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The development of artificial turf in Swedish football fields

From the perspective of different stakeholders

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Short summary

The artificial turf market in football (hereafter referred to as AT) has several stakeholders, who set different priorities, depending upon their interests. The divergent priorities whether it is on player safety, game properties, the durability of the turf, cost, or environmental impact, may lead to a conflict of goals. In addition, external factors such as climatic conditions, societal structure, culture, available technology and materials, regulations, and policies may have an effect when it comes to making decisions regarding the procurement and maintenance of a football field, which add to the complexity of interrelation between the actors in this market-segment.

This report aims to unfold the viewpoints of the different stakeholders within the AT in Sweden, their interests, challenges, perspectives, and to provide a holistic understanding of the driving forces behind the rapid growth of AT fields in Sweden. Further, the report provides an outline of the knowledge needed to increase sustainable development in AT market.

The report is based on data from the literature, site observations, and qualitative analyses of semi-structured interviews. In total three sites with AT were described and 17 personnel were interviewed from 13 different stakeholders from seven categories, which include: different administrations from four municipalities, a national governing organisation, two AT suppliers, two football field maintenance offices, two governing sports organisations, a football trainer, and a professional football player from high division league. The interview guide contained questions about procurement processes, sustainability, maintenance, policy, and final disposal of AT fields. It is worth noting that the qualitative analysis of the interviews is based on the opinion of the above-mentioned interviewees, and may not represent the opinion of all the stakeholders, i.e., all the municipalities, AT suppliers, football clubs, and organisations, and therefore may not be generalised.

Since 2006 the number of AT fields in Sweden increased steadily with about 55 new installations per year on average, and today there are about 830 football fields of 11-man and over 250 smaller fields. The reasons for the rapid development of the AT, as analysed from the interviews, can be explained by the following arguments:

- The game of football gained extreme popularity. The number of members in the Swedish football association tripled in the last decade, and currently exceed one million, with about 600.000 active players all over Sweden.
- The large popularity of football provides a strong political voice to the football culture in society, and the demands from football clubs and football governing organisations, relating to football facilities, may hold great political weight, which could affect local politics.
- Densification processes in urban areas and increasing pressure on Land-use may be one of the factors that resulted in the shift from natural surfaces to AT fields in the last decades due to the higher utilisation rate of AT fields.
- In the Swedish sport model, most of the football facilities are owned and maintained by the municipalities, and the football clubs are not directly responsible for the installation and operation of these facilities. Their focus may lay on increasing football activities, and the availability of the fields for their members, which may also have a positive effect on their economy.

- According to the football's Laws of the Game, "The field of play must be a wholly natural or… a wholly artificial playing surface". During the winter season, natural grass fields are not playable in the Swedish climate.
- The wish to excel in all football divisions may be a reason for football clubs to prefer FIFA quality certified fields similar to the football field used by professional football clubs.
- The Swedish football season appears to be shifting towards the central European schedule and becoming longer with more activity during the winter season, which increases the demand by football clubs for further AT fields.
- The utilisation level of the existing football fields may be uneven, with high activity pressure during specific hours (i.e., between 16:00 and 20:00), and a perception of football clubs that further football fields are needed.
- Football clubs seem to ask mainly for further AT fields.
- There might be a shift in football culture to favour AT fields if these become the primary training and playing fields for youth players.

The analysis of the interviews identified 14 different themes, which were divided into four main clusters: Market aspects, Technological aspects, Design aspects, and Human aspects. Table A shows how these main clusters are related to each other, and Table B shows how the development of football and the need for knowledge relate to these four main clusters.

Table A. The relations of the four main clusters to each other; each cell in the table represents how the type of cluster in the rows affects the respective cluster in the columns.

	Market aspects	Technological aspects	Design aspects	Human aspects
Market aspects	There is a wide range of AT systems in the market, and new systems are emerging frequently. Suppliers seem to have difficulty testing each system, which may lead to a lack of sufficient documentation, especially concerning environmental aspects of AT. Municipalities may rely solely on the suppliers for knowledge, especially small–size municipalities with fewer human resources. Some municipalities may have one or only a few available suppliers due to location and perceived lack of market competition.	The type of AT and its final disposal are decided in the percurrent process, and managed by the supplier or sometimes by a third-party operator. Economical limitations were often referred to as the reason for the choice between final disposal alternatives. Mechanical recycling is the most expensive followed by incineration and landfill. Municipalities lack the manpower to track their disposed AT system, and it may take up to one year until the disposal is confirmed by the supplier.	There is a standard and recommendations for designing AT fields that claim limited granulate spreading. However, not all of the existing AT fields include such design. New procurements should consider such design measures, but strategies for the prevention of granulate spreading may differ depending on climate conditions.	There may be a lack of information, transparency, and trust in the AT sector. Municipalities employees may often find themselves navigating between political decisions, and environmental policies, a situation that may lead to higher uncertainty in the procurement, and thus to higher focus on price. Suppliers mentioned procurements that were biased toward specific technology and other suppliers, and that requirements may change during the procurement process by municipalities.
Technological aspects	Many of the existing AT fields are reaching their end of life and will need to be replaced soon. There is a concern relating to new technologies and their environmental implications that may only become apparent in the future. Sustainable solutions still have high costs, whereas budgets are a substantial constraint. Municipalities may not have the economical flexibility to afford to invest and experiment with new technologies. On-site separation and reuse of infills are claimed as a possible cost-effective solution, as recycling facilities are located outside Sweden with long transportation distances.	Maintenance is important for extending football fields' lifetime and may reduce the amount of infill needed, but still not all AT may be maintained properly due to the high costs involved, which include the use of machinery, energy, water, and newly added infill material. The environmental effects of maintaining AT fields may include the use of natural resources, GHG emissions, and the spreading of microplastics.	Snow removal was mentioned as the main cause for the spreading of microplastics, which could be partly reduced by design measures like snow storage at the edge of the football field, or relocation to a larger site with large volumes of snowfall. Under-soil heating systems may also reduce the spreading of microplastics by melting snow on site. During sunny days the temperature of the turf may rise, and cooling by water Irrigation systems may be needed. Such systems are costly and are not installed in every AT field.	The level and type of injuries on AT may depend on its technology, its age, its maintenance level, seasons and weather conditions, and the player (male, female, or youth). Injuries may be reduced by using under-soil heating that keeps the field frost-free, and by irrigation of the turf, which also improved playability and the performance of the AT field.
Design aspects	Urban areas with land-use pressure that undergo densification processes may prefer AT fields due to their higher possible utilisation rate in comparison for example to natural grass fields.	The FIFA quality pro program tries to ensure consistency in AT performance. It focuses on the development of 3G turf systems, and encourages the industry to continue its development with the aim to mimic natural grass surfaces in performance, appearance, and recently with minimum environmental impact, which is a substantial challenge.		Players are also a source for the spreading of microplastics. Brushing stations for removing granulate from shoes and clothes at the exit of the field can be a counteracting measure, but it seems that they are not frequently used even if there is clear information onsite.
Human aspects	Football is an extremely popular sport, and the football culture may have a strong political voice. Football clubs seem to lobby for additional AT fields that can be played all year round, and municipalities may desire FIFA-certified fields to guarantee "good" quality, although this is not a necessity at lower levels of the association football.	Most of the football clubs do not own and maintain their training facilities, but they may try to impose their demands on how the fields should be maintained, which can include expanding the football season into the winter months, and more available slots in certain times of the days (e.g., between 16:00 and 20:00).		Youth players are seen as the next generation of players, and thus should have the best conditions to excel, and may include access to AT fields. However, many youth players may end their football careers around the age of 14. Possible reasons include Inconvenient training slots and limited access to facilities, which could be enhanced during wintertime.

Table B. The development of football, and the need for knowledge in relation to the four main clusters.

	Market aspects	Technological aspects	Design aspects	Human aspects
The development of football	The development of football and its increasing popularity provide political weight for demands from football clubs. Such demands may concern the number of available AT fields, and may also affect the procurement requirements of new AT surfaces, e.g., choice of turf technology. The development of football and the increasing number of AT fields in Sweden results in larger turf volume that will need to be disposed of. Many of the existing ATs fields are reaching their end of life, and the pressure for finding circular end-of-life solutions increases.	The development of football may motivate football clubs to priorities achievement, and demand for the best available surface technologies, like certified AT surfaces. There might also be a football culture shift, in which AT fields may be perceived as the optimal playing fields for football. The development of football may intensify the maintenance work of football surfaces, in particular the recent development of 3G AT technologies, which include the use of special machinery, freshwater, energy, and materials.	The development of football can be characterised by development for uniform performance of football facilities and equipment, with the current best alternative to natural grass being the 3G turf system. The development of football, the fast growth of AT fields, and the lack of design measures may partially be responsible for the spreading of microplastics to nature. The development of football, its increasing popularity, together with urbanisation processes, densification of urban areas, and pressure on land-use favour AT surfaces in densely populated areas due to higher utilisation time in comparison to natural football surfaces.	The development of football and the interests in international football leagues and tournaments may create a need to extend the football season into the winter months, with demand for playing on artificial surfaces. The popularity of football increased significantly, and in the last 15 years, members in football organisations tripled (10% of the Swedish population), which stresses the need for additional football surfaces, including AT. The increasing popularity of football reached all levels of society, football has a unique potential to promote environmental sustainability in society.
The need for knowledge	Environmental knowledge of turf systems needs to be transparent and reliable and should be shared among all actors in the turf sector. Knowledge should also be reaching all municipalities and their different relevant administrations. Knowledge is also needed to reduce uncertainty in the procurement process, especially concerning environmental aspects.	There is a need for knowledge about the environmental effects of existing and newly developed turf systems with a life-cycle perspective and disposal alternatives. There may also be a need for knowledge about maintenance costs and the overall life-cycle costing of turf technologies. The development of AT demands knowledge and experience on maintenance methods that provide the best game performance with the minimum environmental effect. There is also a need for knowledge about the performance of new materials and AT systems in the different Swedish climates.	There is a need for knowledge about other types of materials and surface systems technologies that could be used for football. The focus of FIFA on 3G AT systems as artificial surfaces is not required in lower levels of the association football, and there is no need for a design that mimics natural grass. There might be a need for knowledge on how to mitigate the spreading of microplastics with cost-effective design measures, which could be applied in the different existing AT fields.	Knowledge is needed about the utilization grade of the existing football fields, which could help municipalities to avoid overexploitation of land for additional football surfaces. Knowledge may be needed about the users of the football field and their specific needs, which could help to make better decisions about the type of surfaces, its size, design properties, and level of maintenance. From an environmental point of view, every player can make a difference, but it might help if they knew the environmental impact of their football activities, and how it could be reduced. Knowledge may be needed about the type and frequency of injuries for different turf technologies, players' age groups, genders, and climate conditions.

Sammanfattning

Marknaden för konstgräs för fotboll har många intressenter med olika prioriteringar som varierar beroende på deras individuella intressen. De olika prioriteringarna, t.ex. spelarnas säkerhet, spelegenskaper, konstgräsets livslängd, kostnader eller miljöpåverkan, kan leda till konflikter mellan olika mål. Dessutom kan externa faktorer som klimatförhållanden, samhällsstruktur, kultur, tillgänglig teknik och material, bestämmelser och politik spela in när det ska fattas beslut om upphandling och underhåll av en fotbollsplan, vilket kan göra de inbördes förhållandena mellan aktörerna i detta marknadssegment än mer komplexa.

Syftet med den här rapporten är att åskådliggöra de varierande synpunkter som de olika konstgräsintressenterna i Sverige representerar samt vilka intressen, utmaningar och perspektiv de har, allt för att ge en helhetsförståelse av drivkrafterna bakom den snabba framväxten av konstgräsplaner i Sverige. Rapporten syftar även till att skissera grunddragen för de kunskaper som behövs för att stärka den hållbara utvecklingen i detta marknadssegment.

Rapporten bygger på data från litteraturen, platsobservationer och kvalitativa analyser av semistrukturerade intervjuer. Sammanlagt beskrevs tre anläggningar med konstgräs, och 17 personer intervjuades representerande 13 olika intressenter från sju kategorier: olika förvaltningar från fyra kommuner, en nationell styrande organisation, två konstgräsleverantörer, två underhållsförvaltningar, två styrande idrottsorganisationer, en fotbollstränare och en professionell fotbollsspelare från en hög division. Intervjuhandledningen innehöll frågor om upphandlingsprocessen, hållbarhet, underhåll, riktlinjer och sluthanteringen av konstgräsplanerna som avfall. Det är värt att notera att den kvalitativa analysen av intervjuerna bygger på de ovan nämnda intervjuobjektens åsikter och att dessa kanske inte representerar alla intressenters åsikter, dvs. alla kommuner, konstgräsleverantörer, fotbollsföreningar och organisationer, och därför inte kan generaliseras.

Sedan 2006 har antalet konstgräsplaner i Sverige ökat stadigt med i genomsnitt cirka 55 nyinstallationer om året, och i dag finns det cirka 830 11-spelarplaner och över 250 mindre fotbollsplaner. Anledningen till konstgräsets snabba framväxt kan utifrån intervjuanalyserna förklaras av följande:

- Det har blivit extremt populärt att spela fotboll. Antalet medlemmar i Svenska fotbollförbundet har trefaldigats det senaste decenniet och överstiger i dag en miljon med omkring 600 000 aktiva spelare i hela landet.
- Fotbollens väldiga popularitet ger fotbollskulturen i samhället en stark politisk röst och krav från fotbollsföreningar och styrande fotbollsorganisationer när det gäller fotbollsanläggningar kan ha stor politisk tyngd, vilket kan påverka lokalpolitiken.
- Förtätningsprocesser i tätorter och ökat tryck på markanvändning kan vara en faktor som lett till att man de senaste decennierna gått över från naturgräs- till konstgräsplaner tack vare konstgräsets högre nyttjandegrad.
- I den svenska idrottsmodellen ägs och underhålls fotbollsanläggningarna av kommunerna, och fotbollsföreningarna svarar inte direkt för att bygga och driva anläggningarna. Deras fokus kan ligga på att öka fotbollsverksamheten och hålla

planerna tillgängliga för sina medlemmar, vilket också kan påverka deras ekonomi i positiv riktning.

- Enligt fotbollens regelbok ”ska planen ha ett helt naturligt eller ... ett helt konstgjort underlag”. Under vintersäsongen går det inte att spela på naturgräsplaner på grund av det svenska klimatet.
- Viljan att nå toppresultat i alla fotbollens divisioner kan vara ett skäl för fotbollsföreningarna att föredra godkända FIFA Quality-fotbollsplaner, liknande dem som används av professionella fotbollsklubbar.
- Den svenska fotbollssäsongen verkar gå mot att likna det centraleuropeiska systemet och bli längre med mer aktiviteter under vintersäsongen, vilket ökar fotbollsföreningarnas behov av konstgräsplaner.
- Nyttjandet av befintliga fotbollsplanerna kan vara ojämnt fördelad, med högt tryck under vissa tider (t.ex. mellan 16 och 20) och föreningarna upplever ett ökat behov av fotbollsplaner.
- Föreningar verkar främst efterfråga mer konstgräsplaner.
- Det kan bli ett skifte i fotbollskulturen mot att föredra konstgräsplaner om dessa blir de tränings- och tävlingsplaner som ungdomarna oftast spelar på.

Analysen av intervjuerna identifierade 14 teman som delades in i fyra huvudkluster: Marknadsaspekter, tekniska aspekter, utformningsaspekter och mänskliga aspekter. Tabell A visar hur dessa huvudkluster förhåller sig till varandra och Tabell B visar hur fotbollens utveckling och kunskapsbehovet förhåller sig till dessa fyra huvudkluster.

Tabell C. De fyra huvudklustrens inbördes förhållande till varandra - varje ruta i tabellen visar hur typen av kluster i raderna påverkar respektive kluster i kolumnerna.

	Marknadsaspekter	**Tekniska aspekter**	**Utformningsaspekter**	**Mänskliga aspekter**
Marknadsaspekter	Det finns en mängd olika konstgrässystem på marknaden och nya dyker upp med jämna mellanrum. Leverantörerna verkar ha svårt att testa alla system vilket kan leda till bristfällig dokumentation, särskilt när det gäller konstgräsets miljöaspekter. Kommunerna kan sätta hela sin tillit till leverantörens kunskaper, särskilt mindre kommuner med liten personalstyrka. Vissa kommuner har kanske bara en eller ett fåtal leverantörer att tillgå på grund av det geografiska läget, och dessa upplevde bristande på konkurrens på marknaden.	Typen av konstgräs och bortskaffandet av planen i slutet av dess livslängd bestäms under upphandlingsprocessen och hanteras av leverantören eller ibland av en utomstående aktör. Ekonomiska begränsningar nämndes ofta som skälet till att man valde ett visst avfallshanteringsalternativ. Mekanisk återvinning är det dyraste alternativet, följt av förbränning och deponi. Kommunernas saknar personal för att spåra sitt bortskaffade konstgrässystem och det kan ta upp till ett år innan leverantören bekräftar bortskaffandet.	Det finns en standard och rekommendationer för utformningen av konstgräsplaner där begränsad spridning av granulat föreskrivs. Men alla konstgräsplaner har inte en sådan utformning. I nya upphandlingar bör hänsyn tas till sådana utformningsåtgärder, men strategier för att förhindra spridning av granulat kan variera efter klimatförutsättningar.	Det kan råda brist på information, transparens och tillit i konstgrässektorn. Kommunens anställda kan uppleva att de måste navigera mellan politiska beslut och miljömässiga riktlinjer, vilket kan leda till mer ovisshet i upphandlingen och därmed ökat fokus på priset. Leverantörerna angav att upphandlingar kan vara styrda mot en viss teknik och andra leverantörer samt att kraven kan förändras under kommunernas upphandlingsförfaranden.
Tekniska aspekter	Många av de befintliga konstgräsplanerna närmar sig slutet av sin livslängd och kommer snart att behöva bytas ut. Det finns en oro kring nya tekniker och deras miljöpåverkan som visar sig först i det långa loppet. Hållbara lösningar kommer att kosta mer, samtidigt som budgeten är en betydande begränsande faktor. Separering på plats och återanvändning av granulatfyllning framställs som en kostnadseffektiv lösning, eftersom återvinningsanläggningarna är belägna utanför Sverige vilket medför långa transporter.	Underhållet är viktigt för öka livslängden på fotbollsplaner och kan minska behovet av granulatfyllning, men alla konstgräsplaner kanske inte sköts på rätt sätt på grund av de höga kostnaderna för bland annat maskiner, energi, vatten och nytt fyllningsmaterial. Miljöeffekterna av konstgräsplanernas underhåll kan inbegripa växthusgasutsläpp och spridning av mikroplast.	Snöröjning nämndes som huvudorsaken till spridningen av mikroplast, något som delvis kan minskas genom åtgärder som snölagring i ena änden av fotbollsplanen eller transport till annan plats med större kapacitet vid kraftiga snöfall. Jordvärmesystem kan också minska spridningen av mikroplast genom att snön smälts på plats. Soliga dagar kan temperaturen på konstgräset stiga och kylning med bevattningssystem kan behövas. Sådana system är kostsamma och finns inte på alla konstgräsplaner.	Graden och typen av skador på konstgräsplaner kan ha att göra med planens teknik, ålder, säsong och väderförhållanden samt vilken typ av spelare som skadat sig (man, kvinna, ungdom). Det går att minska skadorna genom att använda jordvärme som håller planen frostfri och genom bevattning, vilket också förbättrade spelbarheten och konstgräsplanens prestanda.
Utformningsaspekte	Stadsområden med högt tryck på markanvändning som genomgår förtätningsprocesser kan föredra konstgräsplaner, eftersom de har högre nyttjandegrad än t.ex. naturgräsplaner.	Med FIFA Quality-Pro programmet försöker man säkerställa enhetliga prestanda för konstgräsplaner. Det fokuserar på utvecklingen av 3G-konstgrässystem och uppmuntrar branschen att driva vidare utvecklingen för att efterlikna naturgräsets egenskaper, utseende och nu på senare tid även minimera miljöpåverkan, en betydande utmaning.		Spelarna är också en källa till spridning av mikroplast. En borstningsstation för att få bort granulat från skor och kläder vid utgången till planen kan vara en motåtgärd, men dessa verkar inte användas särskilt ofta trots tydliga informationsanslag på plats.
Mänskliga aspekter	Fotboll är en extremt populär idrott och fotbollskulturen kan ha en stark politisk röst. Föreningarna verkar lobba för fler konstgräsplaner som kan användas året om och kommuner kan vilja ha FIFA-godkända fotbollsplaner för att garantera ”bra” kvalitet, fastän det inte behövs på föreningsfotbollens lägre nivåer.	De flesta fotbollsföreningar äger inte eller underhåller inte sina träningsanläggningar men kan likväl försöka ställa krav på hur planerna ska underhållas. Det kan gälla önskemål om att förlänga säsongen in på vinterhalvåret och ge tillgång till fler tider vissa tider på dagen (t.ex. mellan 16 och 20).		Ungdomsspelare ses som nästa generation fotbollsspelare och ska därför ha bästa förutsättningar att nå långt, något som också kan förutsätta tillgången till konstgräsplaner. Men många ungdomar slutar spela fotboll i 14-årsåldern. Som möjliga skäl till det nämns obekväma träningstider och begränsad tilldelning av plantider, något som också kan förvärras vintertid.

Tabell D. Fotbollens utveckling och behovet av kunskap i förhållande till de fyra huvudklustren.

	Marknadsaspekter	Tekniska aspekter	Utformningsaspekter	Mänskliga aspekter
Fotbollens utveckling	Fotbollens utveckling och dess tilltagande popularitet ger politisk tyngd bakom kraven som föreningar ställer. Sådana krav kan gälla antalet tillgängliga konstgräsplaner och även upphandlingskraven på nya konstgräsytor, t.ex. val av konstgrästeknik. Fotbollens utveckling och det ökande antalet konstgräsplaner i Sverige medför en större mängd konstgräs som måste avfallshanteras. Många befintliga konstgräsplaner närmar sig slutet av sin livslängd och trycket på att hitta cirkulära lösningar för de uttjänta planerna ökar.	Fotbollens utveckling kan motivera fotbollsföreningarna att prioritera framsteg och kräva bästa underlagsteknik, t.ex. godkända konstgräsunderlag. Det kan också komma till ett skifte i fotbollskulturen där man uppfattar konstgräs som det optimala alternativet för fotbollsplaner. Fotbollens utveckling kan intensifiera underhållet av fotbollsplanernas underlag, särskilt med senare tids utveckling av 3G-konstgrästekniker, däribland användning av specialmaskiner, dricksvatten, energi och material.	Fotbollens utveckling kan kännetecknas som utvecklingen mot enhetliga prestanda på fotbollsanläggningar och -utrustning där det bästa alternativet till naturgräs är 3G-underlagssystemet. Fotbollens utveckling, konstgräsplanernas snabba framväxt och bristen på utformningsåtgärder kan delvis vara orsaken till att mikroplast sprids i naturen. Fotbollens utveckling, dess tilltagande popularitet i kombination med urbaniseringsprocesser, förtätning av stadsområden och tryck på markanvändningen gynnar konstgräs i tättbefolkade områden tack vare högre nyttjandegrad jämfört med naturliga underlag.	Fotbollens utveckling och intresset för internationella fotbollsligor och -turneringar kan skapa ett behov av att förlänga fotbollssäsongen in på vinterhalvåret, med efterfrågan på spel på konstgjorda underlag som följd. Fotbollen har kraftigt ökat i popularitet och de senaste 15 åren har medlemsantalet i föreningarna trefaldigats (tio procent av den svenska befolkningen), vilket betonar behovet av ytterligare ytor för fotbollsspel, även av konstgräs. Fotbollens ökande popularitet märks i alla samhällsskikt och fotbollen har en unik potential för att stärka den miljömässiga hållbarheten i samhället.
Behovet av kunskap	Miljökunskaper om konstgrässystem behöver vara transparenta och tillförlitliga och bör spridas bland alla aktörer i konstgrässektorn. Kunskaper bör också nå alla kommuner och deras olika relevanta förvaltningar. Kunskap behövs också för att minska ovissheten i upphandlingsförfaranden, särskilt i fråga om miljöaspekter.	Det finns ett behov av kunskaper om miljöeffekterna av befintliga och nyutvecklade konstgrässystem med ett livscykelperspektiv och avfallshanteringsalternativ. Det kan också behövas kunskaper om underhållskostnader och konstgrästeknikens sammantagna livscykelkostnad. Utvecklingen av konstgräs kräver kunskap om och erfarenhet av underhållsmetoder som ger bästa spelegenskaper med minsta möjliga miljöpåverkan. Det finns också ett behov av kunskap om egenskaperna hos nya material och konstgrässystem i de olika svenska klimaten.	Det finns behov av kunskaper om andra typer av material och underlagssystemtekniker som kan användas för fotboll. FIFA:s fokus på 3G-konstgrässystem som konstgjorda underlag krävs inte på lägre nivåer av föreningsfotboll och det finns inget behov av en designlösning som efterliknar naturgräs. Det kan finnas behov av kunskap om hur man minskar spridningen av mikroplast med kostnadseffektiva designåtgärder som kan tillämpas på olika befintliga konstgräsplaner.	Det finns behov av kunskap om nyttjandegraden på de befintliga fotbollsplanerna som kan hjälpa kommunerna att undvika överexploatering av landanvändning genom byggandet av nya fotbollsplaner. Det kan finnas behov av kunskaper om fotbollsplanens användare och deras respektive behov som kan bidra till bättre beslut om typen av underlag, storlek, utformningsegenskaper och underhållsnivå. Från miljöhänseende kan varje spelare utöva stor påverkan, men det kan hjälpa om de har kunskaper om miljöeffekten av deras fotbollsaktiviteter och hur den kan minskas. Det kan behövas kunskap om typen av skador och hur ofta skador inträffar kopplat till olika konstgrästekniker, spelarnas åldersgrupper, kön och klimatförhållanden.

1. A brief history of artificial turf

Artificial turf (hereafter referred to as AT) is generally manufactured to replicate the appearance and feel of natural grass, and has a variety of applications, from landscape gardening to playgrounds and of course, for sport. AT was first introduced to the world at large in 1966 when it was installed in the Houston Astrodome, a covered baseball stadium in Texas, USA, to replace the natural grass surface, which failed to thrive due to the limited natural light. This surface, dubbed "astroturf" was a nylon product, consisting of fibres sewn onto a backing mat. "Astroturf" proved immensely successful in the world of baseball, where its use spread widely over the following decades.

Interest in the AT concept saw the technology spread to other sports. By 1969 the first NFL teams were using artificial turf, and during the 1970s, field hockey embraced the artificial fields, as they offered a vastly improved playing surface, with superior ball roll, bounce, and predictability. The Montreal Olympics in 1976 saw the first major international competition played on AT (won by New Zealand) and throughout the 1980s and 90s, there was a steady development in pitch technology, from the addition of a shock pad under the playing surface to decrease the surface hardness, and injuries, to the addition of sand infill to improve the wear of the pile and durability.

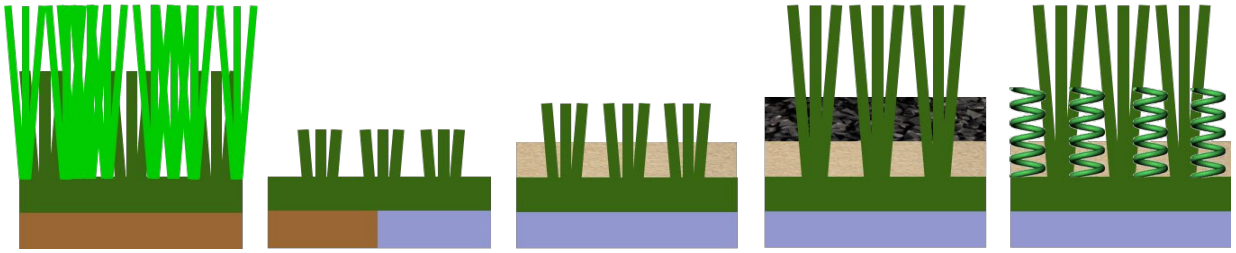
At the start of the 21st century, football entered the scene, which sparked a renewed interest in, and development of AT systems. The existing fields were considered unsuitable for football, so modifications were required to make the surfaces better suited to the game. AT pitches for football have become commonplace around the world, and today there are around 3,500 FIFA certified fields globally, although this only represents around 10% of the total turf market (FIFA, 2015).

1.1. Artificial turf technologies

Since its inception, there have been three official "generations" of artificial turf, as described below and illustrated in Figure 1. In addition, hybrid fields have been developed, which are 95% natural turf, reinforced with around 5% plastic fibres to improve durability and stability. The development of AT continues to progress quickly and claims for 4th, 5th and 6th generations of turf are being made as the technology advances. At the time of writing, none of these "next generation" fields have been approved by any official governing bodies as meeting the standard required for competitions.

1G - 1st generation fields (1960s-1980s) were the original AT surfaces, consisting of nylon fibres tufted onto a backing. The fields were initially laid directly onto concrete or sand bases, giving them a reputation for being very hard, with limited shock absorption. Developments to these fields saw a shock pad introduced, which improved the feel and safety of the surfaces.

2G - 2nd generation fields) (1980s-1990s) built upon the initial AT systems by introducing a layer of sand infill, which added weight to the field, and stabilized the vertical pile, leading to much more durable and stable fields. The use of infill to stabilize the pile meant that longer piles could be used, which increased the playability of the surface. Field hockey, in particular, capitalized on this technology, and it remains the preferred surface for high-level competitions (although the highest level of competition is still conducted on unfilled, irrigated 1G turf systems).



HYBRID	1G	2G	3G	4G-6G
Natural grass 5% artificial fibres	Plastic Fibres 12-15mm No infill	Plastic Fibres ~24mm Sand infill	Plastic Fibres 40-65 mm Sand infill layer with Rubbery granulate	Plastic Fibres 45-65mm Sand and coil-fibres minimize compaction of the "blade"
Elite football and rugby, and recently in cricket and golf	Clubs, Schools and Playgrounds, Field Hockey	Field Hockey, Padel, Tennis, Multi-Use Games Areas (MUGA)	Football, Rugby	Unknown
From 1990	From 1964	From 1970s	From 1998	From late 2010s
800-1000 h/y	800 (elite level) – 2000 (community level) h/y			Unknown

Figure 1: A description of the different generations and types of artificial turf, along with a description of the features that define each of the surfaces. The figure was created by Judith Waller.

1.2. Artificial turf system components

There are three main components in the AT system, as described below. The possibility of using different materials, dimensions, and configurations for different applications, in order to achieve different levels of performance or durability, for example, results in a large variety of turf systems on the market.

- **Carpet/pile:** A Polyethylene (PE) or Polyethylene (PE)/Polypropylene (PP) blend pile, with lengths from 40-60 mm depending on the intended use. The carpet generally has a backing, which can be a hot-melt plastic, similar to that of the fibres, or a backing of latex or polyurethane.
- **Infills:** A two-component system designed to stabilize the carpet, and provide the desired playing properties. A sand infill layer is used to weigh down the carpet, and to keep the pile oriented vertically. In 3G turf systems, this is topped with a granulate infill material, which increases shock absorption properties and improves the "feel" of the turf underfoot. A variety of infill materials can be used in 3G turf systems, however, the most common are the rubbery materials SBR (Styrene Butadiene Rubber), EPDM (Ethylene Propylene Diene Monomer) and TPE (Thermoplastic Elastomer). SBR is the most common infill material used within the EU, as illustrated in Figure 2. SBR is a popular choice for infill as the EU directive on landfill [1] stimulated the recycling of waste, and thus the production of rubber granulate from car tyres [2]. The tyres are cleaned, grounded, and the structural elements removed to produce the granulate used as infill [3], which makes SBR a low cost and readily available recycled material with the desired properties.

  EPDM (Ethylene Propylene Diene Monomer), a rubbery plastic, and TPE (Thermoplastic Elastomer), a block polymer combining rubbery and plastic properties) are other commonly used infill materials as alternatives to SBR. These compounds are most often made from virgin polymers. They are used in higher proportion in Swedish fields compared to the overall EU. Organic materials such as cork, coconut shell, bark and polymeric sands are still being investigated for their suitability.

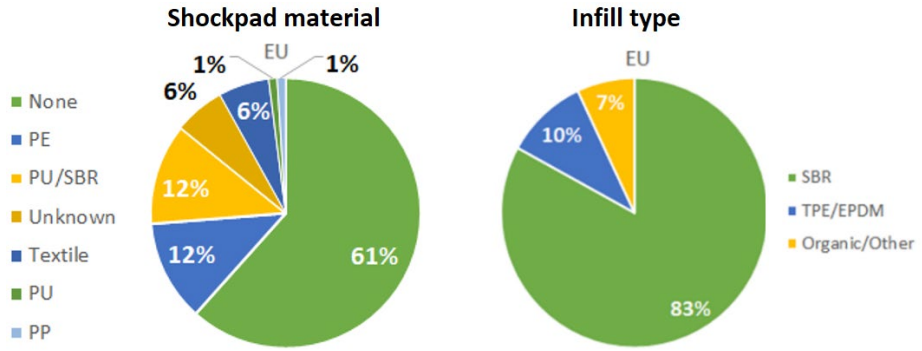


Figure 2: Shock pad type by material for installations in the EU, *and* infill type in the EU, source: Eunomia [4].

- **Shock pads:** The use of infill reduces the need for a shock pad to be installed under the playing surface, as the infill itself provides shock-absorbing properties. 3G fields using SBR as infill are least likely to have a shock pad, as the relatively low cost of SBR enables a higher level of infill to be used in the field, increasing its shock-absorbing capacity, and therefore removing the need to have an additional shock pad. Fields using EPDM or TPE, which are more expensive than SBR are more likely to be installed in conjunction with a shock pad. Where shock pads are installed, the majority are PE or a blend of PU and SBR, as shown in Figure 2.

1.3. Environmental aspects

In recent years, the sustainability of AT technology was questioned. One major environmental problem that is often highlighted in studies related to AT is the materials that are used in the turf system. The first issue is related to the loss of granulate from the pitch to the environment. SBR, EPDM and TPE are considered microplastic according to the EU's definition, which are particles containing solid polymer and are smaller than 5 mm in all directions [5].

It is estimated that 42,400 t of microplastics are unintentionally released to the environment each year in the EU alone, and of this 38% comes from AT infill (Hann 2018). The long-term environmental impact from the spreading of microplastics into the environment is unclear [6], so the EU appears to be applying the precautionary principle, as is looking to ban or restrict the use of microplastic infill, potentially as soon as 2028 [5]. There are also ongoing efforts to develop a framework to develop a risk assessment framework for microplastics, to identify potential hotspots and increase our knowledge surrounding the issue [7]. There have been environmental and health concerns related to the use of SBR, notably from the potential increase in polyaromatic hydrocarbons (PAHs) and Zinc. However, the impact on health has yet to be proven [3, 8, 9]. EPDM and TPE are primarily produced from virgin materials, and therefore don't contain any of the toxic materials that can be found in SBR due to its prior use as tyres. However, they are considered to be fossil-fuel intensive with high associated GHG emissions. They are inherently UV stable and can be coloured to match the field, which is an additional advantage over SBR.

The second major environmental issue is climate change. The Athena report, from 2007, was long considered the primary source of data regarding environmental impact, in terms of greenhouse gas emissions from AT fields [10]. The report concluded that considering a 9,000 m^2 field, over a 10-year period, a natural grass field will have a negative GHG emission of -16.9 t CO_2e, whereas a 3G AT field will have emissions equating to +55.6 t CO_2e. A recent study for the city of Zurich, Switzerland, compared the environmental impact of natural grass to AT, per hour of play. Whereas the environmental impact from natural grass occurred primarily during use (80%, mainly due to fertilizer and water requirements), the artificial turf's impact came from the manufacture of the materials used, and its disposal at its end of life, corresponding to 65% of total emissions [11]. This study, which included field infrastructure, estimated that the annual greenhouse gas emissions for undrained and drained natural grass fields (23,1 and 29.8 t CO_2e respectively) were significantly lower than unfilled (58,6 CO_2e) and filled plastic turf fields (85.5 t CO_2e). It should be noted that location and system boundaries play a role in the exact values obtained in such lifecycle studies, and could lead to significant variations in the results obtained.

The environment is only one aspect to be considered when addressing turf suitability, and within the AT industry, numerous stakeholders set different priorities when it comes to making decisions regarding the installation and usage of a field, depending upon their individual interests. Whether the focus lies on player safety, cost, durability or environmental impact, divergent priorities may lead to a conflict of goals.

1.4. Aim

The aim of this report is to map the perspectives, the challenges, and the interests of the different stakeholders, at all levels, from sports' governing bodies and associations to manufacturers and project leaders, to end-users. The main focus is on the game of football and its different associated stakeholders. Data will be collected from official publications, standards and legal requirements, and through interviews with concerned parties. Identification of conflicts and agreements that exist at all stages of the AT lifecycle will highlight possibilities to achieve common goals, which could form a basis for further development of regulations, new business models, and policies leading to more sustainable development.

2. Methods

This study is based on data from the literature, site observations, and qualitative analyses in the form of semi-structured interviews [12]. In total three sites with AT were observed and 13 different cases were analysed and 17 personnel were interviewed, which include: seven local government civil servants from different administrations from four municipalities (hereafter referred to as municipality employees), one from a national governing organisation, three personnel from two AT suppliers, two maintenance offices, two personnel from two governing sports organisation, one football trainer, and one professional football player from high division. All the interviews were performed online, except for the two maintenance offices, which were interviewed onsite in one of the football facilities in Sweden. The interviewed personnel may represent their own view, and not necessarily the view of their organisation. In addition, other AT sites were observed and described, adding to a total of three case studies. All of the interviews except for the on-site observation followed a semi-structured interview procedure where an interview guide was drafted by the researchers and then administered with small variations to the respondents. The interview guide contained questions about the procurement process, sustainability, maintenance, policy and final disposal of AT fields.

The actors were sampled based on a series of criteria. The sample techniques used are a mix of convenience sampling, diversified sampling and snowball sampling [12]. The municipalities were chosen according to size, geographical placement and participation in the Swedish municipality network of the client group for AT (BEKOGR - Beställargruppen för konstgräs). BEKOGR provided suggestions and contact details for some of the interviewed actors. This is what is defined as convenience sampling. Furthermore, the sampling was also diversified and aimed at achieving a multiplicity of perspectives. The respondents also provided us with additional names and potential respondents for additional interviews, which is snowball sampling.

The respondents were interviewed by one or two interviewers, which lasted between 30 minutes to two hours. Most of the interviews were conducted in Swedish, and the embodied quotes in the text are English translations. All interviews were recorded, transcribed and analysed using the qualitative analysis software NVivo, which facilitates the creation of different themes and codes based on the interviewees' statements [12]. The coding process is based on the discovery of patterns that show respondents' reasoning around a certain topic [12]. All participants were given a consent form to read and sign stating the scope of the study, the modes of data collection and storage as well as their rights in the event of a wish to terminate the participation. This is part of the ethical process of interviewing [12].

The results from the analysis of the interviews are based only on the opinion of the above-mentioned actors, and may not represent the opinion of all the actors, i.e., personnel from all municipalities, all AT suppliers, all football clubs and organisations, and therefore may not be generalised.

3. Policies and regulations

As described by [13], the policy terrain relating to AT is quite complex. Different aspects are involved such as people's health, the safety of the athletes as well as the functionality of the game. The environmental and health-related aspects of AT are regulated in different ways at different levels. For instance, Agenda 2030 [14], which was adopted in 2015, has goals related to water access, sustainable communities and good health, which can all be directly related to the use of AT [15]. Furthermore, AT can have implications related to sustainable consumption, climate change as well as marine environments and biodiversity [14].

When it comes to the game, both FIFA and UEFA have been developing the regulation and standards for artificial turf. This started in the late 90s to the early 2000s when the first games on AT were allowed in football up until 2004 when both UEFA and FIFA agreed on standards for AT [13]. In Sweden, the governance of AT is influenced by how policies and actors are organised and interact with each other. In this context, there is a strong focus on the local government [16]. Consequently, EU legislation is integrated with the national legislation and consequently the municipalities who have room to make decisions as long as there is no conflict with the higher levels of government.

Despite the complex policy terrain, there are no red-flags relating to areas where policies may conflict and generate environmental issues. Rather, policies concerning environmental issues relating to AT are potentially insufficient in their current forms. However, as to understanding of the environmental challenges coupled to AT increases, the development of new policies, regulations, guidelines and recommendations is expected to continue in parallel. Table 1 Provide a list of policies related to artificial turf, which will also be discussed in the following sections.

3.1. International and EU Level

3.1.1. Rules and Standards

3.1.1.1. Laws of the game

The game of football is played globally according to the "Laws of the Game", administered and maintained by the International Football Association Board since 1886. AT was first added into the Laws of the Game[1] as a permitted surface in 2004, and as of 1 July 2021, when the latest edition was published, the new FIFA quality marks became binding for all existing Quality Programmes.

3.1.1.2. Standards

To play at the highest level, e.g. international competitions, FIFA, requires that the football field is certified. The FIFA quality program certified its first field in 2001, and by 2005, the FIFA Quality system was widely accepted as the industry standard. Today there are around 3,500 FIFA certified fields globally, although this only represents around 10% of the total turf market [17]. FIFA's quality programme currently comprises of the following levels of certification, requiring that fields meet requirements relating to durability, resistance, safety and performance.

Table 5. Most relevant regulation regarding artificial turf.

Policies relating to:	International level	National level	Examples of implementation at a local level
Procurement	Directive 2014/24/EU on public procurement.	Swedish Public Procurement Act (Lag (2016:1145) om offentlig upphandling).	Municipalities try to formulate the procurement texts to fulfil their needs.
Technological Aspects	Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).	Swedish Environmental Code (Miljöbalk (1998:808)).	Municipal decisions and policies, such as the decision to not acquire new AT fields.
	Directive 2008/98/EC on waste Regulation (EC) No 1013/2006 on shipments of waste.	Swedish Environmental Code (Miljöbalk (1998:808)) – Swedish Waste Ordinance (Avfallsförordning (2020:614)).	Municipal local requirements for the end of life of artificial turf.
Design Aspects	FIFA/UEFA requirements are included in the Laws of the game (IFAB).	Swedish Football Association (Svenska fotbollsförbundet) follows IFAB rules – recently changed from the Nordic Standard.	Local requirements by individual football clubs.
	European Standards and Best Practices on AT Quality EN 14836: Synthetic turf sports surfaces -Resistance to artificial weathering CEN TR/ 17519: Synthetic turf sports facilities — Guidance on how to minimize infill dispersion into the environment.	No specific Swedish standards exist but follow the EU Standards, e.g. SS-EN 15330-1:2013 regarding synthetic turf for outdoor use - Part 1: Specification for synthetic turf surfaces for football, hockey, rugby union training, tennis and multi-sports use SS-EN 15306:2014 Surfaces for outdoor sports areas - Exposure of synthetic turf to simulated wear.	

- **FIFA Quality** standard is aimed at recreational, community and municipal football, where a field has an expected use level of around 40-60 playing hours per week.
- **FIFA Quality Pro** standard has higher performance and safety requirements and is designed to meet the needs of professional footballers. A pitch of this type is expected to have a usage of up to 20 playing hours per week.
- **FIFA Basic** is currently being rolled out, which will certify pitches that meet the required condition to play football well, and safely. The focus is on setting minimum standards while ensuring affordability for use at all levels of the game.

The European Committee for Standardization includes about 22 standards relating to AT surfaces. The main focus of these standards is on mechanical properties, and testing of different properties of the turf. Of these standards, there is only one with environmental focus: CEN/TR 17519:2020 - Surfaces for sports areas - Synthetic turf sports facilities - Guidance on how to minimize infill dispersion into the environment.

3.1.1.3. Other sports

Whilst football is the primary sport played on AT in Sweden, there is often a requirement that a pitch is suitable for different activities. Rugby and field hockey have well-defined requirements for turf certified for dedicated use for these sports, but FIFA, World Rugby and the International Hockey Federation have been working together to try and develop a one-turf standard, to allow all these sports to be played on the same field at a recreational level [18]. For a 3G field to be approved for use in competitive rugby, a standard is applied that is based on the FIFA quality standard. However, in addition to the FIFA tests, the requirement of a minimum pile height of 50 mm must be met, and a HIC (impact attenuation requirement) test must be passed to ensure player safety [19].

3.1.2. Representation

The different actors involved in the AT market have their interests represented by various groups. From an international perspective, the AT industry is represented by the Synthetic Turf Council International, which combines the North American (STC) and European, Middle East and Africa (ESTC) branches of the STC, and collaborates with others who operate primarily on a regional level, such as the STC LatAm, which focuses on Latin America. This is defined as a "non-profit trade association serving the synthetic turf industry." This council publishes reports and information material on AT and one example is the handling of the end of life and the available options. The STCI works in both sport and landscaping sectors, and focuses on advocacy, knowledge, marketing and networking, with a circular economy model.

An annual forum, The Grass Yarn & Tufters Forum, brings together companies from throughout the global supply chain for AT with the organisations that determine and measure the end-user requirements. It is organised by AMI, who plan and hold various events for the plastics industry globally.

3.1.3. Policies

3.1.3.1. REACH

As shown in Table 1, from a European perspective, AT is mostly regulated by The European Commission Regulation (EC) No 1907/2006 also known as REACH. REACH deals with the Registration, Evaluation, Authorization and Restriction of Chemicals in the European Union.

This legislation is implemented through the European Chemical Agency (ECHA) and in Sweden by the Swedish Chemicals Agency (KEMI). The regulation is the result of growing attention to the role of different chemical substances in the everyday life of people as well as the possible long-term effects on the environment [8]. REACH was first proposed by the EC in 2003 and was adopted in 2006. The REACH contains provisions for existing chemicals and has special deadlines, while newer chemicals that are not seen as already registered do not benefit from these provisions.

3.1.3.2. End of Life Policies

According to a report by the Environmental Working Group of the Synthetic Turf Council [20]: "When synthetic turf reaches the end of its service life and is lifted to enable replacement, the old surface becomes a 'waste' material according to the EU Waste Framework Directive (Directive 2008/98/EC)".

There are other issues connected to whether the materials composing AT, such as granulates from recycled tires, should be classified as 'waste' or not. According to the EU, the infill of AT is a compound. However, it is up to the producers to certify that a product has ceased to be a 'waste' and become something new [21].

3.1.4. Procurement

Public procurement in the European Union is regulated by the Directive 2014/24/EU. Some of the goals of this directive are to make the procurement process more flexible at the European level and to provide a way in which this policy can be used to pursue other policies often through public contracts. Environmental policies are one example. Furthermore, this directive aims at facilitating the procedures for small companies, at opening the procedures even for foreign actors, at supporting tools for electronic procurement, at preventing corruption, at professionalizing the contracting activity and helping with doubts regarding certain concepts [22].

Furthermore, public procurement is also integrated with the European Union Green Public Procurement program (EU GPP), which includes voluntary mechanisms to ensure that the purchases have a lower environmental impact [23]. Furthermore, the public procurement process can also be used as a way to promote innovation. However, for this to work, some criteria need to be satisfied. Some examples are coordination at different government offices, a combination with private demand and a clear connection between supply and demand even before the procurement process is initiated. Furthermore, changes need to take place at the level of the "procurement professional" [24]

3.2. National Level

3.2.1. Rules and Standards

In Sweden, the SvFF is the national organisation governing football, and the game is played according to the IFAB Laws of the game, with some local adaptations [25]. The rules relating to AT are the same as the rest of the world, in that the fields must be green, and be certified by FIFA for competitive use at higher levels.

A Nordic standard, equivalent to the European standards EN15330-1 exists (SKR, 2019), but this appears to have been overtaken in popularity within Scandinavia by the FIFA standard. For instance, from a pitch design perspective, the Swedish Football Association has recently changed from the Nordic/Swedish standard to the FIFA standards (see Table 1).

3.2.2. Representation

Within Sweden, two main organisations represent those involved in the AT product chain. Municipalities, who are the primary customers for the AT industry, are represented by the Swedish Association of Local Authorities and Regions (SKR). This is a political organization and acts as a union spokesperson for the municipalities in dialogue with the government, the Swedish parliament, the EU and other organizations.

In addition, in Sweden, there is an organisation, BEKOGR (Beställargruppen för Konstgräs), which groups people within the municipalities' leisure and environmental administrations, real estate companies, sports facilities, football associations and clubs. The BEKOGR is financed by the Swedish Environmental Protection Agency (Naturvårdsverket) and conducts " various types of feasibility studies, investigations and tests to increase knowledge about the environmental impact of AT and how it can be minimized."

3.2.3. Policies

As illustrated in Table 1, one of the main regulation that is involved in the process of acquiring, installing, and removing AT is the Swedish Environmental Code (Miljöbalken SFS1998:88). The Swedish Environmental Code is a legal instrument designed to, for example, achieve environmental goals. "The code promotes values and principles that need to be considered in decision-making and implementation, as well as norms that must not be overstepped. The code thus offers the municipalities considerable discretion in formulating and implementing environmental policies" [26].

according to the Swedish Environmental Code, there are authorities with a supervisory authority (tillsynmyndighet), which is mostly applied by municipalities and county boards. Municipalities have supervisory authority on AT. Municipalities generally have much freedom in a system as decentralized as Sweden. One example of the implemented measures by individual municipalities is the 'ban' of AT grass with infill or recommendations to not use them, as was the case in Lund this year.

The Swedish Environmental Code also establishes the duties of the Swedish Environmental Protection Agency (Naturvårdsverket), which is an information source and a supervisory actor for several issues, some examples are outdoor activities, sewage, and physical planning. It also aims at developing policies to reach national environmental goals. Concerning AT, the Swedish Environmental Protection Agency explains how the Swedish Environmental Code is applied regarding actors being required to show concrete plans to reduce the environmental impact of activities, such as the acquisition and maintenance of AT. Locally at a municipal level, this translates at a municipal level to some office, for example, the Environmental office or department which needs to apply the requirements dictated by the Swedish Environmental Code for AT.

3.2.4. End of Life Policies

If turf is to be recycled, it needs to be transported in between countries, the Directive 2008/98/EC on waste may be relevant, however, if the turf is intended to remain in Sweden, as for the case for energy recovery, the Swedish Waste Ordinance (Avfallsförordning 2020:614) is the relevant regulation.

3.2.5. Policies related to exercising and health

Physical activity and exercise are considered to be very important to people's health. The Swedish Public Health Authority has different recommendations for people's health that are based on World Health Organization's recommendations. In particular, the Swedish Public Health authority focuses on the positive effects of different kinds of physical activities. The recommendations are for different degrees of 'physical activity' depending on the age group. The benefits of physical activities are also outlined in a report that studied children's movement patterns [27].

3.2.6. Procurement

Another very relevant regulation in this context is the Public Procurement Act (Lag för Offentlig Upphandling - LOU) which implies that the acquisition of, for instance, AT is done through an open procurement process. This is also related to an EU framework so this is not exclusively Swedish legislation, as previously discussed. One important aspect of this law is the contracting of the service or product that has the most economically advantageous ([28].

SKR has also been active in promoting information exchange and lately they have also been working on the creation of a network to support different actors with the acquisition, management and disposal of AT as well as the creation of a framework agreement. This will allow the municipalities to acquire AT with a set of preset criteria to support them in the process. This framework agreement (ramavtal) is now available as a dynamic purchasing system (Dynamiskt inköpssystem - DIS).

4. Qualitative analysis

14 different themes were identified during the analysis of the interviews, which were divided into four main clusters: Market aspects, Technological aspects, Design aspects, and Human aspects, as listed in Table 1. These are described in sections 4.1.1, 4.2, 4.3, and 4.4 respectively. Each of the themes starts with a result summary from the interviews in bullet form, followed by a short discussion.

Section 4.5 include four case studies that provide additional information on the different themes. The case studies are snow removal, "dumping" of AT, design of football fields for recreational activities, and Trends in football surfaces. The first three are based on observations of AT fields, and the fourth is based on statistical data.

Table 6. List of themes of results, and sub-themes.

Market aspects	Technological aspects	Design aspects	Human aspects
Procurement • Information • Internal conflicts • Market	Material and turf systems • Turf systems • Infill • Constrains Maintenance • Machinery • Infill • Snow removal • Energy use • Freshwater use End-of-Life Concerns • Management • Disposal options • Costs	Biomimicry • FIFA Quality Programme • Development Field design Land use	Swedish sport model Surface and purpose Season and playing hours Youth players Behaviour Youth Players injuries

4.1. Market aspects

4.1.1. Procurement

Information

- There is a wide range of AT systems in the market, and new types of systems are emerging frequently, which can differ by type of materials, technology, and maintenance.
- There may be a lack of sufficient documentation, especially concerning environmental aspects of AT systems.
- Suppliers may have difficulty testing each turf system combination, due to the large variety.
- Municipalities may rely on the suppliers for knowledge.
- Small–size municipalities have fewer possibilities to acquire knowledge to support the procurement process due to less personnel, and resources.

Internal conflicts

- Municipality requirements for procurement may lie within different administrations, e.g., environmental aspects, and maintenance aspects may be within different departments.
- Conflicts of interest may exist between municipal council decisions, the administrations, and local politics. There could also be different preferences between different administrations within the same municipality, e.g., the trade-off between sustainability and costs.
- The strong football culture and its popularity may affect local politics.

Market

- Procurement requirements written in general terms, e.g., for the final disposal of used turf systems, may be subjected to various interpretations.
- Currently available sustainable solutions have high costs, whereas the budget is a substantial constraint.
- AT suppliers need to meet the environmental requirement at the lowest price.
- Due to location, some municipalities may have one or only a few suppliers to work with and perceive a lack of market competition.
- The procurement process may perceive to be biased toward a specific producer or a product.

In general, all interviewed actors mentioned that they would like to enhance sustainable development in the AT market. However, it seems that there may be a lack of knowledge, transparency, and trust in the football market segment of AT sector. Municipalities employees mentioned a lack of reliable environmental documentation of available turf systems, and that they often find themselves navigating between political decisions influenced by the football culture, and environmental policies, a situation that may lead to higher uncertainty in the procurement, and thus to higher focus on price [29]. Suppliers mentioned procurements that were biased toward specific technology and other suppliers, and that requirements may change during the procurement process by municipalities.

Broms et al. concluded that some of the procurement processes can lead to frustration, for example in situations, in which the procurement process may be manipulated to favour a certain agenda [30], or if there are differences in requirements among administrations within the commissioning organisation, e.g., quality vs. price [29]. To depart from the price-focused process, uncertainty should be reduced as to how quality may be considered in procurement [29], e.g., quality requirements concerning environmental aspects, and turf performance.

From the interviews, price-focus was mentioned, by respondents from both municipalities and turf suppliers, as the main constraint for not implementing the most sustainable solutions (see also sections 4.2.1 on sections End-of-life concerns and 4.2.3 on Material and Turf Systems), which may drive some suppliers to use unconventional means to win contracts, e.g., having their own interpretation of the environmental requirements, promoting new products as sustainable without scientific basis (greenwashing), and defaming the products of their competitors. It was also mentioned by one municipality employee, that procurements may result in appeals by suppliers that perceived that their

bids were lost based on shaky ground, and even misinformation by competitors, which in turn prolong the procurement process.

4.2. Technological aspects

4.2.1. Material and turf systems

Turf systems

- All respondents were aware of the environmental challenges related to granulate use in 3G turf fields.
- A preferred strategy that was mentioned by municipality employees to reduce infill in 3G turf systems is to use a shock pad in combination with a shorter-pile carpet, which requires less infill. Shock pads were also mentioned to have a longer lifetime than the turf, since they are not exposed to sunlight or direct wear from the players, and therefore do not need to be replaced as often.
- There is a concern relating to new technologies and their environmental implications that may only become apparent in the future.
- The properties of hybrid fields were perceived as good as natural turf.
- "One polymer" system would be easier to recycle but maybe more expensive to produce.

Infill

- Respondents were aware of future possible restrictions to SBR and other plastic granulate use in AT.
- SBR was mentioned as the most cost-effective solution with good performance properties. As a mechanically recycled material, it is associated with low energy use and emission during granulate production.
- SBR was also mentioned to be a good alternative if the spreading of granulate to the environment could be avoided or minimized.
- Bio-infills have not yet gained wide acceptance as proven technology among municipalities, especially in Northern Sweden.

Constrains

- Procurements may focus mostly on playing requirements and turf properties, and in particular, whether FIFA standards would be met, but there are municipalities with a focus on the need to select turf systems based on the environmental effects of maintenance and suitability for recycling.
- Municipalities may not have the economical flexibility to afford to invest and experiment with new technologies.

Even though most of the existing football fields do not require FIFA certification, the focus mentioned by all respondents is on 3G turf systems. Municipalities employees mentioned that they would prefer to invest in proven solutions, and are unwilling to take risks with new turf systems and infills. In addition, several types of bio-based granulate were mentioned, but their performance is not yet fully proven and was mentioned to vary with climatic conditions. Bio-based infills have high costs and are perceived as high investment risk. According to one of the municipality employees from the Northern parts of Sweden, bio-based infills are not an option for them due to the colder climate, instead, they use SBR due to its good performance and low costs. Municipality employees and suppliers mentioned two main strategies related to the use of granulate in 3G turf system: the first is the use of a shock pad with a shorter pile in new installations to reduce the total volume of granulate, and the second is applying measures to avoid granulate spreading (see section 4.3.2).

4.2.2. Maintenance

Machinery

- Part of the maintenance work needs to be performed after a specific number of play hours.
- Providing more available training slots will increase the maintenance work and the use of machinery required.
- Machinery used during maintenance has its own environmental impact.
- The use of machinery contributes to the wear of the pitch.
- The maintenance machinery needs to be cleaned from granulate after use to prevent spreading to the environment, especially if they are used in several football fields.

Infill

- The existing granulate in the turf carpet get compacted over time.
- To retain good football-playing properties new granulate need to be added periodically.
- During its lifetime, tens of tons of infill may be needed to be added to the turf, especially during the first years of use.
- Good maintenance may reduce the amount of infill needed.

Snow removal

- Mechanical removal of snow is perceived to have the largest effect on granulate loss and spreading from the football field, see Case study 1 in section 4.5.1.
- Light snow can be melted by under-soil heating – it is not perceived to contribute to granulate spreading.
- Snow could also be removed to the edge of the football field – if it is not contaminated it could be collected and placed back into the turf.
- At higher latitudes, annual snowfall volume can reach thousands of cubic meters per football field: Such amounts may need to be relocated out of the field boundaries, which requires extensive use of machinery.
- Old turf systems may also release microplastics from the turf pile.

Energy use

- Annual energy use for football fields with under-soil heating may be in the order of 1 GWh but can vary depending on climate conditions. The corresponding annual emissions from the energy production in the district heating may reach tens to hundreds of tonnes of CO_2e, see case study 1 in section 4.5.1.
- Under-soil heating is expensive to install, about 10 to 15 million SEK to construct, and therefore may not be widely used in all football fields.

Freshwater use

- Irrigation of the AT is needed for improved playability, performance and to reduce injuries to players.
- During a single match, about 21 m^3 of freshwater may be used.
- Irrigation of the AT during training is not normally practised, even if is requested by players. Keeping the AT wet all day long may result in an extensive use of freshwater, depending on weather conditions.
- Not all training fields are fitted with water sprinkling equipment, so players may have to train on dry pitches, which can be hard, and the ball movement is different to that on a watered AT field.

The perception of the football player was that AT requires much less maintenance than natural grass, which may be true. However, Maintenance officers described a reality in which AT fields require regular maintenance, especially for FIFA quality certified fields (see section 3.1.1.2). They mentioned that maintenance is important for extending football fields' lifetime, and for their performance. However, one municipality employee mentioned that due to lack of resources maintenance measures are not always performed in all AT fields. The football trainer and football player mentioned that surface properties may differ among AT fields with different technology and with the age of the field, but also the quality and level of maintenance may have an effect as well. The football trainer also mentioned that the playing tactics are adjusted to the specific football field in each match.

Maintenance officers described extensive use of machinery on AT fields. The use of machinery can vary considerably between different football fields, and includes brushing of the surface to ensure uniformity of infill, decompaction and subsequent replenishment of infill, cleaning of the turf from debris, snow removal, and removal of moss, algae and weeds, which may also require the use of chemicals. The use of machinery has its own environmental impact, and may also contribute to the spreading of granulate if not cleaned after use on the field, especially if the same machine is used for maintenance of several fields.

According to respondents from municipalities, snow removal is considered as the main cause for the spreading of microplastic and may require intensive maintenance, especially in Northern climates, (see Case study 1 in section 4.5.1), which is also supported by Anderson et.al [31], and Bø et.al. [32]. Some football fields are equipped with under-soil heating to thaw the field and keep it frost-free. The combination of AT and under-soil heating may extend the playable season by almost four months.

The maintenance costs of AT fields are not negligible, and during its lifetime may reach the total investment cost, depending on the turf system, utilization time, maintenance level, and climatic conditions. Still, it may be cheaper per utilised time as mentioned by municipalities employees. A study from Australia [33], calculated slightly lower maintenance costs for AT compared to natural turf for football, but the overall life cycle costing was more than twice for AT. These values have high uncertainty, and may not represent the conditions in Sweden, especially if calculated per utilised time.

For optimal performance and play conditions, AT requires watering. According to the football trainer and football player, the irrigation helps to reduce the surface friction and improve play quality, and in periods of high temperatures, to keep the turf to an acceptable temperature to reduce the risk of burn injuries. Maintenance officers mentioned that during a single match, the football field is irrigated three times: before warm-up, before the match itself, and at halftime, totalling around 21 m^3 of freshwater per match. The football trainer and football player also mentioned that although there was a preference for watering of a field for training sessions, this was not always conducted when requested. As a result, players may have to train on dry AT fields, which may be perceived as hard, and the ball movement is different to that on a watered field. Water also serves to stabilize the infill, consequently reducing the amount of infill lost to the environment. However, except for elite-level fields, AT fields in Sweden may not be fitted with irrigation systems.

4.2.3. End-of-Life Concerns

Disposal options

- Re-use and relocation of turf systems to other purposes than football is not recommended due to the risk for granulate spreading.
- FIFA quality pro certified turf systems that have reached the end of their guarantee period (about five years) can potentially be relocated and replace other used turf systems.
- There are few facilities for mechanical recycling of turf, all located outside Sweden.
- There are several facilities in different locations in Sweden that can incinerate used AT systems, but the option of incineration depends on the material composition of the turf system.
- New disposal technologies towards a closed-loop circular economy model, like mechanical and chemical recycling, are under development.
- On-site separation and reuse of infills (sand and granulate) from the turf system is claimed as a solution by turf suppliers, and practised by a few municipalities. However, the reuse of the infills depends on their quality.

Management

- Many of the existing AT fields are reaching their end of life and will need to be replaced soon.
- The final disposal of a used turf is often managed by the supplier of the newly installed turf system.
- In some cases, the turf system, or its components may be sent to a third party before its final disposal.
- It may take up to one year until the disposal of a used turf system is confirmed by the supplier.
- Municipalities lack the manpower to track their used turf systems and to ensure its arrival to the agreed final destination.

Costs

- Economic limitations were often referred to as the reason for the choice between final disposal alternatives. Mechanical recycling is the most expensive followed by incineration and landfill.
- Transportation costs for an entire used turf field can be expensive and may reach a few per cent of the entire procurement costs, dependent on the final disposal option.
- Transportation should be avoided following periods of wet weather, as the turf retains water and increases its weight, which increases the number of trucks required to transport it, increasing costs and fuel consumption. Weather is therefore an unknown variable during end-of-life handling.
- The supplier choice of final disposal and associated transportation costs in the procurement bidding process can affect its success, since the margins between different bids may be small.
- On-site separation and reuse of infills can reduce transportation costs of used turf systems, but may increase the costs of mechanical recycling of the remaining carpet, due to the loss of economic re-sale value of the infills for the recycler.

Respondents mentioned that many of the existing AT fields in Sweden are reaching their end of life, and should be replaced. The lifetime of AT system is 8-10 years, but due to the high installation costs, some are still in operation after 13 years of use. According to municipality employees, old football turf systems should be disposed, and not be re-used for other activities like playgrounds, as it could lead to the spreading of granulate. Economic limitations were often referred to by suppliers and municipality employees as the reason for the choice between incineration, landfill and recycling, with the latter often seen as the more expensive choice. The choice of final disposal, and its associated costs, was mentioned by one of the suppliers as a possible whitening factor in winning procurement bids Therefore, it is important that the procurement requirements for the final disposal of used turf systems should be specific, and not leave room for interpretation.

According to the respondent from a national governing organisation, there is no exact statistics about the final disposal method of the used turf systems in Sweden, and it seems that there is high uncertainty even within the municipalities about the final disposal of their own used turf. According to municipality employees, most of the used turf is probably sent to incineration in Sweden, which was mentioned as a common practice especially in northern municipalities. Turf systems are probably also sent to landfills, and some are mechanically recycled, but these are very few according to a respondent from a national governing organisation. "Dumping" of AT may also occur, as described in Case study 2 in section 4.5.2. On-site separation and re-use of granulate and sand from the turf system was claimed as a solution by turf suppliers, and municipality employees, which reduces transportation costs. However, the ability to reuse granulate and sand infills depend on their quality and may differ depending on the type of granulate and its state.

Suppliers mentioned that technologies are being developed to try and move towards a closed-loop recycling model, and there is growing interest in existing technologies including developments in mechanical and chemical recycling, which could achieve very low CO_2 emissions in comparison to landfill and incineration, but their price, including long-distance transportation costs, may still be high, and therefore cost-prohibitive for some actors [34].

4.3. Design aspects

4.3.1. Biomimicry

FIFA Quality Programme

- The FIFA quality pro certification scheme tries to ensure consistency in AT performance.
- Uncertified football fields have no restrictions, and any surface (natural or artificial) can be used. The performance of these uncertified fields can vary substantially, as discussed in section 4.2.2 for AT.
- FIFA quality pro certified systems are yearly tested and are maintained for a period of up to five years.

Development

- The technical advisory in FIFA is a collaboration between the turf industry, representatives of standard licenses, laboratory test institutes and member associations with the aim to regulate, and standardise AT field.
- The technical advisory can regulate to the extent of what is possible, what is realistic for the industry to achieve at a specific moment in time, and as long as there are solutions.
- The FIFA quality pro certification for professional 11-man artificial football surface focuses on the development of 3G turf systems.
- FIFA encourage the industry to continue its development on AT, and try to mimic natural grass surfaces in performance, appearance, and recently with minimum environmental impact, which is a substantial challenge.

The first law, in the laws of the game, states that: "The field of play must be a wholly natural or… a wholly artificial playing surface…". There is no mention of the type of natural surface or artificial surface which must be used. The first law also states that: "Where artificial surfaces are used in competition matches between…national football associations affiliated to FIFA or international club competition matches, the surface must meet the requirements of the FIFA Quality Programme...". According to respondents from governing sports organisations, the FIFA quality pro certification scheme ensures that certified AT fields will have consistent game characteristics. These fields are tested annually to remain certified and are maintained for a period of up to five years, which is generally the length of the producer guarantees that the field will meet the FIFA criteria, providing recommended maintenance schedules and usage limitations have been followed. Uncertified AT fields are not controlled in the same way, and as mentioned in section 4.2.2, may have a large difference in performance.

The process of regulation of artificial surfaces by FIFA seems to progress to the extent of what is possible, what is realistic for the industry to achieve at a specific moment in time, and as long as there are solutions. According to a respondent from a sport organisation., the aim of the technical advisory group at FIFA is to do just that. They meet about two to four times a year and discuss the development of AT fields. This relation between the standardization and the AT industry via the technical advisory may have an effect on the available technological solution for professional football surfaces. It could be understood that the properties of the field may follow the development of technical solutions, which was also an opinion mentioned by the respondent from a national governing organisation. According to one of the respondents from governing sports organisation, via the technical advisory group, FIFA encourages the industry to continue its development on AT, and mimic natural playing surfaces, in particular natural grass. The focus is mainly on the development of 3G AT surfaces, in particular for 11-man football fields, and aim to expand its influence on other types of sports.

4.3.2. Field Design

- Most of the existing AT fields were not designed optimally to limit the spreading of granulate to nature.
- There are recommendations for the design of new AT fields that aim to reduce granulate spreading further, which include: installation of brushing stations, stormwater granulate traps, asphalt surface around the pitch with an edge barrier.
- If spreading of microplastic could be limited, and granulate could be retained in the football plan area, SBR may be a better solution in comparison to virgin fossil-based like EPDM and TPE from an environmental perspective.
- Strategies for the prevention of granulate spreading due to snow removal may differ depending on climate conditions.

AT is designed to have a very similar look and feel as natural grass, in order to replicate the playing experience, but from an environmental perspective, these two types of fields are very different in terms of the use of natural resources, waste disposal, GHG emissions, and spreading of microplastics. A respondent from a governing sports organisation mentioned design recommendations for AT fields, which include: installation of brushing stations, stormwater granulate traps, asphalt surface around the field with an edge barrier. A technical report by CEN [35] also provide similar guidelines for mitigating granulate spreading and also had snow storage compounds, cleaning maintenance machinery, and brushing clothes and shows, but these measures may still not be applied in all AT fields, see case study 3 in section 4.5.1.

Strategies for prevention of granulate spreading due to snow removal may also differ depending on climate conditions and the amount of snowfall (see also sections 4.2.2 and 4.5.1), but also locations prone to extreme weather, like floods, may require new developments in pitch design to address these specific challenges. If the spreading of microplastic could be limited, and granulate could be retained within the football field area, SBR may be the preferred solution in terms of natural resources, emissions, land use, and price (see also infill in the Material and turf systems section)

4.3.3. Land use

- One AT field has a similar useful playing time as three natural grass fields due to a higher level of utilization and longer seasonal availability.
- AT fields are more common in large urban areas due to land-use pressure, while natural turf is more common in less populated areas.
- Since 2006 about 55 new AT fields were constructed on average each year (see also Case study 4 in section 4.5.4.
- The number of AT fields is expected to increase in the future.

In 2006 there were about 3900 natural grass and three AT 11-man football fields (see case study 4 in section 4.5.4). According to a respondent from a national governing organisation, due to urban densification, many of these fields made room for new urban areas. Since then, about 110 football fields were constructed on average each year, of which half were AT. Today there are about one thousand AT fields in total in Sweden, in which 830 are 11-man, and over 250 are smaller fields. Combining all AT surfaces, Sweden has approximately 7 km^2 of AT surface area within its borders.

Respondents mentioned that AT provides up to 3000 hours/year of useful playing time, depending on the turf system and location, and according to a respondent from governing sports organisation, one field made with AT have similar useful playtime as three natural turf fields. Using this reasoning, the current usable playtime has increased by around a third since 2006. Land-use pressure in densely populated areas may favour AT football fields due to their high utilisation rate. Less populated areas were mentioned by respondents to be able to have enough land for both types of fields, i.e., natural grass for use during the summer, and AT as a winter field.

4.4. Human aspects

4.4.1. Swedish sport model

- The Swedish model for sport is very successful, as it has contributed to a very broad, effective and relative cheap participation.
- Most football clubs do not own and maintain their training facilities, but they can set demands on how the fields should be maintained.
- The demands set by football clubs relate to the game of football, as this is their core business, and not environmental issues or sustainable development.
- The knowledge of football clubs concerning the environmental aspects of football may not be high.

The Swedish model of the sport is very successful, as it contributes to a very broad, and effective range of sports, which are relative cheap to participate in. In this model, most of the football facilities are owned and maintained by the municipalities (see Table 3) and rented to the football clubs. According to a respondent from a national governing organisation, football clubs focus on social sustainability, and their core business relates to the game of football, and not sustainable development, and so are their demands. One example given by maintenance officers is that football clubs occasionally complain about the maintenance of the football field if they lose a game. As mentioned by the football trainer and football player, there are no environmental coordinators or any environmental programs or goals in their football club, and the knowledge of the players about the environmental effect of football facilities may not be high.

According to municipality employees, the large popularity of football provides a strong political voice to the football culture in society and their demands relating to football facilities hold great political weight. An example of a common demand by football clubs is the construction of additional AT fields, as mentioned by municipality employees (see also section 4.4.2). Municipality's employees find themselves clamped between the football cultural politics, and environmental politics, or as one described as "pawns in the political game".

Table 7. Ownership and Maintenance of AT and natural turf (NT) Fields in Sweden, source SKR, [36]. Not shown in the table are full-sized hybrid pitches, of which there are at the time of writing, 12 in Sweden, mainly operated by municipalities. There are also a total of 1419 smaller-sized football fields of 7x7 of which 259 are constructed with AT.

Fields/Percentage	Municipality	Private	Non-Profit	Other	Unknown	Total
Ownership AT	618 (82%)	10 (1%)	122 (16%)	7 (1%)	N/A	757 (100%)
Maintenance AT	550 (72%)	20 (3%)	140 (18%)	39 (5%)	8 (1%)	749 (100%)
Ownership NT	1343 (52%)	66 (3%)	1165 (45%)	17 (<1%)	N/A	2591 (100%)
Maintenance NT	938 (36%)	49 (2%)	1338 (52%)	183 (7%)	83 (3%)	2591 (100%)

4.4.2. Seasons and time

- The Swedish football season appears to be increasing in length, with a shift towards more activity during the winter season.
- Football clubs are partly public-funded, which depends on the level of their activities.
- The utilization of the football fields is not uniform and varies depending on the time of the day, and the day of the week.
- A survey of the utilisation time of AT was mentioned as a tool to better utilize existing fields and to assess if there is a real need for additional AT fields.

In Scandinavia, the traditional football season runs from March to November, during the period where the weather is clement, there is no snow on the ground, and grass fields are generally (with the exception of the northern parts of the country) in playable condition. Throughout central and southern Europe, the majority of domestic seasons fall between August to May (a few teams have a month-long winter break integrated into this period). Top-level international tournaments, such as the Champions League, and Europa League, tend to follow the central European seasons, which has reinforced the need for elite-level clubs in Sweden to have access to training and match facilities outside of the traditional Swedish football season.

It is not only the elite levels, but it seems from the interviews that the entire Swedish football season appears to be shifting towards the central European schedule and becoming longer, as mentioned by maintenance officers. This brings with it accessibility issues, as stated by one of the municipality employees: “they do not shout for new natural grass surfaces. These are winter fields they need”. There was a perceived requirement for some municipalities to open fields earlier and to keep them playable for longer than the official season to meet the demands for football “all year round”, which provide more activities, and may have a positive effect on their economy, as mentioned by a respondent from a national governing organisation. However, prolongation of the football season is more difficult for municipalities in North of Sweden, which may conflict with the aim to provide similar playing opportunities and similar playing properties to all, as mentioned by a respondent from a governing sports organisation.

Municipality employees also indicated that the demand for new football surfaces may relate to the uneven utilisation level of the existing fields. There is a high demand from football clubs to schedule activities between 16:00 and 20:00 and in Fridays until 18:00, which was also mentioned by maintenance officers. The current number of football fields cannot provide the demand for these specific hours, and some solutions include the sharing of fields by several teams. One of the municipalities mentioned the importance of collecting data on the utilisation level of all football fields, which could be analysed to know if there is a base for the claim by football clubs for the need for new football surfaces, or if the problem could be resolved by optimisation of the utilisation of all the football fields within the municipality borders.

4.4.3. Football surface and purpose

- The aim of football organisations is to provide similar playing opportunities and similar playing properties to all.
- The wish to excel in all football divisions and youth is a reason for all players to wish to play on FIFA certified fields.
- When procuring a new AT field, municipalities may desire a FIFA certified pitch, to guarantee "good" quality, although this is not a necessity at lower levels of the game.

The performance requirements of elite football pitches are high. For example, FIFA's quality pro label is intended for high-level stadiums with AT pitches used for elite football clubs that include only about 90 football teams (man and woman leagues) in Sweden. For lower divisions, there are no restrictions on the pitch, and they could play on any surface. However, the wish to excel in all football divisions was mentioned as a possible reason for the demand for surfaces with the best performance by a respondent from a national governing organisation.

It was also mentioned by respondents that many of the existing football fields, including AT, provide access to the general public for free-time activities (see Figure 5), and for school children during school time. For these types of users, the performance of the field has minor importance, as their activities do not necessarily involve football. Municipality employees and respondents from national governing organisations stressed the need to be able to match the type of football surface to the user needs to facilitate maintenance and reduce environmental effects like the spreading of microplastics to nature

4.4.4. Youth players

- Football is seen as an inclusive sport and organized football is practised from a young age.
- Youth players are seen as the next generation of players and should have the best conditions to excel, which may include access to AT fields.
- Intensification of sports leads to specific training that may affect specific muscular groups.
- Many youth players end their football career around the age of 14 and only a few continue to train in football academies with aims to play at elite levels.
- Inconvenient training times and limited access to facilities leads to a lot of youths giving up the sport.

Sports activity in all its forms has positive health effects, both physical and mental, especially for teenagers [27]. A respondent from governing sports organisation mentioned that organised football includes youth players from all levels of society, with a high focus on integration. The youth are very important to the football clubs, as they are regarded as the next generation of players, and therefore should have the best conditions to excel. Youth football is played on both natural grass and AT fields. One municipality employee mentioned that there is a whole generation who grew up on AT, and they prefer to play and train only on AT, which may relate to the development of the football culture. The football

trainer mentioned that football was a lot of free-play and more variety was involved before, but today they are specialized quite early with more focus on specific muscles, which may affect the general strength of their body. The intensification of football from an early age was argued, by a respondent from a national governing organisation, to make football more exclusive, and may be reinforced by the conclusion from a study by UB [37] that most of the youth prefer to focus on self-development instead of competing against others. Few municipality employees also question the consequence of the intensification of the training and argued that the youth should diversify their activities, and not concentrate only on football, for example having different summer and winter activities. Winter football may also have higher pressure on access to facilities since only AT and indoor surfaces are playable during this cold period. Inconvenient training times, such as late evenings, and early on weekends were mentioned by the football trainer, as a reason for youth dropouts.

4.4.5. Behaviour

- Players may not brush the granulate from their shoes or clothes after training, which contributes to the spreading of microplastics.
- When AT is used by the general public and schools, proper equipment like shoes for AT fields are seldom used leading to excessive wear of the fields.
- Players are advised to distribute the training exercises all over the field, and not concentrate on specific spots, to reduce the wear of the turf and increase its lifetime but this is not often followed.

A code of conduct is a set of rules outlining the norms, rules, and responsibilities or proper practices of an individual party or an organization. Many sports and sports clubs have their own code of conduct including the Swedish Elite Football Association (SEF), which concerns the issues of discrimination, safety, cooperation, and respect [38]. Football is the most popular sport with 10% of the population as members (see Table 3), as such it could take environmental responsibility for its activities, for example, by enhancing sustainable behaviour via code of conduct.

Maintenance officers, municipality employees discussed several behavioural patterns that concern sustainability in football that could need measures of intervention. The first relates to the spreading of microplastics by players. It seems that players and other users of AT fields do not always brush the granulate from their clothes and shoes in the field even if such brushing facilities exist at the exit of the field with instruction signs. It was also mentioned that not all players can, or do change their clothes after training, and therefore transporting granulate large distances from the field.

Another issue is regarding the use of correct equipment on the AT field, especially shoes. Like many other sport surfaces, AT requires specific shoes, which have the correct sole to provide support on these surfaces and prevent injuries, but also be more durable against the AT's relatively abrasive surface, and help to increase its lifetime by not flattening the turf pile, as a flat-soled shoe does. The respondents mentioned that it is a problem in AT fields that provide access to schools, and this is also probably applicable to recreational sports.

The training pattern of the players on the AT field was also highlighted as an issue related to how behavioural practices can influence the life of a pitch. To increase the lifetime of the AT surface it is advised, to distribute the training exercises all over the field, and not concentrate on specific spots, otherwise specific areas of the field will be prone to extensive wear. According to maintenance officers, such information is provided to the football trainers and football players but is rarely implemented. The penalty spot, the centre and the side-lines were mentioned as the areas that are most prone to wear. It is possible to repair point damages, but with larger damaged areas the whole field needs to be replaced.

4.4.6. Players Injuries

A review study of 76 research articles [39] concluded that the differences in injury definition and the lack of details of the playing surfaces produced varying results from different studies concerning the rate of injuries on AT. The study also concluded that players perceived the fear of abrasion injuries as a major disadvantage of AT surfaces, regardless of the condition of the surface, the level of play, or the sport.

The study behind this report had no intention to reach the level of comprehensiveness of existing studies concerning injuries. However, from the interviews, the football trainer and football player mentioned that the level and type of injuries on AT depends on its technology, its age, how it is maintained (including irrigation and heating), type of player (male, female or youth), seasons and weather conditions, and even the type of warm-up before training. The type of injuries that were mentioned relates to bone membranes, knees, ankles, and wear and tear of joints and back.

4.5. Case studies

4.5.1. Case study 1 – Snow removal

The following information was collected during an onsite interview of the maintenance officers responsible for one of the football sites in Sweden. The site comprises two AT fields: one stadium football field certified by FIFA quality pro, and an adjacent training field, which is not certified. Both fields are equipped with under-soil heating, which is used to thaw the fields, keeping them frost-free even when temperatures drop below freezing. Without this heating, the fields would otherwise not be safe to play on due to being too hard and with an increased risk of slipping, thus extending the football season by a few months.

Small amounts of snow can be melted on the field itself and do not contribute to the spreading of granulate via snow removal. Machinery is used to help 'Wet' snow to penetrate deeper into the turf, where the temperature is higher. Snowfall of over one decimetre is shovelled by machinery to the edge of the field, which causes some granulate to be removed from the field. The field then needs to be brushed to ensure an even distribution of the remaining infill. Larger amounts of snowfall need to be transported to special snow storage within the site, which also relocates granulate, as illustrated in Figure 3. A 4000 m^2 snow storage site was constructed with a hard gravel surface to enable the granulate to be collected and reused in the training field if it is not too contaminated. Snow piles with granulate can be found all over the site, and most of the granulate is collected in the spring after the snow has thawed, but some is always lost to the environment.

Figure 3: Granulate (EPDM) on snow-pile, due to the snow removal process. The photo illustrates a snow storage area within a football site located in Sweden. The photo was taken in May 2020 by Judith Waller.

The football fields are unused during the winter but are prepared for the spring season start on the 15th of February. The accumulated snow on the fields needs to be relocated to the storage site, and then under-soil heating is used to thaw the field and make it playable. During the last winter, over 80 cm of snow were accumulated, which corresponds to around 6000 m^3 of snow per field. About 130 hours were needed to remove the snow from the field with the use of tractors, and trucks. The costs of under-soil heating were estimated to be 1 MSEK for both fields, which could roughly correspond to 340 tons of CO_2e annually from the district heating facility (using average energy resources in Swedish district heating plants and including emissions from biomass energy resources. Fossil based emissions are about 5% of the stated value). Here we use the conversion factors of 1 kWh = 0.88 SEK of delivered energy from the district heating plant [40] and 1 kWh = 0.3 kg CO_2e [40]. The energy resource in the Swedish district heating is mainly from the combustion of wood residues and waste products. The overall annual operating costs of the entire football site was estimated to be 5 MSEK, which includes personnel and running costs for machinery, energy, water, waste disposal, and added infill.

4.5.2. Case study 2 – "Dumping" of artificial turf

Figure 4 includes three photos that illustrate a "Dumping" of used AT. All the photos were taken from the same site adjacent to a football field with natural grass, and newly constructed Padel fields with AT and sand infill. It is a gravel site with nearby water bodies and forest areas. Photos 5a illustrates "Dumping" of a used AT system, while photo 5b illustrates the exact same area four months later, in which the turf carpet was relocated, living behind black granulate (SBR) all over the site. Photo 5c illustrates a "Dumping" of granulate and sand infill sacks. It was not the aim of this study to investigate from where the turf came from, who is responsible for this disposal method when it was disposed of, its final destination, or who will be responsible for the remediation of the area. However, a respondent from a national governing organisation mentioned that such method of disposal may still be practised, mainly by private- or football club owned football fields. The extend of this illegal disposal method of AT in Sweden is unknown and assumed to be small.

Photo 4a

Photo 4b

Photo 4c

Figure 4. "Dumping" of used AT systems (4a), spreading of granulate (4b), and "Dumping" of granulate, and sand infill sacks (4c). The photos were taken in the same location in Sweden. Photo 4a was taken in June 2021, while photos 4b and 4c were taken four months later in November 2021, source: author's photograph.

4.5.3. Case study 3 – Design of football field for recreational activities

Figure 5 illustrates an AT football field for recreational activities in one of the large Swedish municipalities. The field is accessible to the public and is located in a green urban park. The design of the field includes stormwater granulate traps, a granulate barrier that consists of an asphalt belt around the field, and a metal fence, which are all part of the recommended strategies to mitigate the spreading of microplastics to nature.

However, in this location, there were no brushing stations, and no visible information or instructions for players about how to minimise the spreading of granulate, as illustrated in the bottom picture to the right (Figure 5c). According to respondents from municipalities, granulate that is spread to the asphalt belt can be collected, cleaned and returned to the turf. However, traces of black granulate (SBR) can be found all around the exterior of the fence, as illustrated in the bottom picture to the left (Figure 5b). This granulate will need to be collected and probably disposed of if it is contaminated, e.g., with gravel or soil. It is also reasonable to assume that proportion of the infill that leaves the field enclosure is not collected and leaks out to nature.

Photo 5a

Photo 5b

Photo 5c

Figure 5. AT field in one of the large Swedish municipalities, source: author's photograph.

4.5.4. Case study 4 – Trends in football surfaces

According to SCB, the Swedish population is expected to continue to increase in the future [41], a densification process is still ongoing in half of Sweden's localities and occurs mostly in the largest urban areas and regional centres [42]. Therefore, it is possible to assume that the number of football fields, and in particular AT fields, will continue to increase especially in urban areas. If the current trend will continue, the number of 11-man football fields will reach the level of 2006, but with a higher proportion of AT fields, with an estimate of around one thousand 11-man AT fields by 2025 as illustrated in Figure 6.

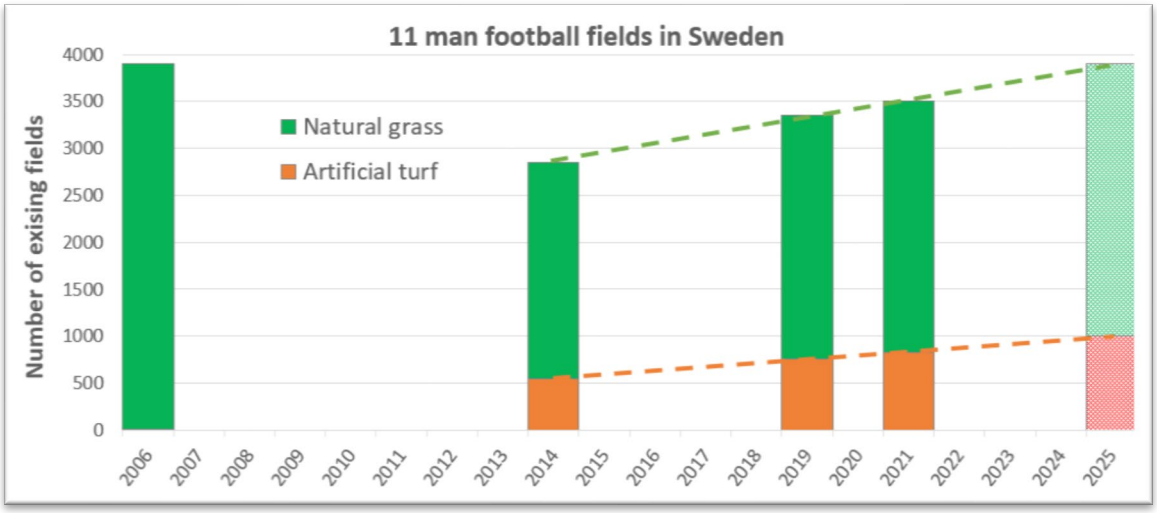


Figure 6. The number of 11-man Football fields in Sweden. Hybrid fields are excluded from this figure, but for completeness, 13 hybrid fields were registered in 2019, primarily in elite-level stadia, source: SKR [36], and by N, SvFF Callenmark (personal communication, March 2021).

The number of football fields in the future probably depends on the popularity of the sport, which has steadily increased and reached over one million members in both competitive and non-competitive settings, as listed in Table 3. According to a respondent from a governing sports organisation, the number of football clubs has decreased slightly, as clubs are merging in sparse areas due to the decline of the population. Currently, there are about 3000 football clubs spread all over Sweden, and 600,000 active players in competitive football with 240,000 men, 86,000 women, and 275,000 youth players. The number of registered players decreased slightly during the COVID-19 period.

Table 8: Number of active participants, and football clubs from 2014 to 2020, source: RF [43].

Year	2014	2015	2016	2017	2018	2019	2020
Men	296 052	340 933	593 170	444 832	648 049	727 425	821 736
Women	145 816	160 439	266496	209 333	291 152	326 814	369 185
Total	441 869	501 372	859 667	654 166	939 202	1 054 240	1 190 922
Clubs	3 230	3 242	3 202	3 230	3 251	3 209	3 095

5. Conclusions

Throughout the results, two motives repeated themselves: the first is the development of football as a sport, and the second is the need for knowledge. The development of football as a sport may be a motive for the presence and the increasing trend of the high number of AT fields in Sweden, and the lack of knowledge may be a barrier for sustainable development. Table 4 shows how these two motives are expressed in relation to the different themes that were discussed in section 4, and provide closure to the whole report.

Table 9. The relation of the different themes to the development of football of sport, and the need for knowledge.

	The development of the football	**The need for knowledge**
Procurement	The development of football and its increasing popularity provide political weight for demands from football clubs. Such demands may concern the number of available AT fields, and may also affect the procurement requirements of new AT surfaces, e.g., choice of turf technology.	Environmental knowledge of turf systems needs to be transparent and reliable and should be shared among all actors in the turf sector. Knowledge should also be reaching all municipalities and their different relevant administrations. Knowledge is also needed to reduce uncertainty in the procurement process, especially concerning environmental aspects.
Materials and turf systems	The development of football may motivate football clubs to priorities achievement, and demand for the best available surface technologies, like certified AT surfaces. There might also be a football culture shift, in which AT field may be considered as the optimal playing field for football.	Knowledge about the environmental effects of existing and new developed turf systems should have a life-cycle approach. Such knowledge is limited. There is also a need for knowledge about the performance of new materials and turf systems in the different Swedish climates.
Maintenance	The development of football may intensify the maintenance work of football surfaces, in particular the recent development of AT technologies, which include the use of special machinery, the use of freshwater, the use of energy, and materials.	The development of AT demand knowledge and experience on maintenance methods that provide the best game performance with the minimum environmental effect. There may also be a need for knowledge about maintenance costs and the overall life-cycle costing of turf technologies. Such knowledge may help to plan for future maintenance costs, to avoid unmaintained fields due to lack of resources.
End-of-life concerns	The development of football, and the increasing number of AT fields in Sweden results in larger turf volume that will need to be disposed of. Many of the existing ATs are reaching their end of life, and the pressure for finding circular end-of-life solutions increases.	There is a need for knowledge about recycling and re-use options of the different materials that are used in turf systems. Such knowledge may help to set requirements already in the procurement process to better allow re-use and recycling options when it reaches its end-of-life.
Biomimicry	The development of football can be characterised by development for uniform performance of football facilities and equipment, with the current best alternative to natural grass being the 3G turf system.	There is a need for knowledge about other types of materials and surface systems technologies that could be used for football. The focus of FIFA on 3G AT systems as artificial surfaces is not required in lower levels of the association football, and there is no need to mimic natural grass.
Field design	The development of football, the fast growth of AT fields, and the lack of design measures may partially be responsible for the spreading of microplastics to nature.	There might be a need for knowledge on how to mitigate the spreading of microplastics with cost-effective design measures, which could be applied in the different existing AT fields.

Land use	The development of football, its increasing popularity, together with urbanisation processes, densification of urban areas, and pressure on land-use favour AT surfaces in densely populated areas due to higher utilisation time in comparison to natural football surfaces.	Knowledge is needed about the utilization grade of the existing football fields, which could help municipalities to avoid overexploitation of land use for the construction of additional football surfaces.
Season and time	The development of football and the interests in international football leagues and tournaments may create a need to extend the football season into the winter months, and the higher demand for playing on artificial surfaces.	
Football surface and purpose	The popularity of football increased significantly, and in the last 15 years, members in football organisations tripled, which stress the need for additional football surfaces, including AT.	Knowledge may be needed about the users of the football field and their specific needs, which could help to make better decisions about the type of surfaces, its size, design properties and level of maintenance.
Behaviour	The increasing popularity of football reaches all levels of society and encourage football clubs to focus on social sustainably in its many forms, but as the largest sport in Sweden with about 10% of the population as active members, football may have a unique potential to promote also environmental sustainability in the society.	From an environmental point of view, every player can make a difference, but it might help if they had access to knowledge to understand how and why. The knowledge should be easily accessible for all football players from professional to recreational players.
Youth	The development of football and the specialisation of training from a young age may have both positive and negative effects on youth players.	
Players injuries	The development of AT technologies probably has had positive effects on players injuries.	Knowledge may be needed about the type and frequency of injuries for different turf technologies, players age groups, genders, and climate conditions.

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