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Geothermal Heating of Iceland`s Football Structures – a Factor in Iceland`s Recent International Football Success?

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ABSTRACT

After its introduction in Iceland more than a century ago, football (soccer) soon became the country's most popular sport. Due to a harsh oceanic climate with long, cold and stormy winters, training and competitions were largely limited to the relatively cool and short summers. Effectively, this meant that football was a summer sport in Iceland, with the main competitions held from late May into early September. The short football season was reflected in poor results achieved by both the national teams and club teams in international competitions. With the building of the first football fields with artificial turf in the 1980s, gradually this started to improve. In the 1990s the Football Association of Iceland (KSÍ) presented its future vision in changing football in Iceland to a sport practiced in good conditions through the whole year. This included building of houses covering both full-size football fields (105 m × 68 m) and half-size (approx. 70 m × 50 m), and numerous full-size football fields with artificial (football) turf. At the start of the 2000s, another major project was initiated in building of mini-pitches (33 m × 18 m) with artificial turf and strong perimeter rebound fence, at school yards and other locations where children had easy access – to maximize their use. The projects were successfully launched in cooperation with the larger municipalities in Iceland, which carried the main financial costs, with the first full-size football hall opened in February 2000. In the period 2002-2007, 6 additional full-size football halls were opened, adding about 20 full-size outdoor pitches. Furthermore, in the period 2004-2008, 111 mini-pitches were built.

One of the important factors considered and recommended in the design and building of these structures was heating - to make the houses as comfortable as possible during wintertime. Similarly, underground heating of the outdoor fields was recommended to maximize their usage – even through periods of difficult winter conditions. Undersoil heating was even considered in some fields with natural turf to lengthen their possible usage in spring and autumn. Here, the availability of cheap geothermal water for heating was believed crucial. In Iceland, over 90% of all houses are heated with geothermal water. Most of it is produced in the many low-temperature geothermal fields distributed over more or less the whole country, and used directly, while the rest is produced by heating cold water with geothermal steam in power plants at high-temperature fields. And importantly, the price of geothermal water for heating in Iceland is low – much lower than can be offered for heating by any other energy source – even on international scale.

During the last decade, a major improvement in Icelandic football has been seen through the results of Icelandic national teams, both for men and women, with participation in the Euro-finals for both men and women, and the WC-finals for men. In this paper, the main factors in the design of these football constructions are presented with emphasis on the heating systems used, as well as an update on the status of football facilities today. Some consideration is also given to the economics of the projects. Finally – has geothermal heating played a significant role in Iceland's recent football success? – that is a key question we try to answer.

1. INTRODUCTION

Football (soccer) was introduced in Iceland at the start of 1900s and soon became the country's most popular sport, as in so many other countries of the world. Its development was though hampered by the climate in Iceland. The country's location in the middle of the North-Atlantic Ocean and at the border of the Arctic Ocean is reflected in its oceanic climate with relatively cool and short summers, and long, fairly cold and windy winters. Thus, traditionally, training and competitions in outdoor sports have largely been limited to a short summer period. Effectively, this meant that football was a summer sport in Iceland, with the main competitions covering the period from late May into early September. This is opposite to most of Iceland's European neighbours, where football is a sport played almost all the year around, and with emphasis on the winter part of the year. Taking also into account the small population of the nation, e.g., with roughly 150,000 inhabitants in the mid-1900s, and now at around 360,000, Icelandic football fans had to be content with poor results by both the national team and club teams when they met international opposition. Victories were rare, but the few were celebrated and remembered.

In the 1970s and into the 1980s, some improvement was seen through increased emphasis on winter training, but still the conditions were not good enough for real progress. With the building of the first football fields in Iceland with artificial turf in the 1980s replacing in wintertime primitive gravel fields, and some of them heated underground with geothermal water to melt snow and ice, conditions for winter training slowly started to improve. At the same time, our Nordic neighbours in Scandinavia took this concept further, not

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only through building numerous football fields with artificial turf, but perhaps more importantly through building of football halls. Some of these were even large enough for a full-size football field (105 m × 68 m), while others had a size of approximately half fields (about 70 m × 50 m). This was something to learn from. Another concept, which also became especially popular in Norway in the 1980s, was the building of mini-pitches approximately 20 m × 40 m with artificial turf as surface, and with strong perimeter rebound fences around to maximize playing time as possible. In Norway, these pitches were usually referred to as "*Bingen*". They were built close to playgrounds or schools, or at least at locations where the kids wanted to be. Through these mini-pitches good football playing conditions were created for the kids through most of the year, and they became extremely popular and were used intensively all the year around.

In the 1990s into the 2000s, the Icelandic Football Association – or KSÍ (using the Icelandic initials) initiated projects aimed at improving winter conditions for footballers in Iceland, through the building of football halls, as well as small and full-size outdoor football fields. One of the important factors considered and recommended in the design and building of these structures was heating - to make the halls as comfortable as possible during the cold winter period. Similarly, underground heating of the outdoor fields was recommended to maximize their usage. Soil heating was even considered in some fields with natural turf to lengthen their possible use in spring and autumn.

In Iceland, over 90% of all houses are heated with geothermal energy. Most of the geothermal water is produced in the many low-temperature geothermal fields distributed all over the country and used directly, while the rest is produced by heating cold groundwater with geothermal steam in power plants at high-temperature fields (e.g., Georgsson, 2018). The price of geothermal water for heating in Iceland is generally much lower than can be offered for heating by any other energy source – and is very competitive on international scale. In Reykjavík, the price of hot water for heating houses through the year is only a fraction (33-42%) of the prices experienced in the capitals of the neighbouring Nordic countries (e.g., Flóvenz, 2018). The availability of geothermal water for heating these facilities was therefore not only considered crucial to create prime conditions for winter training, which was the objective, but also economically feasible. Where deemed possible and economic, geothermal heating was used, and thus the using time of most of these expensive structures was maximized.

During the last decade, a new generation of Icelandic footballers has been seen, who have reached further than most of their predecessors ever dreamed of being possible. A major improvement has been seen in the results of Icelandic national teams, both regarding men and women. The Icelandic women`s A-team qualified for the EURO-finals for the first time in 2009, and repeated that achievement in 2013 and 2017. For the men's team, the first qualification for the U21 EURO-finals in 2011 marked the start of serious improvement. In late 2013, Iceland lost narrowly against Croatia, in the playoffs for the World Cup finals in Brazil held in 2014. Qualification for the finals of a major football tournament was achieved for the first time for EURO 2016 in France, when the team reached the quarterfinals by beating England, a memorable achievement. Qualification was repeated for the finals of the World Cup in Russia in 2018, with Iceland becoming by far the smallest nation to have reached WC-finals for men. Individually, the improvement is manifested in many Icelandic footballers now playing as professionals abroad and seen in most top leagues in Europe.

In this paper, the Icelandic football halls and the heating systems used in them will be described, as well as the geothermally heated outdoor fields with artificial turf. Access to cheap geothermal energy has been very important, allowing heating of most of these structures, and thus creating prime conditions for training through the year.

There are many factors which have contributed to Iceland's success story in football during the last decade. Besides the football halls, a strong coaching education system must be mentioned creating a large pool of high-quality coaches both for grown-ups, and perhaps more importantly for youth, a licensing system for participation in the higher leagues, putting demand on the main clubs to be run in a professional way based on sound management, and easier access for players to become professional footballers abroad with high-quality clubs. Then luck might be added, in getting a large group of promising young players at a crucial time, maturing fast and well to create the nucleus of a strong team, and in making the right decisions with regards to coaches in charge of the international teams. Here, the focus will be on a special angle of Iceland's success story, the football infrastructure projects aimed at creating good training conditions throughout the year, and specially the heating of the football halls and fields with geothermal energy. Has this played an important role in Iceland's recent successes in football? This is a question where an answer is being sought.

2. "FOOTBALL ALL THE YEAR AROUND"

2.1 Projects initiated by KSÍ to improve winter conditions for training

In early 1990, the Football Association of Iceland – or KSÍ – established a special football infrastructure committee which was given the task to develop and establish standards for football facilities in Iceland, which could take Icelandic football further. Improving the rather primitive football stadia was of course important, but more so was realising ideas related to improving conditions for winter training and competitions. In the 1990s and the early 2000s KSÍ was under the leadership of Eggert Magnússon, president of KSÍ 1989-2007, and Geir Thorsteinsson, General Secretary 1997-2007, and president 2007-2017. In the mid-1990s, KSÍ presented its future vision in changing football in Iceland to a sport practiced under good conditions through the whole year – referred to as "*Football all the year around*" (KSÍ Infrastructure Committee, 1996). This was a vision which included building of several houses covering both full-size and half-size football fields with artificial turf as the playing surface, and with a distribution around the country.

To implement the vision, KSÍ sought cooperation with the larger municipalities, as in Iceland the municipalities have the responsibility of building or at least supporting building of official sports facilities, including those for the local clubs. Citing one of the better-known Icelandic footballers in the late 1970s, Teitur Thórdarson, a former professional player in France and Sweden and later a coach at international level, who was active in the agitation for football halls in Iceland in the early 1990s: *"Those of us, who have been a part of football in Iceland, know that in order to develop we have to be able to practise certain things and spend long hours in training, and there is a limit to what can be achieved in difficult circumstances. In my mind, it is most important that we get into houses, where we are liberated from the wind and cold. Then things will start happening here, and sooner than most suspect."*

The 1990s also saw an increasing number of football fields with artificial turf being built, many of them with underground geothermal heating, as well as building of several mini-pitches, mostly in the capital area, which became quite popular. The latter led to a major project, which was initiated by KSÍ in 2004, through a strong support from UEFA – the European Football Association (KSÍ, 2004). This project focussed on building many mini-pitches (18 m × 33 m) with artificial turf on the surface and rebound fences around, at schoolyards, parks and other locations where children had easy access to the pitches. The majority of these had underground geothermal heating.

2.2 Project "Football all the year around"

In the brochure "Football all the year around – building of football halls – policy of KSÍ" (Figure 1), published in 1996 (KSÍ Infrastructure Committee, 1996), different types of football halls were introduced and discussed, including the following:

Competition houses, covering a full-size football field (68 m × 105 m) – but of two different types:

A. *Fully equipped competition hall*, with a good aerial height (10-12 m at side-lines and 20 m along the ridge), high-quality artificial turf, changing rooms and stands for spectators, and all technical systems.
B. *Inexpensive competition hall* with good artificial turf on the surface, but where general costs were kept at a minimum. These were mostly intended for training. Here, lower aerial height was eventually accepted at 10-12 m at the ridge and about 5 m at the side lines.

Training halls covering roughly half-size football field, and importantly keeping close to full width (65-70 m), which is of key importance for training purposes:

C. *Training hall,* height 5.5 m at side lines and 10 m along the ridge.

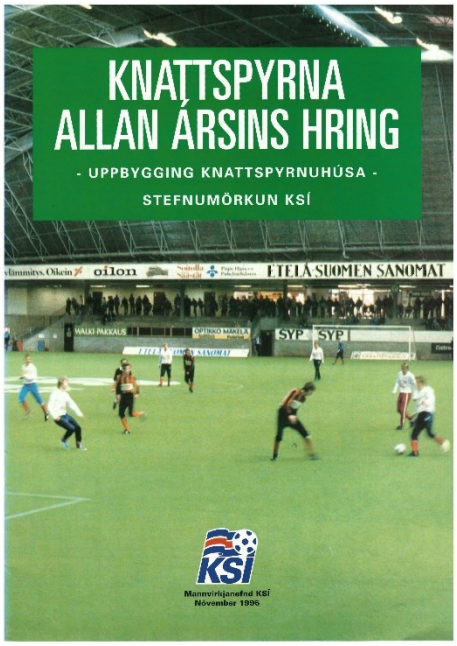

Figure 1: The cover of the KSÍ brochure "Football all year around" (KSÍ Infrastructure Committee, 1996)

Many of the demands for the halls are traditional for most houses while special demands included: Good-quality artificial turf on the playing field, good insulation in halls, which were to be heated, inside surfaces of the halls designed to keep reasonably low sound reflection, and fairly good lighting, at least 500 Lux for competitions, air conditioning as necessary, and importantly, *heating systems keeping temperature during training at least at 7-10°C, even during severe winter conditions, but optimally up to 15°C*. In the brochure, cost estimates were given for the different types of halls, and a 15-year time-schedule as an assessment on how the project could develop. The project *Football all the year around*, was presented at the annual congress of KSÍ in December 1996.

As a follow-up, in late 1997, KSÍ invited city council members from larger municipalities to participate in an excursion to Norway and Denmark, where they could visit similar football facilities and experience their use. The attendance in the excursion was good (21) and it proved to become the real start for the project, as soon afterwards important decisions were taken by the main municipalities towards realising some of the plans presented and discussed in the brochure and visualized in the excursion.

In the brochure the costs of the halls were assessed as follows (with the rate of 1 USD at approximately 66 ISK in November 1996):

Competition hall A: 450 million ISK; Competition hall B: 340 million ISK; Training halls C: 135-200 million ISK

Table 1 shows the assessed need for football halls according to the brochure to be built over a period of 15 years, 1998-2012, distributed into all regions of Iceland. This included in total 1 type A competition hall and 2 of type B, and 12 training halls. The total cost of the project over the same period was assessed to be about 3,300 million ISK – distributed fairly equally through each 5-year period. Table 1 also shows the actual number of football halls built in this period. As can be seen, reality turned out to be somewhat different. Ten years later, at the end of 2007, 7 full-size football halls had already been built, including 2 of type A, both of which have since hosted international games for men and women, while only 1 training hall had been built. It can be added that both largest football halls are built as multi-purpose sports halls, even though their use for football has been dominant.

Table 1: Assessed need for football halls in Iceland to be built in 1998-2012 according to the project *Football all the year around* (KSÍ Infrastructure Committee, 1996), and actual number built in the same period

Competition halls A-type		Competition halls B-type		Training halls C-type	
Assessment	**Built**	**Assessment**	**Built**	**Assessment**	**Built**
1	2	2	5	12	5

The results show that the underlying need for this type of sports houses had been seriously underestimated. Football infrastructure had been low in the financial priorities of the municipalities for a long time. And now when new ideas were presented and the opportunity came to improve on this, the municipality councils wanted to excel in their decisions. This led to larger houses being prioritized instead of training halls. Table 2 summarizes some key information for the competition halls, while Figure 2 is a photo from Egilshöllin, the large football hall built in Reykjavík and officially opened in 2002, taken during a women's international game.

The years 2008-2012 were heavily influenced by Iceland's economic crisis, with many scheduled infrastructure projects put on hold, but still a few training halls were built in these years. At the end of the 15-year period in 2012, it could be argued that the number of houses built was very much in line with the original assessment, but through fewer and larger houses. And probably at higher costs than assessed, due to the emphasis on competition halls. As important was the fact that the distribution of the houses was not far away from being in line with what was proposed, with only the sparsely populated NW-Iceland and the Westfjords not having a football hall.

Table 2: Full-size football houses in Iceland, built in the period 1998-2012

Name	Municipality	Type	Year finished	Size of field	Heating system	Seats/Stands
Reykjaneshöllin	Reykjanesbaer	B	2000	64 m × 100 m	Yes – air heating	0
Egilshöllin	Reykjavík	A	2002	68 m × 105 m	Yes – air heating	1690/600
Fífan	Kópavogur	B	2002	68 m × 105 m	Yes – floor heating	0
Boginn	Akureyri, N-Icel.	B	2003	68 m × 105 m	No – but air heating installed in late 2007	0/400
Akraneshöllin	Akranes, W-Icel.	B	2006	68 m × 105 m	No	409/0
Fjardabyggdarhöllin	Fjardabyggd, E-Icel.	B	2006	68 m × 105 m	No	409/0
Kórinn	Kópavogur	A	2007	68 m × 105 m	Yes – floor heating	1464/100

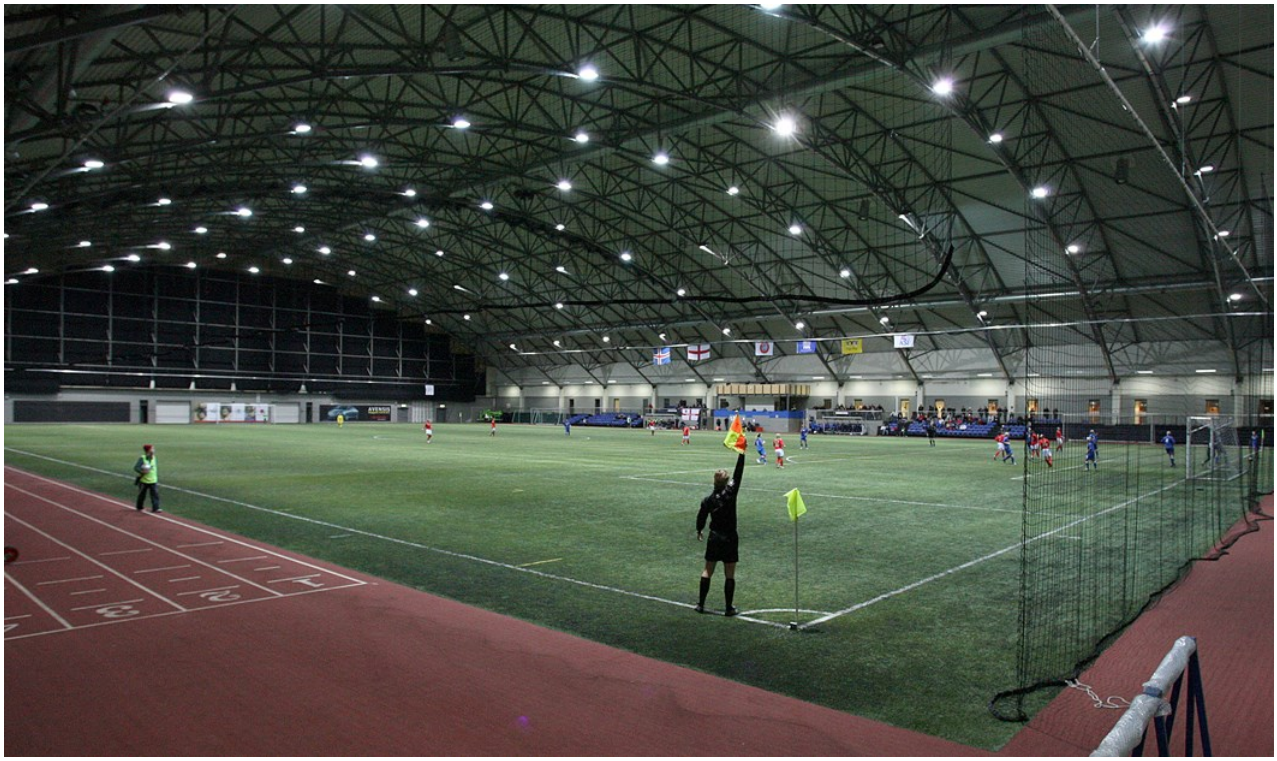

Figure 2: Egilshöllin, the large football hall in Reykjavík, which was opened in 2002. The photo is taken during an international women's game

2.3 Football fields with artificial turf

Through this important period, when most of the football halls were built, many outdoor training fields with artificial turf were also built as well as the first stadia with artificial turf. In 2012, 5 stadia with artificial turf had been approved and were used in the 3 highest divisions for men, also adding 19 training fields in full-size. The majority of these (13 out of 24), had underground heating, to increase their possible use during winter conditions.

At this stage it can be said that most larger clubs had at least some access to football halls for their winter training. Additionally, they also had access to outdoor fields with artificial turf, many of which were heated, thus fulfilling their needs for moderate to good winter training conditions.

2.4 The "KSÍ mini-pitch project"

In 2004, the *KSÍ mini-pitch project* was launched, a project aimed at providing good training/playing conditions for kids at any age, and as such a typical grassroots project (KSÍ, 2004). The project was partly initiated by UEFA – The European Football Association, with 1 M. Euro being donated to all its member associations to be used for building mini-pitches. To be able to take this project further KSÍ sought special financial support from the Icelandic Parliament and from four of its main sponsors, receiving positive feedback from all. Manager for the project was Eyjólfur Sverrisson, an energetic guy and one of Iceland's best footballers in the 1990s. His contribution to the project was very important.

To be able to utilize the financial backup as well as possible, the following project was introduced. Mini-pitches were to be built in the size 33 m × 18 m with strong perimeter rebound fences around, from which the ball would bounce instantly back onto the field, with artificial turf of good quality as playing surface, with floodlights*, and with heating where financially feasible*. KSÍ provided the drawings for the design of the mini-pitch, allowing some flexibility and KSÍ supplied the artificial turf for the surface of the mini-pitches after the main structure had been built. On the other hand, the municipalities were responsible for building the pitches in locations where kids had good access to them, such as at schoolyards, in parks, etc. Figure 3 shows the blueprint drawing of the mini-pitches built through this project.

Figure 3: Drawing of a typical mini-pitch, with necessary technical systems, as advocated for in the *KSÍ mini-pitch project* (modified from KSÍ, 2004).

The original plan was to build 40 mini-pitches all around Iceland, but reality became much more positive. In the years 2004-2005, 64 pitches were built, but many additional municipalities wanted to participate in the project. Through additional funding from Parliament and the sponsors, the project was extended for two more years and eventually into year 2008. Through this, a total of 111 mini-pitches were built all around Iceland, providing kids in Iceland in most villages and all towns, small and large, with prime conditions for playing football, all the year around. Figure 4 shows full action at one of these mini-pitches (in Hveragerdi, S-Iceland).

Figure 4: Full action at the mini-pitch in Hveragerdi, S-Iceland.

3. HEATING OF FOOTBALL HALLS AND FIELDS

3.1 Introduction

The focus of this paper is on the heating systems used in the football structures built in the late 1990s and early 2000s. The majority both of football halls and fields with artificial turf were heated, and in all cases the benefits of geothermal energy were enjoyed. Heating of a house covering a full-size football field is expensive, so it is important that a decision on this is taken based on sound data, proving its feasibility. Here, the price of the geothermal water used was of key importance. The decision was fairly easy in municipalities, which have ample access to cheap geothermal energy, like the capital area, while it was more difficult in municipalities with more expensive or more limited resources of geothermal energy, especially in E-Iceland, where geothermal energy for heating is hardly available. As can be seen in Table 2, four out of seven full-size football halls were built with a heating system, while the other three were without heating. However, in Boginn at Akureyri, in the winter-cold N-Iceland, the door was kept open for heating in the future, by using roof material with insulation. This was strongly recommended by the KSÍ Infrastructure Committee, which had serious doubts about this decision. And this proved important, when the municipality decided to install heating system in the football hall in 2007, because of complains of the house being too cold for conventional activities through Mid-winter. On the other side, Akraneshöllin in W-Iceland, and Fjardabyggdarhöllin in E-Iceland are not heated, which is understandable when the small size of the respective municipalities is taken into consideration. Also, in the beginning of the 2000s, due to long piping distances, heating costs at Akranes were high, despite access to geothermal energy (Georgsson et al., 2010), and as stated above, in E-Iceland geothermal heating is hardly available and not at all in the municipality of Fjardabyggd.

3.2 Principles in heating of football facilities

3.2.1 Heating of football pitches with artificial turf

Football pitches with artificial turf are built up by several layers on top of a compressed drained gravel foundation, including the bottom sand-layer with heating, elastic shock pad, woven fabric with fibre straws, sand infill and EPDM plastic infill (Figure 5). The system is designed to create optimal surface playing conditions for the footballer, as close as possible to those experienced on natural turf. The product has gone through several generations with gradual improvement. Earlier generations of artificial turf with short straws and sand infill were more suitable for distribution of heat to the surface and for these, the heating system could be considered as practical for "snow melting". Development of artificial turf through the 1990s into the 2000s saw a marked improvement, through creation of products which could challenge natural turf and which have the big advantage of being possible to use for much longer hours than natural turf, especially during the colder part of the season, as well as being suitable for indoor football fields. The disadvantage is that development of artificial turf with longer fibres, rubber/plastic infills, and shock pads, considerably reduces the thermal conductivity of the surface. This results in much slower melting of snow, when used outdoors. Even with raised running temperature, snow melting is much reduced. Today, the main purpose of a heating system for outdoor pitches with artificial turf is to provide a soft field, free of ice. To keep the field in playable condition, during days of snowing, snow must be removed mechanically, if the layer of snow exceeds 30-50 mm, while thin layers will by pressed into the infill by players and melt.

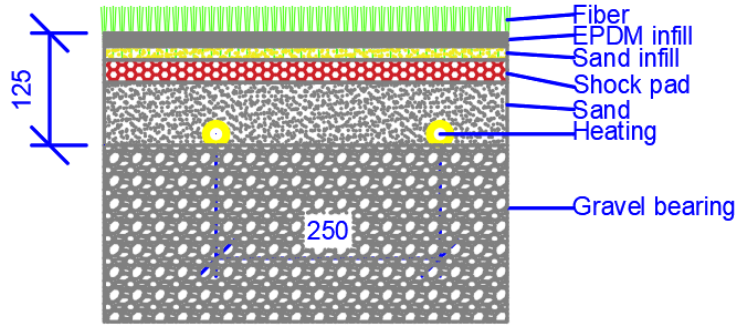

Figure 5: A cross-section of the structure of a football pitch with artificial turf with geothermal heating system

3.2.2 Heating of football halls

As can be seen in Table 2, 5 out of 7 large football halls have heating systems based on geothermal heating, and most smaller football halls are also heated. Heating is either supplied by floor/soil heating based on similar systems as used for heating outdoor pitches (2 of the larger halls) or through centralised or decentralised air heating systems (3 of the larger halls). The need for heating is like building heating in general and depends on the intended use and comfort level. Multipurpose halls may have higher demand for heating, because of running tracks and stands, including more comfort for spectators, while football-only halls only need playable field. In all cases sufficient ventilation must be provided to avoid condensation, and thus corrosion of the construction. Some insulation of the roof is recommended for the same purpose as well as to reduce heat loss.

Soil heating has some advantages such as noise free heating and no space demand for installation. The heating must be supported with natural or mechanical ventilation. The advantages of centralised air heating systems are good air distribution, possible heat recovery from extract air and easy demand control.

3.3 Heating systems for football pitches

3.3.1 Full-size football pitches with artificial turf

Layouts for heat pipes can be longitudinal or transversal loops connected to mains on one side of the field. Transversal layout is preferred due to flow/pressure. Loops are connected to the main supply/return piping either directly to in-ground mains (Figure 6) or to distribution manifolds in wells (Figure 7). The advantage of accessible manifolds is the possibility of leak location and single loop shutoff, especially for antifreeze systems. The heating pipes are usually installed with 250 mm interval and with 100 mm cover. The total length of heat pipes in a full-size pitch is 33-34 km.

Figure 6: Lay-out of longitudinal loops with direct connection to the mains supply; a) Overview of the field; b) Detail photo at the connection to the mains supply.

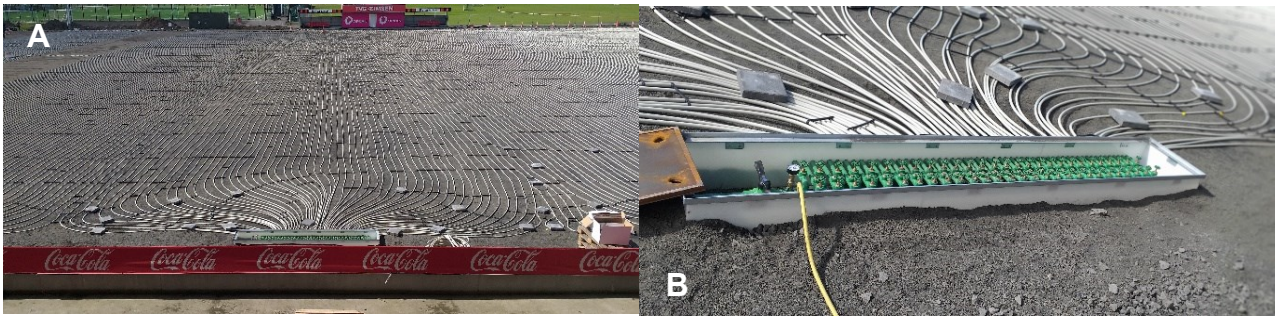

Figure 7: Lay-out of transversal loops with distribution manifolds/wells for a football-turf pitch; a) Overview of the field; b) Detail photo from the distribution manifolds in well.

3.3.2 Mini-pitches

Mini-pitches with artificial turf have been installed in most school playgrounds. Most of the pitches in regions where geothermal energy is available have heating installed. The mini-pitches have similar fibres and infill as full-size pitches but do not have the shock pad. Due to less surface insulation the heating is more effective and therefore may be run at lower temperatures. Often, heating is partly supplied with return water from building heating systems. Heating in mini-pitches makes them playable all year round.

3.3.3 Heating of football pitches with natural turf

For climatic reasons, conditions in Iceland for use of natural grass on football pitches are difficult, and the season is short. Hence, time of usage is low, approximately 200-400 hours per summer, compared to annual use of 1000-2500 hours for pitches with artificial turf. Effort has been made to improve the condition for the grass and extend the football season on grass pitches. On behalf of KSÍ, emphasis has been placed on improving the structure of the fields and for this purpose brochures have been published with best practices for developers of football infrastructure. Heating systems have been installed in natural grass pitches at four stadia in Iceland. In the mid-1970s, the municipality of Kópavogur in the capital area decided to build a stadium with a geothermal heating system in the pitch. Some years later two other stadia were constructed with a heating system, in Gardabaer in the capital area, and in Ólafsfjördur in N-Iceland, and in 2008 one more such stadium was built in Reykjavík.

The aim of the heating systems in these fields was to have the grass surface in good shape at the beginning of the season, and to make them ready to for increased load from competition games. Later, the demands for a prolonged competition season increased and it was looked at as possible benefits of the use of heating systems. Experience indicated that heated pitches could be ready for use 1 - 2 weeks earlier in the spring than pitches without a heating system. The results of research initiated by Agricultural University of Iceland (LBHÍ) and Reykjavik Energy (OR) in 2009-2015 confirm this experience (Thorvaldsson and Óskarsson, 2015; 2018). The prolongation of the season into the autumn is more uncertain. During that period, other climatic factors can have more effect, especially daylight, wind and rain, but also risk of frost.

The municipal authorities in Kópavogur and Gardabaer later decided to install artificial turf on the competition pitches in their main stadia, and the same was decided for the Reykjavík stadium. The reason for this was first and foremost to achieve more efficiency and increase the utilization of expensive facilities. Interest in football, especially among youngsters, has grown a lot and there is a need for more facilities. Pitches with natural grass can only be used for a maximum of 400 hours per year in Iceland, while artificial turf can be used up to 2500 hours per year, and therefore, increased land space is needed if natural grass pitches are to be used, and they are not available during winter. Heating helps to increase the use of grass pitches but does not make a big difference. But to get the most out pitches with artificial turf through the whole year, a heating system is necessary.

3.4 The cost of geothermal heating of football facilities

In Iceland, sales units for district heating are generally not by energy (kWh) but by volume (m^3/h). For the capital area the supply temperature from OR is 75-80°C, with similar prices seen in many of the main geothermal heating systems around Iceland. The energy received for each sales unit therefore depends on the return temperature from the heating system.

3.4.1 Cost of heating football halls

As previously mentioned, there are two types of heating systems in the heated football halls, air heating systems and soil heating systems. The cost of heating of the two different types of football halls has been compared. The first one is a big air-heated multipurpose hall, type A as defined in Section 2.2, with a volume of 200,000 m^3, while the other is type B football hall of a volume of 115,000 m^3 and heated with a soil heating system. The result of this comparison shows that the energy cost pr. m^3 is the same for both types of halls, i.e., 35 ISK/m^3. At first glance a higher heating cost of the hall with the soil system would be expected. But as mentioned earlier, the multipurpose halls are operated at higher temperatures than halls solely for football activities. That is the main reason for the result of the two halls compared.

On an annual basis, in total the heating cost of the larger football hall (Type A) is thus about 7 M ISK/year (USD 56,000 at the current rate 125 ISK/USD), while the heating cost for the smaller hall (Type B) is around 4 M ISK/year (USD 32,000).

3.4.2 Cost of heating outdoor football pitches

Recent generations of artificial turf systems with increased insulation have resulted in higher return temperatures and less energy used per sales unit. The raised temperature of the heating systems also increases the heat loss to the ground. Until now the fields in Iceland have not been built up with an insulation layer under the heated area to reduce losses to the ground. This is due to installation costs compared to low energy prices. The gravel foundation layer (0.8-1.0 m) gives some insulation, but extra insulation pad could reduce the energy consumption considerably and increase the effectivity of the heating system.

Pitches with artificial turf. The energy consumption for heating a 68 m × 105 m (heated area 76 m × 108 m) football field is around 18,000-20,000 MWh/year. With supply temperature at 75-80°C the consumption is 40,000-50,0000 m^3/year (values based on experience). Unit price for geothermal heating in the capital area is currently 125 ISK/m^3, taxes included. The municipally owned supply company (OR) awards sport field heating and provides geothermal water at 30% lower unit price compared to conventional prices for heating buildings. In the southern and western parts of Iceland, snowfall is most frequent at temperatures of 0 – -5°C and infrequent at lower outdoor temperatures. Thus, the peak demand for pitch heating is not simultaneous with building heating peak demand. Hence, the systems can mostly be supplied from the existing distribution net, even though the distribution system was not designed for this use.

Calculating the annual costs for heating a full-size football field in Reykjavík, based on the above, comes to about 4 M ISK (3.5-4.4 M ISK), or about USD 32,000. Despite the benefits of geothermal, this is not cheap. On the other side, municipalities support sport clubs with emphasis on youth development, giving grants per individuals and/or training opportunities given to the youth sector.

Pitches with natural turf. Included in the research on heating of stadia with natural turf, were analyses of the heating period, effect of different temperatures and a cost analysis (Thorvaldsson and Óskarsson, 2015; 2018). To keep the soil temperature at 10°C during March, April and May, 1.40 kWh/m^2/day were needed. If this is transferred to a 7,140 m^2 football field it would cost about 750,000 ISK/year (USD 6,000).

3.5 Results of heating football halls and pitches.

Heating of the modern football facilities in Iceland has been important for their use. In the heated football halls, the comfortable training temperature, 7-15°C, creates prime training conditions for the players, and for spectators watching matches. The heated outdoor football pitches with artificial turf were also a revelation, though not quite in line with the luxury of the football halls as here Icelandic winter weather had to be endured. The soft surface material, produced in the image of good summer grass, was a big step forward in comparison with the older generations of artificial turf, not forgetting the hard gravel pitches used for outdoor winter training in even earlier periods. The heated football halls are used for 16-18 hours of day throughout the winter period of 8-9 months, and they are even used quite a lot during the summer period. And the heated pitches with artificial turf are also used extensively, here the main usage is though after school hours, during afternoon into the early night.

The costs of heating these facilities have been discussed above. They are considerable but here geothermal energy provides a reliable and cheap alternative for most of the well-populated regions in Iceland. With the support the clubs get for youth training from the municipalities and from the parents of the younger players, these costs have been acceptable. On the other hand, in municipalities where geothermal heat has not been an option (e.g., Ísafjördur in the Westfjords, or Fjardabyggd in E-Iceland), these costs have been too high, and the football facilities in these areas have generally not been heated, leading to lower utilization at least during the coldest periods.

It is due to recall the words of Teitur Thórdarson, stating: *In my mind, it is most important that we get into houses, where we are liberated from the wind and cold. Then things will start happening here, and sooner than most suspect*". With confidence it can be said, this is exactly what happened. Giving the most promising players in the early 2000s this possibility, certainly created a larger generation of talented players than Iceland had seen before, who took their skills to a higher level, and the best were rewarded with contracts with professional clubs abroad where they could continue improving.

4. DEVELOPMENT IN RECENT YEARS AND CURRENT STATUS

After slow development in the aftermath of Iceland's economic crisis in 2008, municipalities and clubs are again putting increased emphasis on building and improving sports facilities. They have seen the advantages for footballers having access to good winter conditions for training. Being able to offer such conditions to the whole range of youth teams from the age 6, adding professional coaching for all age categories and better club structure, has created large new generations of players in Iceland, who are technically better than earlier generations. Here, it is tempting to discuss the municipality of Kópavogur in the capital area as a good example. The two football clubs in Kópavogur, Breidablik and HK, have probably enjoyed a stronger support from the municipality in provision of good football facilities than any other clubs in Iceland. Both now have full access to a heated full-size football hall and additional outdoor pitches with artificial turf and soil heating systems. Breidablik, the older and larger club, has more than 1200 youngsters from the age 6 practising football regularly under its banner. It is a club with a fantastic record in producing good footballers, both male and female, who, when ripe, have gone abroad to play football as professionals. Their women's team has usually been the strongest in Iceland, winning more titles than other teams. They have also developed some of the best male footballers in Iceland in recent years, despite their men's team not having won many national titles.

Breidablik had 4 players in the group of players participating in the EURO U21 finals in Denmark in 2011. Three of them have been key members in the Icelandic A-team ever since, with two playing as esteemed professionals in the Premier League in England and one in the Bundesliga in Germany. The best-known of these, Gylfi Sigurdsson with Everton, had his football upbringing at the club's main local rival, FH in Hafnarfjördur, which was a dominant force in Icelandic club football in the early 2000s, a promising player equipped with a strong determination. In 2003, at the age of 14, he decided to change clubs to Breidablik – and not for the money. He wanted to be able use the superior football facilities at Breidablik, i.e., to be able to train indoors in a heated football hall as much as he could, to improve his skills. Gylfi went abroad at the age of 16 and turned professional a little later, eventually creating considerable amounts of money for his club through his international transfers. He has since developed into Iceland's number one football player.

In recent years, the emphasis has been on improving stadia and at the same time decisions have been made on changing playing surfaces. The trend has been to change from natural grass to artificial turf with geothermal heating to prolong the using time of these fairly expensive facilities and make winter matches and training possible. Other important factors have been the decrease in land use compared to natural turf, as land is expensive in the capital area and other larger municipalities, as well as the gradual lengthening of the outdoor football season defined by the Icelandic Championship (not considering pre-season tournaments). This trend is expected

to continue. Iceland has still the shortest season in Europe, about 5 months, despite having expanded it for almost a month since the turn of the century, extending now from late April to the end of September. However, playing on natural turf from late April through May as well as in September is testing in Iceland with the playing fields with natural turf often not in good conditions. Many clubs have concluded that the benefits of first-class artificial turf during the early and late parts of the season, when it is not possible to rely on good natural turf to play on, may be more important than the benefits of having good natural turf during the main summer period. In 2020, 7 out 12 clubs in the Premier Division for men played on artificial turf in their stadia, and in the 1st Division for men, 4 out of 12 clubs. For the women, 6 out of 10 clubs in the Premier Division played on artificial turf, in most cases the same stadia as for men. About half of these pitches with artificial turf date from the last 4-5 years. The process of more clubs relying on heated artificial turf in their stadia is expected to continue in the next few years. Figure 8 shows aerial view of the Premier Division's Fylkir stadium – Lautin, after artificial turf had been installed on the pitch in 2018.

Figure 8: The Fylkir stadium – Lautin, Reykjavík; a winter photo taken after laying of the artificial turf with heating system in 2018. No snow is seen on the surface of the pitch compared to the surroundings.

Finally, building football halls is again on the agenda. In late 2019, Skessan, a B-type full-size football hall (not heated) was inaugurated in Hafnarfjördur, and in Gardabaer a large A-type full-size football hall (heated) is under construction (late 2020), expected to be completed in 2021. Three smaller training halls (C-type) have also been built, in Mosfellsbaer (inaugurated in 2019), in Reykjavik (inaugurated in 2020), and at Selfoss, S-Iceland, expected to be completed in early 2021 (all heated). All except the last one, are within the capital area. To this can probably be added another full-size football hall in Hafnarfjördur and a training hall at Ísafjördur, in the Westfjords, to be built in 2021, according to the public plans of the respective municipalities.

5. HAS GEOTHERMAL BEEN A FACTOR IN ICELAND'S RECENT INTERNATIONAL FOOTBALL SUCCESSES?

In the introductory section the question was raised if geothermal heating of the football facilities in Iceland aiming at providing prime training conditions throughout the year had played a significant role in Iceland's recent success story in football. This is of course not an easy question to answer outright but a few facts should be considered.

- The use of geothermal heating in most of the football halls has certainly led to their increased use. It can also be stated that the great majority of Iceland's more promising players had access to relatively good training facilities throughout the winter from around 2002-2005. This was realised through the first football halls and outdoor pitches with high-quality artificial turf and underground heating.
- The heated football halls have been in constant use throughout the winter part of the year from very early morning into the night, and offer prime training conditions in any outside weather, not forgetting the comfortable conditions for the coaches and assistants as well as for spectators (mainly parents following their children to training or games). They are even popular to use during summers providing a reliable solution to Iceland's unpredictable weather. The training hours are not free for the clubs but through the general support from the municipalities towards youth training and the fees paid annually by the parents, the leading clubs have been able to cope with that, and thus provide much better training conditions for their promising players than earlier. Here, the access to cheap geothermal heating has certainly been an important factor. This is illustrated well through the example of the club, Breidablik, and especially Mr. Gylfi Sigurdsson, as presented above. Football has also become a sort of a fashion sport in Iceland, with the young generation focussing on the success of the Icelandic football players and wanting to repeat the deeds of their idols. For this the support of parents is important and it has grown a lot, sometimes based on dreams of greener pastures if the children "make it", taking reference in the enormous amounts of money involved in modern football.
- Heating of outdoor football pitches with modern artificial turf is not easy due to the insulating properties of the system. However, through heating they can be kept in good playing conditions during most winter days. In the capital area in SW-

Iceland, the winters are mild (Icelandic standard), and usually there are only a few days during winter when snow and frost prevent utilization of the fields. So even here, geothermal heating has been of importance.

- Most of the mini-pitches were built in 2004-2008. Heating of these makes them playable all the year around. They are located at schoolyards, parks, and other places where children gather in. Being mainly used by the younger players (6-14 years), they probably did not contribute much to the upbringing of Iceland's golden football generation, as these players were already in their teens when the mini-pitches were being built. On the other hand, they have certainly had a strong influence in creating a new generation of technically gifted football players to take over from the current team.

6. CONCLUSIONS

Icelandic football had the luck in that a large group of young talented football players came through the ranks of the youth system of Icelandic clubs around 2010, who a few years later matured to become Iceland's golden football generation who has won fame for reaching the finals of both the EURO Championship and the World Cup for men, with Iceland by far the smallest nation to reach that level. During the same period, the Icelandic international women's team qualified for the finals of three consecutive Women's EUROS (2009, 2013 and 2017).

Many factors contributed to this success story. In this paper, the importance of the football halls built through the project "*Football all the year around*" in 1998-2007 is highlighted, as well as the heated outdoor pitches with artificial turf, many of which were also built in the early 2000s providing Icelandic footballers with greatly improved training conditions during the main winter period. This gave them the possibility to train more and under much better conditions than earlier generations of players.

Several other factors were important in this success story. A very good coaching education system was developed at the same time to create a large pool of high-quality coaches both for grown-ups and perhaps more importantly for youth down to the youngest ages making sure that football players were trained in the best possible way. A licensing system for participation in the higher leagues, put demand on the bigger clubs to be run in a professional way with good management. At the same it became easier for players to become professional footballers abroad with high-level clubs. Then luck might be added in making the right decisions with regards to coaches in charge of the international teams.

Most of the football halls and the football pitches with artificial turf are heated with geothermal energy. The heating of the football halls and even of the outdoor football pitches has been an important factor in creating the comfortable quality conditions necessary for the extensive use of these facilities.

Costs of geothermal heating of the football halls and outdoor pitches with artificial turf have been calculated. The results show the costs to be around 35 ISK/m^3 volume of a building) for the football halls, which gives the total annual heating cost of Type A competition halls (multipurpose halls) as 7 M ISK (56,000 USD), while floor heating of Type B football halls comes to around 4 M ISK (32,000 USD), due their lesser volume. It is though probable that the multipurpose halls are on average run at slightly higher temperatures, than the Type B football-only halls. Heating of a full-size outdoor football pitch with artificial turf is assessed to cost about 4 M ISK (32,000 USD). These are reasonable prices which the clubs can cope with based on the financial support they get from their municipalities and through regular payments from parents of the younger players.

It is the believe of the authors that this paper provides strong evidence for geothermal heating having played a significant role in the Icelandic football adventure.

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