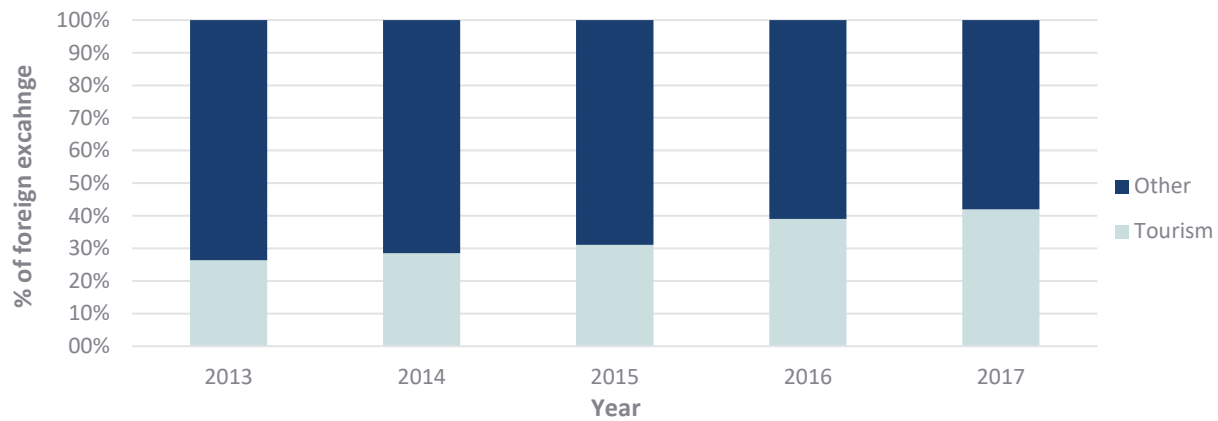


Figure 6: The share of foreign exchange earning in Iceland. Tourism earnings categorized separately.

Iceland has a lot to offer as a tourist destination, the opportunities are widely available and not in all cases self-evident. For example, the tourist interest in renewable energy occurred rather unexpectedly. Harnessing renewable energy is a current and universal topic related to the increased awareness of global warming. Iceland is and has for some time been well-known for its reliability on renewable energy sources, both hydro and geothermal. As the country has developed and improved infrastructure to support renewable energy sources, gradually, the numerous opportunities regarding renewable energy and tourism have become more evident. Not that all tourism activity related to renewable energy has come as a surprise, as the tourist sector has throughout the years proposed a strategic thinking into the potential opportunities. Iceland has a unique nature and it attracts most of the tourists to the country. So, the nature sites have been one of the focus points on developing an attractive tourists' destinations. Building up infrastructure and service related to the nature sites is therefore a clear way to service and support the increasing number of tourists. But as the sector is evolving there have been emerging more and more opportunities in a broader context. It has resulted in e.g. related jobs and export of goods which have risen parallel to the more obvious opportunities.

To evaluate the attractiveness of Iceland for tourists it is relevant to observe the data that the Icelandic Tourism Board gathers. Every year the Icelandic Tourist Board releases a status report of tourism in Iceland which analyses a survey result to observe and understand the behavior of tourists. Latest report indicates that in the winter, as in the summer, tourists were particularly interested in activities related to nature, health and well-being. Swimming was the activity that most tourists paid for during their stay, both in the summers as well as winters. When evaluation what kind of activity and experiences attract foreign tourists to a trip to Iceland, the nature is a dominate factor. In the summer of 2016, 83% tourists said that "Icelandic nature" was the factor that had major impact on their decision to visit Iceland and 12,7% stated mentioned spa and wellness. Both factors are closely related to the geothermal opportunities found in Iceland. Most of the visits that summer, a little more than 90%, were for vacation or holiday purpose (Icelandic Tourist Board, 2017).

2. TOURISM AND GEOTHERMAL RESOURCES

2.1 Types of tourism

Regarding the tourism growth and tourism behavior in Iceland, it is clear that a large proportion of tourists are looking for the nature experience that the country offers, e.g. geothermal experience, wilderness etc. There are a few branches of tourists which are closely related to geothermal activities and experience, the most obvious one is the so-called geothermal tourism. There is not a single accepted definition of the term, but it is thought to be closely related to volcano tourism, though it does not need magma to occur and can be distant from volcano centers, which makes it different from the volcano tourism (Climo, Blair, Stott, Mroczek & Addison, 2017). Therefore, geothermal and volcano tourism is often interchangeable. Geothermal tourism can additionally include activities which are related to heated water rising to the surface (also known as hydrothermal tourism). Geothermal tourism is often related to hot springs and natural environments. Internationally hot springs is closely related to health and wellness tourism, as it is thought to have beneficial impacts on the health. Health and wellness tourism (often also including the term spa) has been increasing steadily over the last years with the emerging focus of health and wellness globally (Erfurt-Cooper, 2010). Given the beneficial health impacts of hot springs and their chemical compositions, medical tourism is another category which can be related to hot springs. Other branch of tourism which are often related to geothermal tourism are hydrothermal tourism, which utilize the hot water and eco-tourism which includes wildlife, nature and outdoor adventures as well as nature-based tourism as well as adventure tourism. Iceland has focused on the nature attraction of the country, which undoubtedly is one of the driving factors of tourism. But there could be some unexplored opportunities to develop Iceland as a wellness destination, at least on the entrepreneurial level.

As mentioned there are many aspects of geothermal tourism and activities which can be optimized in country so rich in geothermal areas, such as Iceland. In that case, it is interesting to look at other countries and how they have been developing the tourism industry around geothermal activities and experiences. Hot springs and geothermal resources are known to add value to destination as well as being the fundamental part of purpose of the destination or trip. The geothermal resources found in Iceland are not unique, but the utilization of the resources is in some cases special compared to other countries which are also rich in geothermal resources.

Most of the development with geothermal utilization throughout the years has not solely being focused on tourism, with among other, the exceptions of the development of natural pools and similar pool areas. Though, as has been described before, geothermal activity is rich in the history of Iceland for as long as people inhabited the country its role as a vital part of the tourism industry is quite recent

and, has in some cases been unexpected. There are various location and activities in tourism which can be, at least at a certain degree, be related to geothermal conditions of the country, as has been discussed.

Being introduced to the various branches of tourism that can utilize geothermal and hydrothermal areas as well as the main categories of where such operation thrives, it is interesting to look numbers regarding the development in recent years. Guest numbers, number of employments related to the industry, the financial aspect etc. can be good indicators regarding the development of tourism related to geothermal resources.

2.2 Projects related to geothermal resources and tourism

In recent years the authority in Iceland, both at a national and regional level have been focusing on seizing and mapping the opportunities of the geothermal areas. This strategic optimization of the geothermal areas has been crucial in identifying and highlighting future development towards utilization. One of these projects is Eimur, which is a public-private partnership/cluster in the field of energy, increased utilization of geothermal resources and innovation in Northeast Iceland. Eimur runs sustainability innovation and design workshop as well as summer school which focus on the optimization of geothermal resources, and often with references to tourism. One of Eimur's main goals is to strengthen the region's ability to take on challenges when it comes to interaction of energy, environment and society with sustainability and value creation (Eimur, 2019a). Eimur held (in cooperation with other companies) an idea challenge on ways to utilize the low to medium enthalpy resources in Vaðlaheiði which were discovered while tunnels through the heath were being constructed (Eimur, 2019b). The winning idea consisted of so-called Black Caves a geothermal bath caves constructed into the rock opposite to Akureyri, the largest town in the northern part of Iceland (RÚV, 2019).

Another project is the Iceland Geothermal Cluster initiative which is a non-profit organization which was established in 2013 with over 50 members that together manage the geothermal resources in Iceland. The main role of the initiative is, as stated on their website, to promote Iceland *"as the land of geothermal energy and geothermal utilization"* (Iceland Geothermal Cluster, 2019). Their work has been focused and closely related to knowledge, communication and innovation and they have e.g. collaborated with the Startup Energy Reykjavik in the year 2013, a business accelerator program. They have also cooperated with the Iceland Tourism Cluster to highlight the opportunities in combining tourism and energy, the cooperation has resulted in conferences and workshops regarding the topic (Iceland Tourism Cluster, 2019).

3. ATTRACTIONS AND EXPERIENCES

Different branches of tourist activities and experiences as well as exports of goods which can be related to geothermal resources are divided and discussed in the following section. The categories are intended to divide the current sites and operations in categories which cover the field of geothermal related tourism in Iceland. These categories are: Geothermal sites, geothermal power plants and exhibitions, natural pools and swimming pools and other utilizations, which includes, greenhouse farming, fish farming and productions of goods.

3.1 Geothermal sites

There are various nature sites in Iceland which offer the direct experience of geothermal fields and can therefore be categorized as geothermal sites. The most common layout are the geothermal parks, which are open areas with minimum infrastructures such as trails, fences and signs to increase safety and manage the traffic at these areas. Such parks can be found across the country, e.g. in the Namaskard Pass in the northern part of the country, Hveravellir Nature Reserve in the central Iceland and Seltún Geothermal Area on Reykjanes Peninsula in the southwestern part of the country (Bjornsson & Kristmannsdottir, 2015). These sites, unlike the ones that are discussed in chapter 2.3 do not offer any kind of swimming or pooling experience and are therefore not directly related to health, well-being and spa tourism. Iceland has two geoparks which are part of the UNESCO Global Geopark program, the Reykjanes Global Geopark and the Katla Global Geopark (UNESCO, 2019a). The aim is to highlight the importance of uniqueness of these areas as well as *"give local people a sense of pride in their region and strengthen their identification within the area"* (UNESCO, 2019b). There can be various types of geothermal sites e.g. aquatic entertainment parks which utilize geothermal resources are found in Slovakia, Uruguay, Poland and Rumania. An interesting way to attract tourists and utilizing geothermal resources.

Popular among geothermal sites are the geysers which is one of the main sightseeing experiences in Iceland. The most famous one is Geysir which is a part of the golden circle tour which receives enormous number of tourists every year. It is located in the southern part of the country, fairly closely to the capital area and the most popular tourist region of the country. The Golden Circle consists of Thingvellir National Park, the Geysir Geothermal Area and Gullfoss waterfall. Only Reykjavík and the Blue Lagoon, another destination which is based on geothermal resources, can compete with the popularity of the Golden Circle when it comes to visitor numbers.

The number of visitors at nature sites has been identical to the overall tourism growth in Iceland. As expected, when most of the visitors come here to experience the nature of the country. At Geysir the number of visitors in the year 2016 was roughly 1.200.000. The increase of visitors during the wintertime is also remarkable and composes a different challenge regarding management. It is located at an area where a large proportion of tourists visit and one of the areas which have been under the most pressure by number of tourists in recent years.

3.2 Geothermal power plants and exhibitions

The importance of geothermal power plants as a renewable energy source is well known, and Iceland has throughout the last decades been increasing the proportion of energy generated by geothermal resources. In recent years Iceland has been developing a way to welcome tourists as well as locals to visit these power plants and learn about the operation and the nature of this valuable resource. The geothermal exhibition that Hellisheiði power plant geothermal offers is an example of a well-established way to attract tourism as well as supporting the educational responsibility that follows the operation (ON Power, 2019). And the development of the destination has been a great success and has been noticed on an international basis. There is an opportunity establishing guided tours as well as exhibitions based on such industry. It does not only highlight the way geothermal sources are used for electricity productions

and its role in making a renewable energy sources larger but also gives an opportunity to increase the education and information regarding the technique and method. By doing so, it is possible to support the society by spreading out knowledge and the at the same time environmental issues and the responsibilities of Iceland on an international level. The former president of Iceland mentioned this as a unexcepted success of the tourism growth at a Sustainable Innovation Forum in Paris in the year 2016 (Ólafur Ragnar Grímsson, 2015). It emphasizes the opportunity related to the renewable energy development in Iceland and in a broader context. Exhibitions operated parallel to geothermal power plants become an unexpected success regarding tourism, both with the domestic and the international. The one that attract most visitors is the Hellisheiðavirkjun which is located only about 30 minutes outside of Reykjavik. The power plant has also a vital education role for the youth of the country and do most of schools go to an organized trip to the power plant. Hellisheiðavirkjun is not the only power plant in Iceland which offers an exhibition parallel to its operation, e.g. as does Krafla in the northern part of the country, where Landsvirkjun the National Power company offers exhibition without charging entrance fee. Landsvirkjun also operates a visitor center related to other renewable energy sources such as hydropower and wind energy in their visitor centers located at Ljósafoss hydropower plant and they provide guided tours during the summer at the Kárahnjúkar dam in the eastern part of the country.

How geothermal power plants can be utilized as a tourist attraction has brought attention internationally. In a 2017 article regarding how New Zealand can utilize the rich geothermal resources they have, Iceland is used an example. The way Iceland has optimized the geothermal power plants to attract tourists by making them open to public (usually with an entrance fee) through exhibition is mentioned as a way New Zealand could use their current infrastructure to attract tourists (Climo, Blair, Stott, Mroczek & Addison, 2017).

The exhibitions are not solely related to the geothermal power plants themselves as more traditional museums and shows have been opened in recent years. One of the most ambitious is the Lava Centre which is an interactive, high-tech exhibition in Hvalsöllum in the southern part of Iceland (Lava Centre, 2019). The geothermal resources are a part of the experience in the museum and exhibition “Perlan – Wonders of Iceland” located in central Reykjavik. The museum offers an informative perspective on the nature of Iceland across the country (Perlan, 2019).

3.3 Natural and swimming pools

One of the most known ways that the tourist industry has been working with the geothermal conditions in Iceland are the bathing and swimming pools. While analyzing the development and potential of geothermal heat regarding bathing and swimming it is necessary to make a difference between those who are focused as natural pools and the traditional swimming pools. There is a fundamental difference in both the experience and the marketing of modern public swimming pools which can be found everywhere in the country and have been gaining more popularity, especially by tourists in recent years and the natural pools, which are in most cases based on hydrothermal conditions. Therefore, are these two things separated in the discussion, though in some cases the boundaries between them are not obvious. E.g. some swimming pools are developed for leisure and spa rather than traditional swimming activities such as school swimming lessons, family water park and competitive training.

Bathing and swimming which are closely related to health and well-being tourism is without doubt the best-known way to attract tourists to places which use the conditions of geothermal sites. The Blue Lagoon is the place that most tourists visit and one of the main sites when it comes to commercialize Iceland tourism industry. In recent years there have been an emphasize on developing similar experiences around the country as well as the natural geothermal pools keep getting more popular among tourists. The success of geothermal springs such as The Blue Lagoon and the Mývatn Nature Baths have resulted in noticeable increase in such sites across the country. Figure 7 displays this evolution in opening of geothermal spas in the recent years. Additionally, EFLA has been involved in the preparation and design of 8 other geothermal spa developments in Iceland planned to open in the coming years, among those are a geothermal lagoon project in Kársnes, near Reykjavik and Highland Baths in Þjórsárdalur.

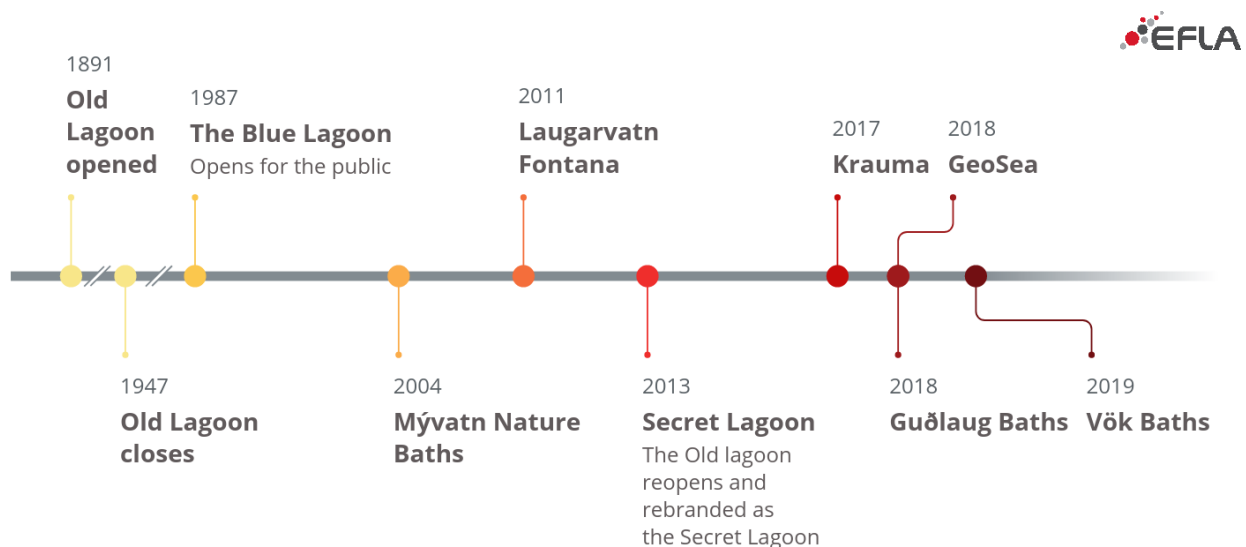


Figure 7: Development of Geothermal Spas in Iceland (EFLA, 2019).

Nauthólsvík is a geothermal beach located in Reykjavik, which opened in 2001, and gives a different geothermal experience compared to the geothermal spas and swimming pools. Nauthólsvík offers a lagoon with large sea walls, where cold sea and hot geothermal

water fuse together resulting in more convenient water/sea temperature. When the weather is good, people gather at the beach to sunbathe and recreating purpose in and out of the sea. Throughout the year, including the winter time the area is popular among sea swimming enthusiasts, which use the facilities offered at the site, including changing rooms, sauna and hot tubes as well as swimming in the cold sea, even in the freezing temperature during the winter months (City of Reykjavik, 2019).

3.3.1 Swimming pools

There is a rich history of bathing in Iceland and the hot springs were mainly used for bathing purpose. Since early in the last century outdoor swimming pools as we know them today have been gaining popularity and they are today a part of the daily life of a large part of the nation. There are about 165 recreational swimming centers in the country, 140 of which use geothermal heat to keep the water temperature at 28-30°C year-round (Ragnarsson, 2015). It is interesting that 25 pools are operated without the utilization of geothermal heat, as it generally much more expensive to operate. The main reason for a limited number of pools heated with other means than geothermal is the associated cost of energy is much higher than the cost of a traditional geothermal pool. The combined surface area of the geothermally heated pools is about 34.000 m² (Ragnarsson, 2015). Most of the swimming pools are open to the public throughout the year. They serve for recreational purposes and are also used for swimming lessons, which are compulsory for ages 6-16 in schools. In the greater Reykjavík area alone, there are seventeen public pools, most of them outdoor pools (Sundlaugar.is, 2019). The largest of these is Laugardalslaug. These swimming pools have always been popular among tourists and the rapid growth tourism has led to a increase in visitor numbers in these swimming pools. And, at no wonder, because tourists are generally curious about the way of life by locals and visiting the swimming pools is an excellent opportunity to experience such a thing.

In the year 2010, over 2 million visitors visited the swimming pools in Reykjavík, with Laugardalslaug, located near the old laundry pools, being by far the most popular with approximately 800.000 visitors (Viðskiptablaðið, 2011). From April 2018 to April 2019 the total number of visitors in the pools in Reykjavik were around 2,3 million, (Reykjavíkuborg, 2019).

3.3.2 Geothermal and hot springs

Geothermal and hot springs are one of the main attractions for tourists in Iceland. The increasing consumer focus in health and wellness has been “back to nature” and wholesome lifestyle. As part of the popularity, geothermal pools have become increasingly popular. It goes also with the trend towards natural looking environment and these two factors together are well-known in Iceland.

The largest one being the Blue Lagoon. In recent years the site has experiences a rapid growth and the facilities have been developing in context to the increased popularity. The Blue Lagoon has an 8.000 m² surface pond that receives effluent brine from the Svartsengi power plant. When the operation of the power plant began in 1977 the effluent water was discharged into the surrounding lava field, which was thought to absorb the water due to its high permeability. However, with time scaling from the geothermal water clogged the lava and a pond started to form. People began to bath in the pond and psoriasis patients discovered that the water had a beneficial effect on their skin. Later, facilities were added to the operation and in 1999 a man-made lagoon with a temperature of 37- 39°C was created along with improved facilities for visitors (Ragnarsson, 2015). In addition to the bathing facilities there are other important activities of the Blue Lagoon company as well as a hotel resort was opened next to the lagoon in 2018. They have also put an emphasize on treating psoriasis patients that takes advantage of the chemical composition of the water.

The number of Blue Lagoon visitors has increased rapidly during the past years and reached 1.250.000 in 2018 (Bláa Lónið hf., 2019), making it one of Iceland’s most popular tourist attractions. The increased visitor numbers in recent years have been remarkable, as the number of guests in 2015 were approximately 920.000 and the year before the numbers reached 700.000 (Bláa Lónið hf., 2016). The newly introduced advanced booking system for the operation gives the company a tool to manage the number of guests and their distributions throughout the day as well as over longer period. The booking management system prevents a seemingly never-ending increase of visitors as fixed number of slots are available during the day, and in many cases, they sell out well in advance. Therefore, it is expected that the increase in visitors will slow down in the following years as they reach maximum capacity with their current lagoon size. The system will result in better management of flow of the guests in the lagoon and other facilities as well as emphasizing increasing the quality of the experience of each guest.

The development at Mývatn Nature Baths has been similar to the one in the Blue Lagoon, though located at entirely different region of the country. It was opened in the year 2004 as a response to the lack of infrastructure at the site, which was already being used for bathing in pools found there. The site has become one of the main tourist attractions in the region and vital in helping distributing tourists across the country. In 2008 the site was expanded and the number of annual visitor that year were around 65.000. In the year 2015 number of visitors were around 150.000, year later 202.000 and in the year of 2018, 210.000. So, over the last 10 years there has been an increase of 323%.



Figure 8: Vök Baths, which opened in July 2019 in East Iceland.

3.4 Other utilizations

3.4.1 Greenhouse heating and vegetation

In the year 2008, the total area of greenhouses which were heated with geothermal energy was 192.000 m². Geothermal heat has been used to heat up greenhouses for growing purpose since 1924 in Iceland, even though some not so successful attempts had been made earlier (National Energy Authority of Iceland, 2019b).

An example of an, at least partly, unexpected popularity and success is Friðheimar, a family-run geothermally heated greenhouse. The operation has evolved from mainly growing tomatoes in 2010 to be a popular destination for tourists interested in sustainable food production. The site now offers a guided tour through the production, a restaurant with tomato base cuisine and small shop as well as operating horse breeding and shows. The restaurant is only open for four hours each day, but its popularity has grown rapidly in the last years and it is necessary to reserve a table in advance during high-seasons. The production is based on a greenhouse which uses geothermal heat to run the operation. The farm has abundant supplies of geothermal water, which provides heat to the greenhouses. The borehole is 200 m from the greenhouses and the water flows into them at about 95°C (Friðheimar, 2019). Friðheimar is the leading example of how to optimize the use of greenhouses to grow vegetables but at the same time to attract visitors. For funding, the owners needed to make plan regarding the development and in 2011 they expected 25.000 guests annually by 2016. The numbers for 2016 went way beyond their expectations, with 135.000 visits (Viðskiptablaðið, 2019).

Close to Friðheimar is a small community called Flúðir which offers a different kind of activity and experience related to geothermal areas. There the Secret Lagoon is a popular destination among locals and tourists, a natural hot spring, which has gained increased popularity in recent years. The community is also home to Flúða sveppir, a mushroom farm supplying the entire white mushroom consumption in Iceland. They are a fantastic example of the circular economy where nothing goes to waste as the farmers grow their own corn and straws specially to produce their own soil to grow the mushrooms in. Once the mushrooms have grown to a desirable size they are picked, and the remaining soil is steamed using geothermal heat to kill mushroom spores. It is then mixed with Icelandic peat and Hekla pumice to make excellent potting soil sold to the public (Farmers Bistro, 2019).

3.4.2 Fish farming

Fish farming has and is an expanding industry in Iceland and counted for around 5% of the geothermal energy utilization in Iceland in 2014 (section 1.3, figure 4). Fish farming has, at least until now, not been considered a tourist attraction. Iceland is not the only country where an increase in fish farming and tourism occurs. The interaction between these two industries have been discussed in e.g. Scotland and Chile (Outeiro, Villasante & Ovarzo, 2018). There are possible negative impacts of fish farming, which can affect attractiveness of tourists. However, at the same time, there are also possible opportunities which can be expanded. Fish farming is quite new industry in Iceland and therefor can be assumed that it will take some time to find the best way to combine the industry with tourism. When observing the development throughout the years regarding the interaction between geothermal resources and tourism it indicates that there could be some unused opportunities in combining these two operations, i.e. fish farming and tourism (Nimmo, Cappell, Huntington & Grant, 2011). The location of fish farms in Iceland can be seen in figure 9.



Figure 9: Map of fish farms in Iceland (EFLA, 2019).

3.4.3 Manufacture of goods

There are numerous opportunities with the geothermal heat and energy when it comes to production of goods. These goods are often targeted as part of the tourists' experience, where the nature and the geothermal conditions are the focus point. They are often related to certain sites or experience, such as the many goods that the Blue Lagoon produce and sell, and it is marketed related to their operation. Other operations use the benefits of geothermal areas for practical reasons, such as drying fish indoors and produce the popular Icelandic "*harðfisk*" as well as the famous "*geothermal bread*", a typical Icelandic rye bread steamed for up to 24 hours in a hot spring or warm ground near geothermal sites. Generally, natural products related to e.g. hot springs are used for a wide range of purpose in the cosmetic industry (Erfurt-Cooper, 2010).



Figure 10: Left: Product from Saltverk. Right: The production of salt at Saltverk.

Production of salt by geothermal in Iceland dates back to the 18th century, when the Danish King established a salt production in Reykjanes Western-Iceland. The production was an innovative twist in the Northern European salt making method where lumber was used to dry the salt. The site at Reykjanes is enriched with active natural geysers and the salt production used them as a source of energy for the salt production. In 2011, Saltverk was founded, building on that history and reestablished salt making in Iceland. They now produce sustainable, hand harvested quality salt with 100% geothermal energy, and since geothermal energy is the only energy source the whole process leaves zero carbon footprint on the environment (Saltverk, 2019). Their product and productions can be seen in figure 10.

GeoSilica was founded in 2012 and is inspired by the nature of Iceland. The first product was released two years later, a liquid silica supplement made from 100% natural silica. The company has developed a two-step production process. In the first step, the silica concentration in the separated geothermal water is increased tenfold without changing the chemical composition of the water. In the second step, the geothermal water is gradually replaced by clean ground water from the area while keeping the silica concentration constant. The end product is highly pure silica in the form of extremely small silica particles in clean ground water. Absolutely no

chemicals of any kind are used in the production. As of now, GeoSilica has already started developing a new product to increase its product range (GeoSilica, 2019).

The byproducts of the Blue Lagoon are great example of the numerous opportunities that comes with a successful tourist attraction. Due to its impact on treating psoriasis, it has utilized the resource to develop a product. The Blue Lagoon consists of the Blue Lagoon Bath, Blue Lagoon Clinic and the Blue Lagoon Skin Care as well as carrying out research and development. Additionally, it operates a spa in central Reykjavik, called Blue Lagoon City Spa and shops in Keflavik and Reykjavik. The Blue Lagoon skin care products are established products and they have developed a mineral salt and silica production. A recent example of production that is referenced to the Blue Lagoon is the jewelry line One by Raus Reykjavík, which is inspired by the Blue Lagoon and its natural environment (Raus Reykjavík, 2019). In section 4.1 is a further discussion regarding the value of the Blue Lagoon.

4. GEOTHERMAL TOURISM AND SUSTAINABILITY

With increasing number of tourists in Iceland, there has been a rich discussion and analyze regarding the impacts they can have in a wider context. There is an ongoing work with the authorities and tourism sector to evaluate the thresholds that the country can sustain, regarding tourism (Stjórnstöð ferðamála & EFLA, 2018). The project is focused on the big picture, such as infrastructure, experience of tourists and residents, environment etc. One indicator analyzed for natural sites includes many of the sites that combine geothermal activity and tourism. It is interesting and necessary to define a measurable indicator which can be used to assess and track the condition these sites, to evaluate at any given time if they are threatened by the number of tourists. The project is in fact the only one yet that evaluates the impact and potential of tourism at a national level. It is therefore a work which suits well in future planning and strategy for the country regarding the tourism sector. In that case, it is interesting and necessary to evaluate the impacts of geothermal tourism on the three dimension that define sustainability; economic, society and environment. The impacts on some of these, e.g. economic and society are obvious but to meet the goals of sustainable tourism it must fulfill all of them.

The positive impacts of tourism related to the geothermal and hydrothermal tourism in Iceland are at some degree expected. Even though, as discussed earlier, the magnitude, success and the broad variety of opportunities related to tourism has been in some senses unexpected. The authorities in Iceland have been aware of the potential impacts on the environment that has and can follow the rapid increase in number of tourists. Sustainability of the geothermal optimization itself has been discussed over the years, i.e. how much energy production can be obtained from geothermal areas, so the resources will be maintained (National Energy Authority of Iceland, 2019e). The focus in this article is on the tourism and how it can optimize geothermal areas, such as the nature sites etc. and maintain sustainability.



Figure 11: The Blue Lagoon and Svartsengi power plant can be seen in the back.

The distribution of tourists in Iceland both in time and space is important. The sector has been developing into an all year around operation as increasing number of tourists visit the country in all seasons. Distribution across the country is important as well, when dealing with rapid increase of tourist it is helpful to distribute them as much as possible across the country. Spatial distribution has been an on-going discussion parallel to the tourism growth and as the number indicates, for a good reason (Ólafsson & Þórhallsdóttir, 2018). Number of tourists in 2016 show that the difference by regions is significant. In the summer of 2016, 93,7% stayed in Reykjavik and surrounding area while 47,6% visited the north and 19,1% the Westfjords. The numbers for the winter of 2016 are more even drastic when 94,7% visited Reykjavik and the surroundings while 15,4% the north and 5,7% the Westfjords. The region which is closest in visitor numbers to Reykjavik and the surroundings is the south (Icelandic Tourist Board, 2017). When the geothermal opportunities are observed, e.g. on figure 2, it is clear that they can be vital in altering the distribution across the country. The development of tourism related activities and experiences related to the geothermal sites can also be crucial in making a more diverse base for running tourism services across the country. The increased tourism and development of destination such as geothermal pools and spas can now give small municipalities and community's a more variety in jobs and derived jobs around these

destinations, e.g. in the year 2018 the Blue Lagoon had 874 employees (Bláa Lónið hf., 2019) while the adjacent geothermal power plant operated by HS Orka (Svartsengi) employed 63 in the year 2018.

4.1 Economic

The positive impacts of the tourism growth on the economy of the country is undeniable and has already been discussed. The role of tourism related to geothermal energy in the overall economic benefits is not obvious, at least not numerically, but it is safe to say that it is one of the thriving factors of the industry. Therefore, it plays a vital role in the one of the largest industries of the Icelandic economy. The employment related to tourism is significant to the country and has been increasing in context to the tourism growth.

HS Orka owned 30% of the Blue Lagoon until a group of Icelandic pension funds bought the share in 2019. The share was sold for a total of 15 billion ISK, which values the Blue Lagoon at roughly 50 billion ISK (roughly \$400 million). The international investment company Blackstone had offered 13.1 billion ISK for the 30% share in 2017 but the offer was rejected (Kjarninn, 2019). The great value created in the Blue Lagoon shows clearly how the development of the geothermal resources can bring to the owners, locals and others. The value of the Blue Lagoon is, as is previously mentioned, far beyond the spa itself and is also in related products and experiences.

4.2 Society

Increased tourism can have positive impacts on communities, such as employment availability. Therefore, it is important to distribute the numbers across the country. Some of the smaller rural communities in Iceland have declined over the past decade and in an attempt to attract people to the communities, they have been looking at establishing diverse businesses. Tourism is an ideal sector to strengthen these communities and distribute the pressure of increasing tourist numbers in Iceland. With tourism follows an opportunity for further development, of e.g. infrastructure which can boost societies and make them more attractive both for the local as well as tourism development. Well established tourist destinations such as The Blue Lagoon and Friðheimar have been and are constructing residential buildings for their staff, located close to their operation, to increase the security of available and affordable housing. They are located outside of the capital area and have strengthened the communities close to their operation.

There is an educational opportunity with the increasing infrastructure and focus on nature sites and operations related to the geothermal areas and geothermal utilization. Educational emphasis can be found in other countries which are rich of geothermal areas, such as the US. Yellowstone National Park has the world greatest output of geothermal water and the parks authority have focused on the educational value of the park. They offer various ways to inform guests and interested parties about the geothermal area, such as online programs and having rangers on the site. Furthermore, they offer an insight into the science of the park through junior rangers and young scientist programs (Climo, Blair, Stott, Mroczek & Addison, 2017). With increased education and knowledge among the locals, such as through the school system, comes valuable knowledge which can generate wealth as well as having positive impacts on the local society.

It is necessary to mention that there is a certain danger included in utilizing geothermal resources and combining tourism and such conditions. Various hazards which must be considered when dealing with such tourism destinations and tourists. For example, potential gases and high temperatures soils and fluids must be considered. Therefore, an emphasis should be put on risk management and hazard mapping when combining tourism with geothermal resources (Erfurt-Cooper, 2010).

Furthermore, the number of tourists and the strain on infrastructure that comes with them can have negative impacts on the society. Attitude of the locals towards tourists can cross certain threshold as well as too many tourists can have negative impact on each other and reduce the quality of the experience.

4.3 Environment

With increasing number of visitors at many of the geothermal sites comes an increasing load on the infrastructure and the environment. The need for an appropriate infrastructure which helps dealing with the numbers and at the same time highlights and maintains the uniqueness of each destination is crucial. The Environmental Agency of Iceland publishes annually a report with a list of nature sites which are in danger of losing their natural value. The sites are divided into two categories, based on their conditions and priorities for actions: the red-colored sites which is in most danger and the orange-colored sites which are in some danger. Two of the six sites on the red-colored list are geothermal sites, Geysir and Reykjanesfólkvangur National Reserve. While utilizing the opportunities related to tourism that the geothermal offers it must be assured that it will not have an irreversible impact (Umhverfisstofnun, 2017).

The environmental impacts of plans and projects are assessed for each project and can be very different. The landscape impacts can as well be debated but is more subjective to environmental impacts of geothermal power plants and their infrastructure rather than the tourism that utilize the already built infrastructure and, at least partly, impacted environment. Different kind of tourist related operation must also be assessed due to environmental impacts based on the law on environmental impact assessment of projects in Iceland. The main environmental issues involved in geothermal development are usually: Surface distribution, physical effects of fluid withdrawal, noise, thermal effects, chemical pollution, biological effects and protection of natural features. As geothermal resources utilized for tourism can vary extensively their impacts are unclear and based on the location and operation for each of them (Kristmannsdóttir & Ármannsson, 2003).

5. CONCLUSION

Different types of tourism can be related to geothermal activities and experiences. The most obvious is the geothermal and hydrothermal tourism but the experience and activity related to geothermal conditions can also be related to eco-tourism, health and wellness spa tourism, nature-based tourism as well as adventure tourism. Therefore, the opportunities to combine these two elements, tourism and geothermal areas is excessive.

The history of tourism development related to geothermal activities highlights that it can be difficult to pinpoint the future development opportunities related to the tourism sector. It has been and probably will be an unexpected development, full of opportunities for innovation and evolution. Though Iceland has been successful throughout the years regarding geothermal resources, it can still learn from other countries. And the resources cannot be fully utilized as new opportunities and innovations can emerge from both traditional and new opportunities. Iceland can e.g. learn from the US when it comes to the educational role of geothermal areas, such as in the Yellowstone National Park.

By observing the utilization of geothermal resources in Iceland as well as the tourism development it can be stated that most of it has come as a byproduct, with the main purpose of fulfilling the everyday life of the inhabitants of Iceland as well as powering industries and therefore supporting the economy of the country. It raises a question whether greater emphasis should be put on utilization of the tourism opportunities related to the geothermal conditions we have in Iceland or if the industry itself should work around the main utilization categories as it has been doing. The importance of protecting the value of these destinations cannot be overlooked or underestimated. It is a prerequisite to attracting tourists to Iceland and geothermal destinations in the long-term. Sustainability is vital to make sure that tourism and geothermal resources can work together to strengthen and promote each other.

Countries should look towards geothermal to attract tourist and expand the variety of experiences and attraction they have to offer. Tourism related to geothermal is quite rare globally and countries should take the opportunity to look beyond merely electricity production when considering utilization of their geothermal resources. Other renewable energy sources can also be expanded and developed into an innovative and informative destination or attraction for the environmentally cautious traveler as well as the tech-savvy energy enthusiast.

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