Ground Source Heating of Soccer Fields: Systems and Market Potential in Cold Climates

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Ground Source Heating of Soccer Fields: Systems and Market Potential in Cold Climates

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ABSTRACT

In Scandinavia there are more than 3 000 soccer fields with artificial turf. About 300 of these have subsurface hydronic heating systems. The heated turfs make it possible for training and games throughout most of the year. Furthermore, a pitch that is kept frost-free prevents injuries caused by a slippery turf and frozen ground conditions. Practically all heated soccer fields in Scandinavia use district heating as a heat source. Only a few fields are using ground source heat pump systems (GSHP). However, the potential for a more extensive use of GSHP systems seems promising due to the considerably lower energy cost. In this paper the use of GSHPs for subsurface heating of soccer fields with artificial turf is analyzed in terms of design, functional characteristics, and energy cost saving. Finally, aspects of market conditions for a broader use of GSHP systems for these applications are given, focused on the Scandinavian countries.

INTRODUCTION

Soccer (also called football outside of America) is one of the largest sports worldwide. It is also a sport that is played all year round even in cold countries such as Sweden, Norway, and Finland. In these countries artificial turfs are often used, mainly to cut the maintenance cost compared to natural grass fields. Using artificial turf will also prolong the season for games and training.

To secure a prolonged season some of the artificial turf (AT) fields are heated by a hydronic subsurface coil system. These fields are often full-sized arenas with some 7000-8000 m² of heated surface area, and also some smaller fields used for training and youth games. The approximate total number of artificial turf fields in Scandinavia and the share of subsurface heated fields are shown in Table 1 (SvFF 2023 and Hällfors 2021)

Table 1. Number of AT soccer fields in Scandinavia

Country	Full sized fields	Smaller fields	Total fields	Of which heated
Norway	1 190	640	1 830	180
Sweden	800	300	1 100	80
Finland	No statistics	No statistics	Approx. 500	Approx. 60

The growth rate of artificial turf fields is 55 new ones per year in Sweden and about 45 new ones in Finland (Danielski 2021). The main reason for new establishments is the lack of proper fields for youth training and games. Hence, the recent new fields are often smaller ones, while the fully sized arenas are already equipped with heating systems. The total number of artificial turf fields in European countries counts to some 30 000 distributed over 35 countries (OECD 2021).

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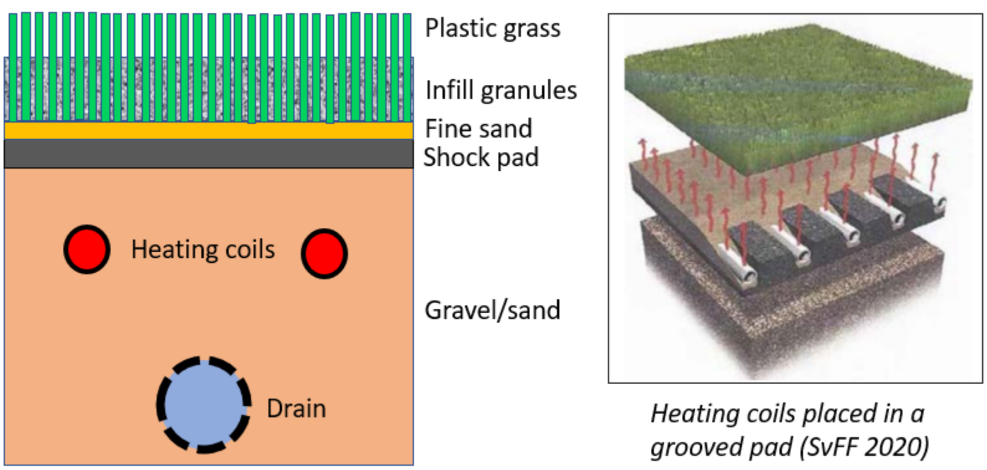
One environmental problem with AT fields is the filling material, which consists of granules that easily spread outside the fields in different ways. The granules are classified as microplastics (Danielski 2021). In September 2023 a new EU regulation - Regulation (EU) 2023/2055 (EU 2023**)** **-** bans the further use of such granules and stipulates that existing infills must be phased out. Instead granulates of organic material should be used, for instance cork or coconut fibers.

With few exceptions the heated soccer fields in Scandinavia are using district heating as the heat source, which has led to a steadily increased energy cost in later years, some 30 % only the last 4 years. This has become a challenge for both the owners (often municipalities) and the soccer clubs as users. One solution to significantly decrease the energy cost and this way secure full use of the heated soccer fields is to use GSHPs as a heat source. The energy cost reduction is estimated to be at least 70 % using underground thermal energy storage combined with heat pumps. Furthermore geothermal systems will also reduce the CO2 emissions in comparison with traditional district heating or fossil fuel boilers, in Swedish applications with 95 % or more (Andersson et al 2023).

ARTIFICIAL TURF HEATING SYSTEMS

Turf design

The installation of artificial turfs is normally designed to be certified by FIFA (Fédération Internationale de Football Association), who regulates the quality and maintenance demands for field certification (FIFA 2015). The design is principally the same regardless the field is heated or not, and the national soccer associations are supplying guidelines on how to construct and maintain the fields, (e.g., SvFF 2020). In the older design of existing heated fields in Scandinavia the coils are placed below the top structure, while in a more modern design the coils are placed in groves in the shock absorbing pad (Figure 1). The latter design makes the heating of the turf more effective. Such a system will mainly be used with an on-off strategy, while the older systems react slower and require operation for more hours.



Heating coils placed in a grooved pad (SvFF 2020)

Figure 1. Principal design of a heated artificial turf soccer field. Left: Traditional. Right: Later design

From top to bottom the traditional layout consists of a mat with plastic straws in which elastic granules of rubber are placed. Beneath the straw mat there is a thin layer of fine sand to level out any unconformities beneath. Under the sand layer there is a shock pad to improve the absorption properties of the turf system. The pad is slotted to make it permeable for rainwater drainage or melting snow. The lower layer is usually sand or gravel. At the bottom of the strata there is a drainage pipe system. The field surface has a slope of approximately 1% from the middle line towards the sides to promote runoff of water. The heating coils are commonly made of PEX with a diameter of 25 mm. The distance between the coils is typically 200 mm. Manifold pipes are commonly placed on the short side of the field.

Load demand and heat consumption

The heating load demand is primarily determined by the outdoor temperature and the desired capacity of the heated pitch. In Sweden the mean outdoor temperature varies with some 10°C from South to North, and practically the same is the case in Finland and Norway. The amount of precipitation also affects the heat load, especially if snow is intended to be melted on the soccer field.

The peak heating load is commonly designed for the lowest outdoor temperature that keeps the turf free of frost. This design also allows for melting of light snow precipitation at milder temperatures, while more heavy snowfall is removed mechanically by plowing and brushing. The most common strategy is to have the turf playable down to minus 15°C for training turfs and minus 20°C on arenas used for games (e.g., Ericson et al 2016).

The heating energy demand is in general related to the number of days with frost temperatures. These vary but are typically 200-250 days in the North, less than 100 days in the middle part of Sweden and even less than 50 in Southernmost parts of Sweden (SMHI 2023). For this reason, the energy demand is expected to be much higher in the North than in the South. The annual heating demand for the Swedish soccer fields ranges between 500 and 2,300 MWh (Lindgren 2013), while in Finland the demand varies between 155-3,000 MWh. A well-functioning heated field in Southern Finland requires 300–600 MWh per year (Hällfors 2021).

Based on a survey that covered 15 soccer fields located all over Sweden (Wedlund 2010), the energy demand was measured to an average value of some 800 MWh/year and with a variation between 500-1200 MWh. However, these figures cover only three months (January-March 2010). By adding two more months (November-December) this study indicates an average energy demand of approximately 1000 MWh/year, or about 150 kWh/m^2, year. The lowest values seem to be on arenas used for soccer teams in the lower leagues, while the highest consumption is connected to arenas where the national league teams play. This study also indicates that the energy demand in the North does not differ significantly from the South, probably due to limited use in the coldest part of the winter season.

In another study of a soccer field in Uppsala in the middle part of Sweden the energy demand was investigated for a period of two full years (Ericson et al 2016). The heat consumption for 2014 and 2015 was found to be 760 and 820 MWh/year respectively. The heated area was 6 830 m^2 and the specific use of heat then becomes approximately 120 kWh/m^2. In this pitch the heating coils are placed in the shock pad and the supply temperature is +20°C as lowest and +35°C as highest. The maximum heating capacity was in this case just above 300 kW (42 W/m^2) at minus 20°C outdoor temperature. This system is manually operated and there are reasons to assume that most of the other systems are manually operated with the on-off method and only used to prevent frost. However, there is a general lack of knowledge of how the system are actually controlled.

Most references indicate a supply temperature of +35°C as commonly used the coldest days in the winter. However, there is an example with supply temperatures up to +50°C or more (Wedlund 2010).

GROUND SOURCE HEATING SYSTEMS

The technology of using Ground Source Heat Pump (GSHP) systems is well developed in the Scandinavian countries. Smaller GSHP systems with one or a few vertical boreholes or a couple of groundwater wells are dominating. However, larger systems with several kilometers of total borehole length are steadily growing on the market, while groundwater systems are levelling out (Gehlin et al 2022). The larger systems are often supplying both heat and cold to commercial and institutional buildings and are referred to as Aquifer Thermal Energy Storage (ATES) and Borehole Thermal Energy Storage (BTES). Due to their ability to store heat from summer to winter, ATES and BTES systems would in theory be a first choice for heating of soccer fields in Scandinavia.

ATES systems for subsurface heating

Groundwater pumped from 10-15 m under the surface will typically have the same temperature as the average annual outdoor temperature. However, in areas with a long season of snow cover the temperature would be somewhat higher. This means that temperatures from 3-10°C are commonly found in densely populated parts of Scandinavia. The aquifers mainly consist of glaciofluvial deposits in the form of eskers and deltas. In this type of formations cost effective and high-capacity wells can often be drilled. The groundwater temperature may in some cases be high enough to keep the temperature of a heated soccer field above the freezing point at outdoor temperatures of several minus degrees. However, the use of ATES systems with heat pumps is more effective.

The advantage of using an ATES system is first of all the separation of the aquifer into a warm and a cold side. This makes it possible to produce a relatively high temperature as "free heating". Even if a heat pump is used for peak demands the groundwater is an excellent heat source that is favorable for the heat pump COP. The disadvantage is that suitable aquifers rarely are found in the immediate vicinity of a sport facility. Another factor that limits the use of ATES is restrictions in groundwater-use for heating purposes. Furthermore, the permit procedure for an ATES plant may take years and entails a significant cost. These disadvantages restrict the potential of using ATES.

BTES systems for subsurface heating

These systems consist of many vertical boreholes drilled into the bedrock. In Scandinavia the boreholes are drilled mainly with the air hammer drilling method, most often to a depth of 200-300 m in hard crystalline rock. The boreholes are fitted with single U-pipes that are connected in parallel by a horizontal pipe system. The boreholes are normally groundwater-filled. Thermal grout is occasionally used if stipulated by permit requirements. The dominating rock types are granites and gneisses with a mean thermal conductivity of approximately 3 W/m, K. The principal layout for a BTES application for turf heating is shown in Figure 2.

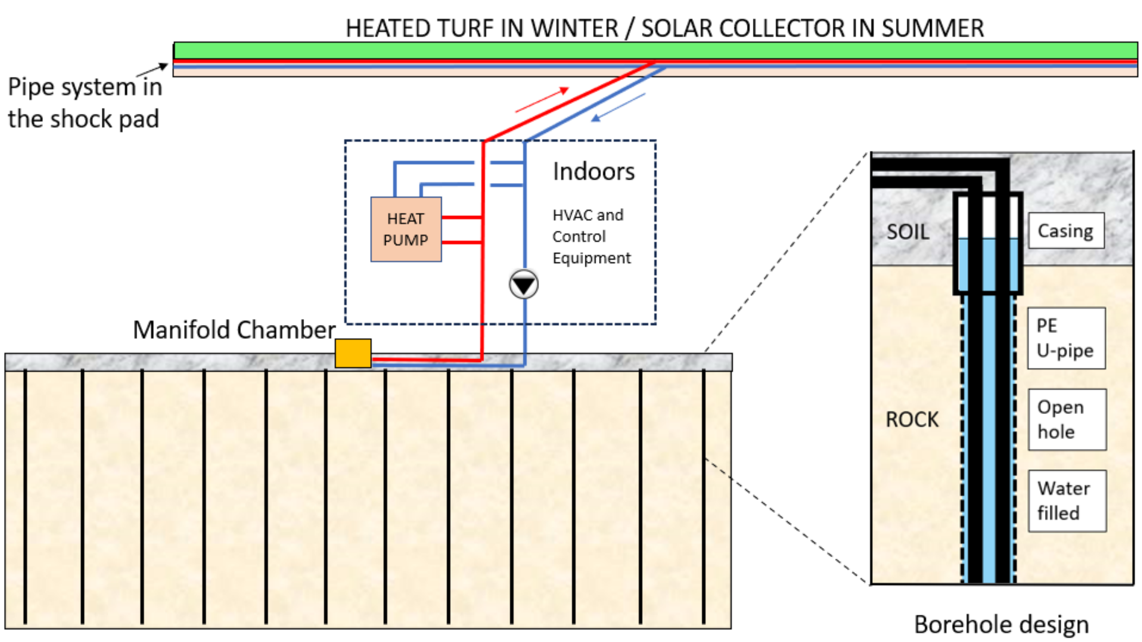


Figure 2. Principal concept of using BTES for heating of soccer fields

One advantage with BTES systems is that boreholes can be drilled in any geological formation. This makes the system applicable almost anywhere. However, the supply temperature will be considerably lowered due to the high thermal resistance of the borehole heat exchangers, making a heat pump necessary to meet the supply temperature criteria.

To keep the distance between the boreholes as short as possible it is essential that the soccer field is used as a solar collector during the summer season. The more heat that can be stored in the summer season the less spacing of the boreholes are needed. A way to limit the number of boreholes is to drill them as deep as the geological conditions admit. This way the geothermal gradient will help to increase the direct use of the BTES system by producing a higher temperature. In the Scandinavian crystalline bedrocks, the geothermal gradient is approximately 1,5°C/100 m.

Hybrid systems

In these systems excess heat, such as condenser heat from an ice hockey arena, is stored in the ground instead of being disposed of to the atmosphere (Figure 3). Chilling the condenser with the brine from a BTES system gives a win/win situation since BTES cooling is more efficient than using a dry condenser cooler at high outdoor temperatures.

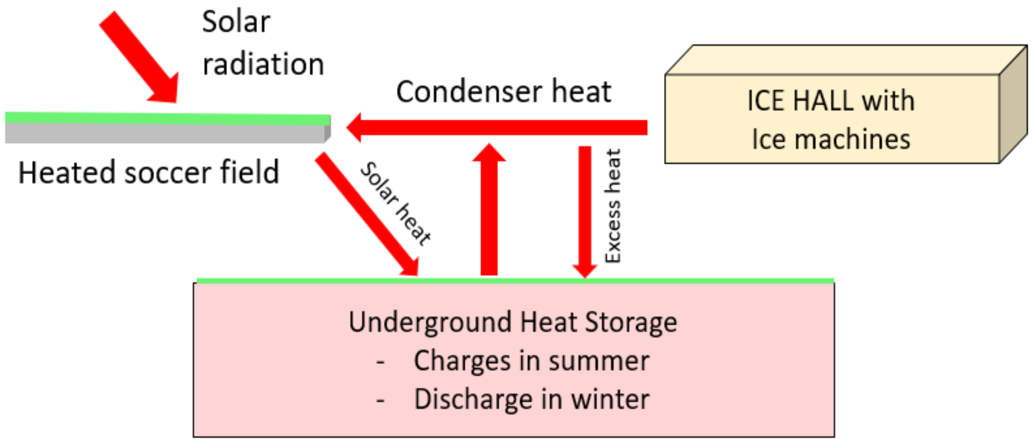


Figure 3. Principal concept of using hybrid geothermal systems in sport centers

In the figure condenser heat from an ice rink cooling system will primarily be used directly for heating the soccer field whenever the cooling machine is running for making and maintain the ice. However, seasons when there is no heating demand for the soccer field, especially in autumn and spring, the waste heat will be stored in the BTES system at a typical supply temperature of +35^{o}C. Together with captured solar heat from the soccer field, the BTES system will then heat the field in wintertime when the cooling machines are not in full operation. Due to the low thermal efficiency of U-pipes the supply temperature from the boreholes will not be high enough to cover all the heating as "free heating". For this reason a heat pump is needed to increase the supply temperature most part of the winter season.

An advantage of using the solar energy capture in summer is that the turf is chilled during hot summer days. In this way it will provide a more comfortable temperature for the players and also reduce the wear on the turf.

SWEDISH EXAMPLES OF EXISTING GEOTHERMAL SYSTEMS

There are just a few Swedish BTES plants for soccer field heating. However, details regarding their design and operational function are missing. The systems presented in Table 2 are all hybrid systems (Svensk Geoenergi 2018). The thermal capacity in the table includes the heat pumps in the system.

Table 2. Swedish soccer arenas heated with BTES systems

Name/City/year	No of boreholes/depth	Heating power (kW)
Backavallen/Katrineholm/2009	91/180 m	490
Kungsängen IP/Uppl. Bro/2009	40/180 m	350
Täby IP/Täby/2017	66/300 m	950
Torvalla SC/2018	91/230 m	950

In the case of Backavallen it is an ice rink cooling system that delivers excess heat to the BTES system. Most of the stored heat is obtained in the autumn when the first ice is made. In winter and early spring the cooling machines are run now and then to maintain the ice. Over a full season the machines emit about 1700 MWh of condenser heat, which is recycled in Backavallen's energy system. Some 1300 MWh of this heat is stored in the BTES that also stores around 400 MWh solar heat from the soccer field (SENS Undated).

The first ground source heated soccer field in Finland started operating in 2023. It is located in Sipoo close to Helsinki and was earlier heated by district heating. In 2018 the field was retrofitted with heating coils placed in a grooved shock pad covering 7 700 m². By load tests with district heating the heating demand at various temperatures was studied and used as basis for the thermal simulations of the coil system (Pikkarainen 2019). In a second study the number of boreholes, depths and spacing was simulated by using a design tool. In this study 28 boreholes of 275 m length were considered optimal (Hällfors 2021). The simulations show an annual heating demand of approximately 700 MWh of which around 600 MWh is covered by the BTES system at a maximum load capacity of 320 kW. For peak shaving 100 MWh district heating was used with an additional load capacity of 200 kW or a total of 550 kW (~70 W/m²).

In the city of Hallsberg in middle Sweden a soccer field is heated by groundwater that is pumped from a well that drains the sport facility area. The field area is about 7 000 m² and the heating coil system is placed 100 mm below the shock pad. The groundwater temperature is constant throughout the year at +8°C and pumped at a constant rate of 14 l/s. The water is first used for condenser cooling of a cooling machine in the nearby ice hall. When the machine is in operation the groundwater temperature increases to +14°C. The return temperature from the soccer field is +2°C at the lowest, indicating a maximum heating power of 700 kW (~100 W/m²). This capacity is said to keep the turf free of frost at an outdoor temperature down to minus 20°C (Carlsson 2010).

Economics

Some older figures for the investment in artificial soccer fields are given by Lindberg (2013). These indicate a cost of 10 million SEK (~1 million USD) for a new construction of which 3-4 million SEK (~300-400 000 USD) account for a hydronic heating system with district heating. These prices are likely to be considerably higher today, more than 10 years later.

There are only a few examples of recent reported costs for ground source heated soccer fields. The most remarkable is the plant in Hallsberg, heated by a an already existing water well combined with waste heat. The cost for the additional equipment is said to be 750 000 SEK (~75 000 USD). The investment would have been almost the same as for installing district heating. This means that there is no additional investment for the ground source system compared to district heating, and the only energy cost is for pumping the groundwater.

The additional investment in the BTES system at Backavallen was approximately SEK 9.4 million SEK (~0.9 million USD). With an energy saving value of 0.9 million SEK (90 000 USD) the system was estimated to be paid back over approximately 10 years (SENS undated). For the plant in Sipoo in Finland the investment in the BTES system is reported to be €660,000 and the annual energy saving to €90,000 (Östnyland 2023) giving a straight payback period of 7,5 years.

MARKET POTENTIAL DISCUSSION

In general, an increased energy cost for district heating in later years has resulted in restrictions in using already heated soccer fields to their full potential. This will primarily affect the younger players that already have problems to find proper fields for training and games. It also increases the risk of injuries caused by a slippery or frozen surface. A conversion to ground source heated systems will significantly decrease the energy cost and should therefore be of interest for the field owners and the soccer clubs.

The growth rate of new soccer fields with artificial turfs in Scandinavia is estimated to approximately 150 new systems annually. Presumably several of these will be equipped with subsurface heating coils. Furthermore, some of these fields are located where district heating is unavailable. For this reason, ground source heating systems seem to be a promising alternative as a heat source for these soccer fields.

Due to the regulation of prohibiting further use of micro-plastics as infilling granulates in turfs, most of the existing fields have to be refilled with approved granulates within the lifetime of the turf (about 10 years). This alteration may be an excellent opportunity to change the heat source to a less costly heat source. It is also an excellent opportunity to consider ground source heating if the turf is not already heated.

The initial investment cost for GSHP heating may be an obstacle that leads to hesitation. However, the cost-effective drilling technology in Scandinavia, combined with modern heat pump technology, make it likely that the investment cost for a properly designed BTES system will be paid back within a reasonable time. An additional market factor is that ground source heating is renewable, tax free, and that the greenhouse gas emission is limited to the use of electricity for operating the heat pumps and the circulation pump. Furthermore, BTES systems have a long technical lifetime (>50 years) and have practically no, or very limited maintenance cost.

All the factors described above will be favorable for marketing GSHP-systems in the sector of heating soccer fields with artificial turf but may also be applicable for other sport arenas with similar heating needs.

CONCLUSIONS

About 300 out of 3000 artificial turf soccer fields in Scandinavia are today heated, mostly by district heating. The main reason for heating the fields is to extend the season for both games and training over most of the winter, especially for the young players.

The consumption of heat varies with local climate conditions, but the average annual consumption is around 1 GWh, representing an energy cost of almost 1 million SEK (~100 000 USD) for a full-sized field using district heating. By using ground source heating this cost can be considerably lower. Examples from Sweden and Finland indicate a cost saving of 70 % or more (Seasonal COP >4.0 with an electricity price of 120 USD/MWh).

The specific heating capacity to keep the turfs frost-free down to an outdoor temperature of minus 20°C varies. Obtained data indicate 40-50 W/m^2 for turfs with the heating coils placed in the shock pad, while the coils placed in the sand below the pad may need up to 100 W/m^2. Due to the lack of detailed field measurements these values need to be improved by detailed analyses using in situ monitoring at several plants over at least one full heating season.

From a market point of view BTES seems to be the most promising ground source heating system since it can be applied in almost any geological condition. However, ATES systems are more efficient, and may for that reason be preferred in places where a suitable aquifer is available.

The energy cost of district heating has increased significantly in recent years and owners and clubs are looking for less costly alternatives. This may be one of the most important factors for further market growth, besides that geothermal energy is renewable, tax free, and less sensitive to increasing energy prices in the future.

There are already a few BTES applications operating in Scandinavia- They seem to have performed well and show a decrease in heating cost with 70 % or more. They also appear to be profitable since the additional capital investment in ground source heating systems is likely to be paid back in a reasonable time.

The references given in this paper represent insufficient information on the design and system control with respect to changing weather conditions. Furthermore, the actual inlet and outlet temperatures as well as the system energy performance are not very well known. For this reason it can be concluded that detailed case studies on existing applications are needed in order to 1: accurately predict the heat exchange between the embedded pipes and the turf surface as well as the absorption of solar heat, 2: improve the designing criteria, and 3: optimize system control. The main goal is to introduce GSHP systems as a sustainable and cost-effective heating alternative for soccer fields with artificial turf.

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