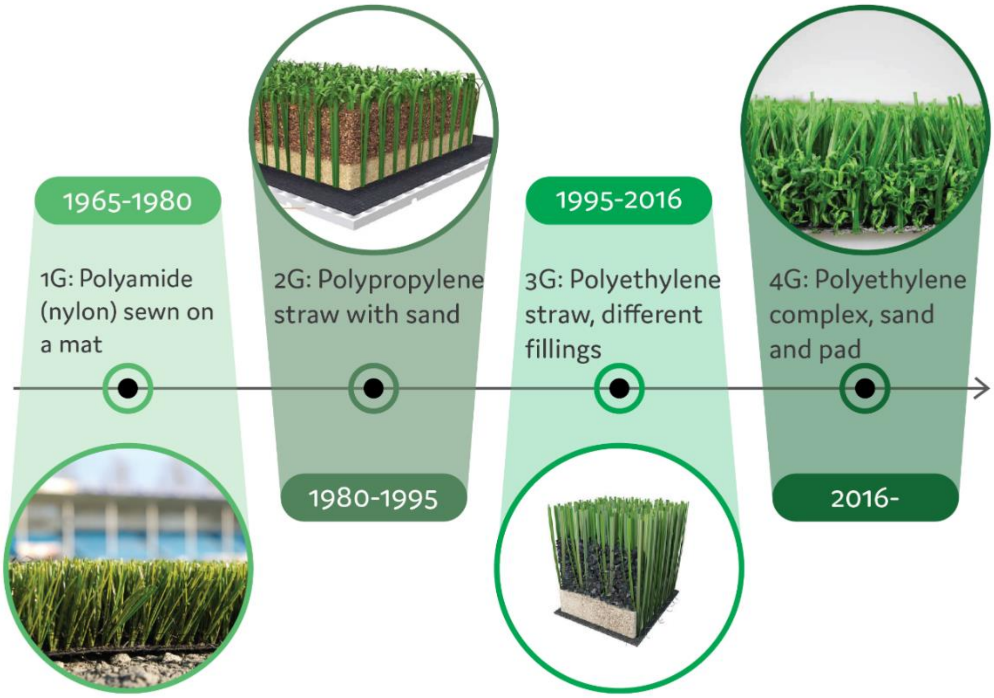
Report for the purchasing group of The Swedish Association of Local Authorities (SKL)

Market analysis artificial turf

2018-08-31



Content

Executive Summary

The market for artificial turf fields in Scandinavia developed rapidly from 2000-2015, and counts up to around 3 000 fields. The growth in numbers follows the trend of developing more appropriate turf systems, and the football sport's demand of year around access to fields for training. While turf design and test systems are developed for male elite level athletes, the vast majority of the users are children and youngsters.

Technology of artificial turf has developed in four stages or generations, starting with the 1G system first seen in USA in the sixties, and known in Scandinavia from 1977 to 1980. The 2G system introduced sand infill, and replaced the 1G system for football fields from 1980 to 1995. The 3G system brought synthetic infill as a replacement or addition to the sand, where rubber granulate, styrene butadiene rubber (SBR) was the new invention. Introduced in 1995, the 3G system has been the preferred solution up to the recent years. Cheap rubber granulate (SBR) processed from old car tyres, became an industrial product combining good sport's properties and low price. Some environmental concerns with the SBR allowed introduction of other infills, as TPE, EPDM and a variety of organic products like cork, coconut husk and sugar derivatives.

With a typical lifetime of 10 years, there is a fast growing aftermarket for removal of old turf systems and installation of new systems.

The growing number of fields has uncovered environmental impact aspects which now have reached a scale where attention from NGOs and politicians are growing. International research and studies shows that some of the products used, among others the rubber infill from old tires (SBR), also contains heavy metals and may oppose a threat to ground water aquifers.

Some of the major manufacturers in Europe are now in stage of introducing the 4G system, where the infill is limited to be just a thin layer of sand. The turf system is designed in such a way that there is no need of an elastic infill like the rubber granulates. At present, the 4G systems does not comply with the test procedures of FIFA for level 1-3. On the other hand, for all the fields used in lower level league and for children, the 4G system comply with present certification procedure ("Nordic certificate").

By introducing 4G systems as the solution by the next renovation of the fields, the environmental concerns related to artificial infill materials are facing substantial reduction. The total quantity of synthetic material reduction is in range of +80%.

The value chain of the artificial turf industry is fragmented, and there is a strong need of establishing a knowledge hub including manufacturers, distributors, civil contractors and maintenance contractors. Further, there is need of developing procedures for testing and verification of product, with respect to expected lifetime. The product declaration should also include details on raw material of the turf (virgin/reused), UV-resistance, and expected lifetime, taking into account climatic conditions as well as operational hours. Further, test methods to identify and quantify fibre loss are lacking.

In Norway, the project KG2021 is organised in order to build knowledge on the artificial turf systems in a broad perspective.

Scope of Project

SKL is in stage of developing a knowledge hub for artificial sports turf, with the priority on football fields. A reference group, comprising of municipalities, universities, industry and representatives from the environmental agency in Sweden is established. The aim of the work is to develop knowledge on how to build, operate, maintain and renovate sports fields containing artificial products like plastics and rubber.

The reference group has assigned Centre for Sports Facilities and Technology at Norwegian University of Science and Technology in Trondheim to write a report on marked and products in Scandinavia.

This document is discussing artificial turf system for European Football.

Figure 1: Granulates in action calls for new approach to turf design

Sports Turfs – an overview

History

The development of artificial turf systems globally is a response to climate conditions, user requirements and operation of the fields. In warm and arid regions, growing grass for golf turfs, lawns and other sports fields is difficult due to high air and soil temperatures and the lack of grass qualities fit for the wear and tear under these conditions. Water scarcity is another restriction, faced particular in touristic areas where turf sports are available. Costs of water – if available at all – may not allow the use of natural turf.

Accessibility of use is different for an artificial turf and natural grass. In Norway, natural grass is only available during the summer period when the climate is adequate, giving an approximation of 200-250 hours/year of use. Implementing a hybrid turf may allow for 2-3 times more time of usage.

The expectations from users to have a stabile turf quality through all seasons of the year may not comply with the seasonal variations in growth and development of pure natural grass systems.

Introduction of artificial turf systems has been a welcomed response to this call, and show a substantial growth in the global markets.

An artificial turf for low level matches and training can be used year-around, regardless of the local climate, giving a use of 1 500 - 2 000 hours per year. Artificial turf for elite level, is normally designed for 800-1000 hours per year (The Norwegian Ministry of Culture 2015).

Development of hybrid turf systems has followed the development of artificial pile systems, and is an interesting option, covering the gap between the traditional natural turf systems and the hi-tech artificial turf. Hybrid turf systems also allows for important climatic opportunities with respect to CO_2 – uptake and oxygen release.

In the global context, ball sports are an ongoing activity all over the world, and seasonal adaption considered as a hurdle to overcome. Different sports has chosen different strategies. While ice hockey and swimming nowadays is a pure indoor activity with respect to organized sports and competitions, golf, hockey, rugby and football is extending the outdoor seasons in order to unify the leagues and tournaments in different countries, organizing world cup championships etc.

This is in particular visible within football, where the European league have different seasons in different countries. While UK, Spain, Italy and France among others has a season from August to May, Scandinavia has a season from March to November (In Norway with a summer break), and Germany has August to May, but with a winter break. The larger tournaments (Champions league, Europa league) follows the south European season, and for Scandinavian countries, this may imply the need of access to proper football fields on annual basis in order to provide home match arenas as well as fields for training. For the major clubs in Europe, the turf is a part of the total club management and operation, and in order to keep a proper turf quality, replacement of the natural turf up to 2-3 times annually could happen.

The drivers for this development are less described. Unifying seasons in order to improve quality of the large tournaments clearly has a commercial driver. Extension of the seasons due to more clubs in the major league/more matches played may be an answer.

Moreover, the idea of more field access=>more time for playing=> higher skills developed by players seems to be another underlying driver. As long as football is an outdoor sport, climatic conditions will be an issue, and the dream of the perfect all-weather pitch will remain as so.

Following this development, a system of field-testing and certification of fields has been developed by the sports federation (FIFA). Further, there is an industrial product development process undergoing, where FIFA both takes the role of advisors and certification body.

The present test procedures developed by FIFA seems to be determined to fulfil requirements for senior male players. There is a need of understanding better the preferred field properties for kids and young players, and develop turf systems accordingly. At present, tests are subject to execution during first year of operation. There is no follow up test during lifetime of the fields.

After some years of transition, at least in the Norwegian market, artificial turf systems received approval for elite level matches, and the major part of the clubs at level 1-3 offers such systems on their home ground. In accordance with present FIFA certification guidelines, only turf systems of the 3G style are approved for the upper league levels (in Norway, level 1-3).

It should be mentioned, that club managers as well as players on elite level seems to prefer natural grass. Hybrid systems are a welcomed option in this respect.

Turf design

Turf design for football fields is part of the history of the sport, and with particular development the recent 40 years following the global information flow with respect to TV-transmitted matches from the major leagues.

Starting with sand and gravel pitches, the natural grass came as the solution for development of the game, less injuries of the players and more spectator-friendly arena. Accordingly, the climate impact gives restrictions on accessibility, and both rain and snow may cause suspension of a match on a field with natural grass surface. Expected lifetime of a properly designed and operated natural grass turf may be 5-10 years, while the time of usage is limited to around 200 h/year for elite level fields. Maintenance costs (fertilizer, grass moving, irrigation etc) may be substantial, much depending on local climatic conditions, user group's demand and opening hours.

As a response to the demand of more accessibility and predictive properties, the hybrid turf system was introduced in the 90-ies. In the hybrid turf, different concepts of reinforcing the natural turf with 10 - 30% plastic turf improves strength of the root zone and stability of the surface. The system is widely used in Europe, and as example, Lerkendal Stadion in Trondheim (home ground of Rosenborg FC) may hold the world's most northern hybrid turf for elite football. The hybrid turf is gaining popularity in Germany and other central European regions as the preferred turf by the players if natural grass is not applicable. Expected lifetime of a properly designed and operated hybrid turf system may be 20 years. Annual usage may be in range of 800-1000 hours. The hybrid systems are following three different direction of development:

- Root zone low layer reinforcement
- Turf reinforcement by use of plastic piles, around 5% of the straw numbers
- Root zone upper layer reinforcement

Artificial turf systems were introduced as the long lasting, year-around solution for football fields. It has developed by four generations of system from 1G to the upcoming 4G systems introduced the recent 1-2 years. Since introduction of the first generation (1G), there has been a continuous development of fibre material, composition and design, as well as fibre density (no of fibres pro area, weight pro area). Experience from the first generations also proved that fibres exposed to UV radiation from sun degraded over time, a known process for plastic products in general. Adding UV stabilizers may retard the development, but these additives rise costs, and the environmental impact is subject to further research. There is a trade-off between lifetime, environmental impact and costs.

The foundation of the field comprises in any case of fine sand and gravel or crushed rock, forming a subbase. Base foundation and a drainage system are applied in accordance with local conditions and guidelines (Magnusson 2017).

The 1G systems constituted of an artificial turf tufted on a backing, more like a carpet. The systems were normally installed (or rather rolled out), on sand, concrete or asphalt base, and gave a rather rough response to the player with respect to absorption and suppression properties.

Figure 2: 1G-system without any infill

The 2G system developed the concept by introducing a sand layer on top of the backing, giving stability and weight to the system, and allowed the turf to have a more stable structure. Further, the absorption and suppression properties improved accordingly. Using the sand layer allowed for increase of the height of the fibre, with subsequent improvement in interaction between ball and turf. In dry periods, dust from sand may cause improper air quality above the field, and the systems are normally including irrigation systems to avoid the dust formation, and reduce the friction properties of the system.

Figure 3: 2G system with sand infill

The 3G artificial turf system is for now the most commonly produced turf for football fields. The system includes an additional infill material, and in some systems, a soft PAD applied below the backing in order to improve the absorption properties of the system. The recent years, various infill materials have been introduced, as well as different PAD-designs holding different hydraulic properties, materials composition thickness and on-site/off site manufacturing.

Artificial turf systems had a poor reputation after introduction of the first and second-generation. The 3rd generation has proven far better properties for the athletes. However, there are still issues regarding friction and absorption related to injuries (McGhie 2014). Further, there is a need of research on the leg-shoe-turf interaction for young athletes.

Artificial turfs are supposed to provide the characteristics of a natural grass football field. The level of comfort and protection that is required should be sufficient for athletes using the field. Figure 4 describes the composition of 3G artificial turf.

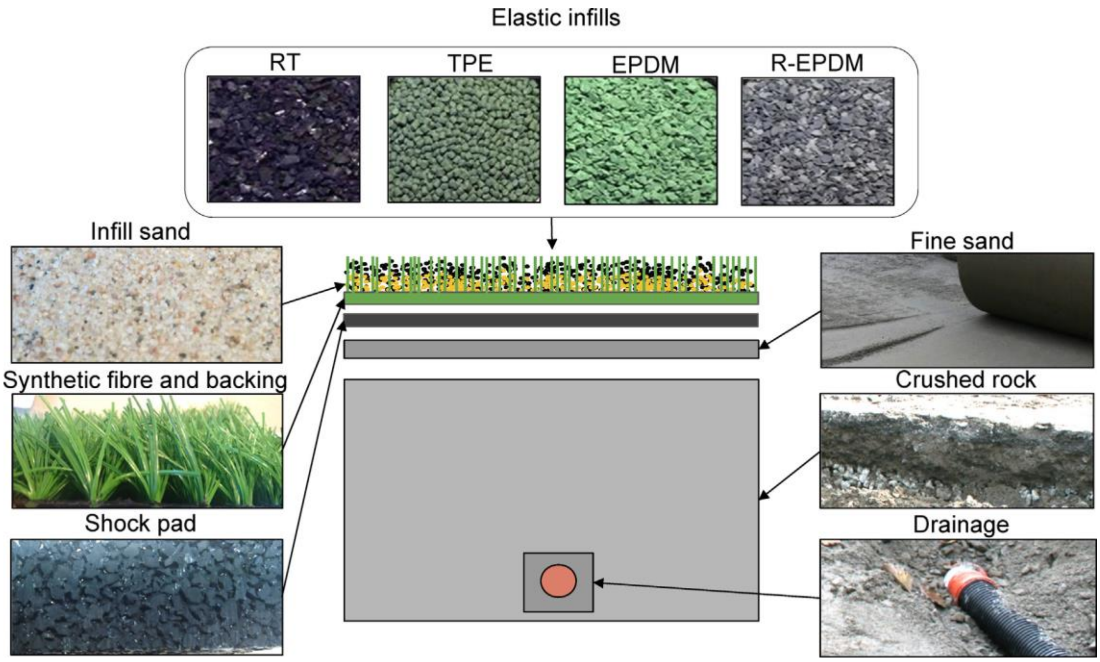


Figure 4: 3G systems (Magnusson 2017)

A shock pad is be applied underneath the synthetic carpet. Depending on length of the fibers, between 15 - 35 mm elastic infill applied on top of the sand layer will improve the absorption properties and to hold the piles in position. In present 3G systems, fiber length may be in ranges from 40 – 60mm. The free height of the fibers over the added granulate should not exceed 15 mm (The Norwegian Ministry of Culture 2015).

The elastic infills may be of various origin:

Figure 5 : Infill products (Magnusson 2017)

Most widely used is the SBR, deriving from old car tires, grinded and refined with respect to separation of rubber from steel cord and other structure elements.

SBR is a mixture of products used in the tire production (ECHA 2017). Heavy metals is added during production of the tires, and subsequently present in SBR, where the initial purpose is to improve the quality of the tyre with respect to ozone and UV-impact, aging etc.

An optional infill may be EPDM (ethylene propylene diene monomer), a synthetic vulcanized rubber polymer. An advantage of EPDM is that there is no addition of anti - ozonants to the rubber as an UV-filter, since the polymer is already resistant to weather and daylight (Nilsson 2008). EPDM can be produced both from virgin and recycled rubber (Mount Sinai 2017). Research has shown a variation in the quality of EPDM, and producers seem to add different chemical additives (COWI 2012). High concentrations of phthalates have been detected in EPDM. The zinc leaching from EPDM infill is, however, significant lower than from SBR (Nilsson 2008). Poor quality EPDM will during use crumble easily, reducing the quality of the turf (PlanMiljø 2017).

If infill without rubber-based products is preferred, the use of TPE may be an option. TPE (Thermo Plastic Elastomer) granulate is specially made for use on artificial turfs and contains less organic pollutants and heavy metals. TPE is composed of block polymers or a mix of plastic and rubber. Block polymers differs from rubber since there is no vulcanization involved in the production, reducing the concentration of zinc (COWI 2012). TPE may not be recycled together with the fibers, but will need a separate recycling line.

Available in the market is also infill made of pure polyethylene, same material as the turf material. Lower weight may reduce transport costs, but on site, there is a risk of the infill to flush off the pitch during heavy rain or flooding. The (green) color will reduce the heat accumulation in the surface during sun exposure. During renovation, this product may be recycled together with the turf, making the supply chain simpler and processing costs lower. Snow moving may cause removal of the granulate particles from the field.

The recent years, some organic products, like cork, coconut husk and sugar straw derivatives, are introduced.

The Scandinavian markets have a fairly different approach to the use of infill. While Sweden reports 60-70% use of SBR granulate (Magnusson, Eliasson et al. 2016), Norway reports in range of +85% (The Norwegian Football Association 2018).

In the European market, the use of infill shows this spread:

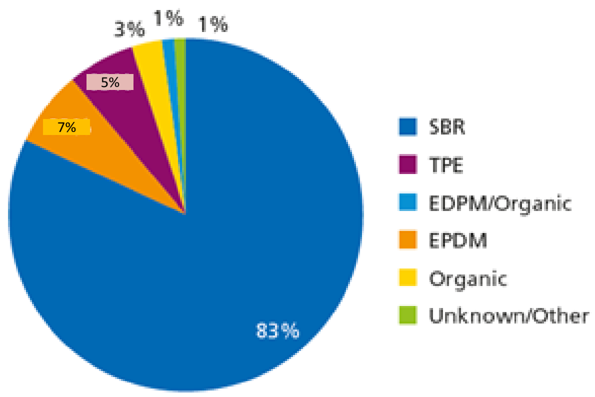


Figure 6 Infill materials in European fields (Eunomia 2017)

The 4G artificial turf is in stage of introduction in the Nordic countries, following a trend in Europe. The new approach includes a turf with no need of elastic infill. A number of manufacturers are introducing their products in the market these days. The interest is growing, due to the poor record from infill-based turf systems with respect to environmental impact, complicated maintenance and high lifetime costs.

Figure 7 : 4G system including section with and without PAD

The 4G system represents a new approach of turf design, where the filament fibre plays the major role in the system. First, the fibre density is substantially higher (2 - 3times more). Secondly, improvement of the fibre properties with respect to design of the straw, thickness, and the raw material itself is developing. Suppliers are using virgin polyethylene, either the basic industrial version or special compositions for turf fibres. Design of the straw is showing substantial variations among different suppliers. An example is shown in Figure 7, where the system contains of two layers of turf. The curled root-zone monofilament turf forms a foundation in the system. The slit film turf pile is rising to a height of 30mm above the backing, and 15mm above the curled turf layer.

In order to stabilize the turf, sand infill with a layer of around 10mm may be applied. The sand layer is limited to the lower part of the curled turf layer.

At present, only four fields of the 4G style design are in operation in the Norwegian market. The systems are from different suppliers in Europe, and the fields are for use by clubs in the level three and below. Some of the fields are prepared for ice sports during winter, and this was among the criteria for selecting a non-infill system. The feedback after 2 years of use is good (Haslum Sports Club, Municipality of Bærum, Leangen Arena, Municipalilty of Trondheim).

All the fields have passed the Nordic test, and certified for matches at level 3 and below accordingly.

Due to strong involvement from politicians with respect to the concern of micro plastic pollution, rapid growth of installations in years to come is expected.

Following the public interest and expected growth in the market, new suppliers are entering the market. At the FSB trade fair in Köln 2017, +90 manufacturers was registered under the term "artificial turf" (FSB Exhibitor search review 2017). The largest growth in the market is East Asia, and China in particular.

The product's value chain is complex, and comprises of the following key elements:

- Monofilament production, virgin or reused plastic
- Backing material production
- Turf tufting, based on monofilament from own or others production
- Pad production, reused or virgin materials
- Infill production, virgin or reused materials
- Sand fractioning and washing

Turf manufacturers execute design of systems, and the same perform initial performance testing in lab.scale. The retail business on national basis either constitutes of branches of the manufacturing company, or own enterprises on distribution contract basis. The final value chain will be:

- System design and supply, by national distributor
- Civil work, field and ambient area, by local contractor
- System assembly by turf contractor
- Field testing and certification, by accredited lab
- Maintenance by owner's staff or hired contractor

Experience from the Norwegian market indicate that average life time of distributors in this market is rather short. From the customer's point of view, this makes the market complex. From an analyst's perspective, the market appears to be less mature, and this include products, distributors, legal framework and international standardisation. Accordingly, it is difficult to develop and maintain the required level of knowledge on the owners/purchaser's hand. Moreover, it creates challenges for the contractors doing assembly and maintenance, as new products with limited records in Scandinavian climate being introduced to market.

There are no independent product certificates equal to TUV, DNV or similar as reference.

Synthetic materials by quantities

Of particular interest is the impact of quantity. The following table gives specific numbers and estimate totals for a full size football field:

Product	Generations of artificial turf					
	Unit	1G	2G	3G	4G	5G
Fibre	kg/m2			1,4		
Sand	kg/m2			14		
Syntetic infill (SBR)	kg/m2			13		
Fibre	kg/m2				2,5	
Sand	kg/m2				13	
Syntetic infill	kg/m2				0	
Total syntetic q'ty, 11-size	tonn			101	18	

Figure 8 Weight of artificial turf system (SIAT 2018)

If the objective is to reduce environmental impact, reduction of the total amount of synthetic materials may be a good start. The 4G system allows for this approach.

Turf properties over the life cycle

Design and construction of artificial sports fields is an example where the private clubs and municipalities as customers meet the professional counterpart, as designers, contractors or suppliers. The expectations of a long lasting system for sport's use meets a complex of product - and construction details, where product lifetime is a key word. In lack of a framework regarding environmental impact or product properties, the focus is on the performance test by FIFA, executed in first year after commissioning. There is no procedure to validate that the system performs in years to come, except the users operational experience.

In Norway, grants for funding sports facilities are available from the state, provided the system will last for 10 years or more. Even if some product suppliers offer a 10y warranty, it is not likely that the whole system will last 10y at a given location, with given climatic conditions and a given pattern of use. In other countries, system lifetime of 5-7years are experienced.

The FIFA test procedures requires certification during first year of operation. There is no requirement with respect to declaration of performance after first year of operation. Accordingly, users experience is only reference for evaluation of different systems.

From a LCA performed in Germany, and the following figures are given:

Live cycle cost analysis for pitches (without taxes)

Surface	Tamped areas	Natural turf	Hybrid turf (penalty area)	Hybrid turf (middle field)	Artificial turf (EPDM)
Area m²	**7.630**	**7.630**	**7.630**	**7.630**	**7.630**
Construction	**300.000 €**	**310.000 €**	**330.000 €**	**370.000 €**	**550.000 €**
Maintenance / m²	1,70 €	2,50 €	2,70 €	2,70 €	1,65 €
Maintenance / year	12.971 €	19.075 €	20.601 €	20.601 €	12.590 €
Maintenance in 30 years	**389.130 €**	**572.250 €**	**618.030 €**	**618.030 €**	**377.685 €**
Re-construction in 30 years in m²	15.260	3.000	1.500	1.500	15.260
Costs / m²	4 €	25 €	50 €	50 €	32 €
Re-construction in 30 years	**61.040 €**	**75.000 €**	**75.000 €**	**75.000 €**	**488.320 €**
Total costs in 30 years	**750.170 €**	**957.250 €**	**1.023.030 €**	**1.063.030 €**	**1.416.005 €**
Difference to artificial turf	**- 312.860 €**	**- 458.755 €**	**- 392.975 €**	**- 352.975 €**	
per year	**- 10.429 €**	**- 15.292 €**	**- 13.099 €**	**- 11.766 €**	
Percentage	**53%**	**68%**	**72%**	**75%**	**100%**

Figure 9 LCC Analysis football fields. (Dr. Harald Nonn 2017)

Product challenges

In order to improve the position of the end user (=owner of the field), there is a need of developing product declaration systems under an international framework. Starting with the turf itself, defining products of virgin polyethylene, products of mixed materials and products of recycled plastics may be preferable. Accordingly, the main infill products are of interest. The properties of the products may be determined using nomenclature from other sectors, as for instance the Construction Products Directive (89/106/EEC), or Product Safety Directive (2001/95/EC).

The following pictures shows different turf products after a wear-test:

Figure 11 Turf made of recycled plastic bags

Figure 10 Turf made of virgin polyethylene

It is reasonable that a turf made from recycled products will have less lifetime than a product from virgin materials. Another approach is the impact of UV-radiation to the turf. The following pictures shows two products with different rate of UV-protection, after the wear test:

Figure 12: Fibre with 6 000 ppm UV Stabilizer

Figure 13: Fibre with 10 000 ppm UV Stabilizer

UV Stabilizer rise the initial product cost, but extend the lifetime substantially.

Design challenges

Design of football fields using artificial turf is a task with a general lack of framework ensuring compliance with guidelines and regulations. Among paradoxes to mention is that rubber granulate is categorized as a mixed product (RIVM2017). The regulative describes in this case maximum content of hazardous agents, but no figures on release limits of the same agents to the environment. To put this paradox in perspective, the rubber granulate would neither comply with Dutch Building Decree (Verschoor 2007) nor the Consumer Product Decree (RIVM 2017), if applied for.

As seen from a Norwegian perspective, this lack of framework influences among others, the following topics:

- Environmental impact assessment procedure on system level
- Assessment of discharge of hazardous agents to water and subsequent treatment measures
- Design of water collection pipework, drains and particle separation systems
- Design of field boundaries as to avoid spread of micro plastics to ambient area due to rainwater run-off, snow moving or maintenance. Measures to prevent particles to be carried off by the players
- Qualification measures regarding installation, operation and maintenance
- Procedure and supply chain for “end of life”-disposal of the waste products
- Product declaration is based on manufacturers own code, and validation is complicated - if possible at all. FIFA and licenced lab’s own code is the reference for certification.

- Product warranties are widely depending on supplier's approval of performed operation and maintenance, and accordingly they may hardly come into power.

Ownership and operation

As known from other types of sports facilities, the bulk part of the football fields are owned, and operated, by clubs. Operation and maintenance are typically performed by club members, accordingly. The professional market for operation and maintenance is fragmented, and most of the companies in the Norwegian market are small, private enterprises, in some cases with one person only. The larger cities have to an extent built up their own group of staff doing operation and maintenance, but in the broad perspective, they counts for a limited number of fields.

The expertise in the market is by the suppliers of turf and infill, another typical aspect of the sports facility segment. Combining member owned clubs with non-professional organisation and large international suppliers may lead to un-even relation with respect to qualifications and guidance.

Operation and maintenance of artificial turf fields in Norway are studied in a reports from Rambøll and SIAT in 2017, and states a very wide spread of results. Taking refill of granulate as an indicator, the operational cost may vary to a magnitude of 10 or more.

Sports turfs in Scandinavia

The numbers

Total no of artificial turfs (7-,9-,11-size) by country (2016):

Country	Football turfs
Sweden	1 336
Denmark	325
Norway	1 750

Figure 14 Artificial football turfs in Scandinavia (SIAT 2018)

The growth in use of artificial turfs in Norwegian market may be described, using findings from a survey in 2017:

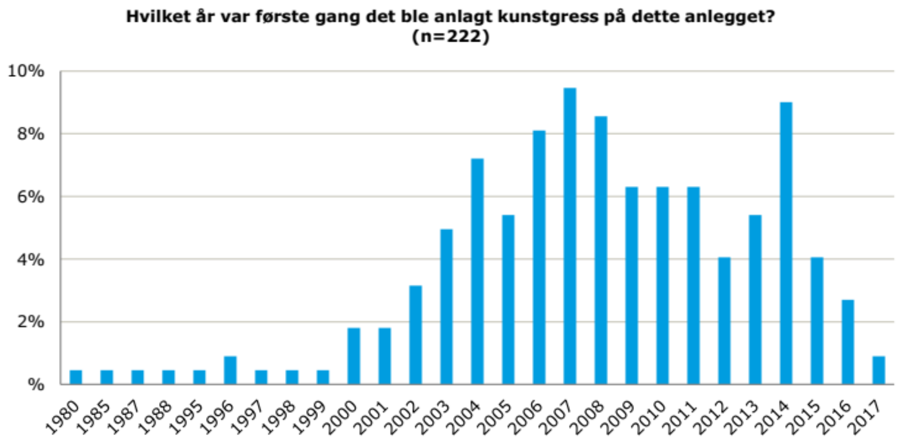


Figure 15: Survey of Norwegian football fields (Rambøll 2017)

It is in the following, anticipated that the growth profile is equal in the Scandinavian countries.

The big boom in the market came with introduction of the 3G turf systems using rubber granulate as infill. The substantial growth in the markets from 2000-2010 allowed for growth in the manufacturing industry as well as contractors and maintenance operators. Accordingly, the aftermarket developed with equal growth in sale of granulate for the annual renovation and refill of the turfs.

With reference to Figure 14Figure 15: Survey of Norwegian football fields (Rambøll 2017), Norway holds 50% of the total no of fields in Scandinavia. In Norway +60% of the fields are full size (The Norwegian Football Association 2017).

From Figure 15 and Figure 16 it may be seen, that in the Scandinavian market, there will be a substantial and slowly growing volume of renovation projects in the coming years. It may be anticipated that the sale of turf and granulate for renovation will be equal to the waste stream, given the assumption that the field owners want to replace the present system as is.

Figure 16 shows that the annual use of rubber granulate infills counts up to +60% of the total volume of granulate annually brought into the market.

The following figures may be determined, by extrapolating figures from the Norwegian survey (Rambøll 2017) to Scandinavia:

Item	Unit	Quantities
Total no of fields	Pcs	3 500
Renovation of turfs	Pcs/year	300
Synthetic infill waste	t/year	30 000
Turf waste	t/year	6 000
Granulate refill	t/year	19 000

Figure 16 Artificial Turf products - Market Estimate, Scandinavia (SIAT2018)

The growth in numbers of new fields is not known in the Scandinavian market, but from the sports federations, there is a constant call for more fields to be constructed.

A closer analysis of the refill volumes for each 11-size field shows the following (Rambøll 2017):

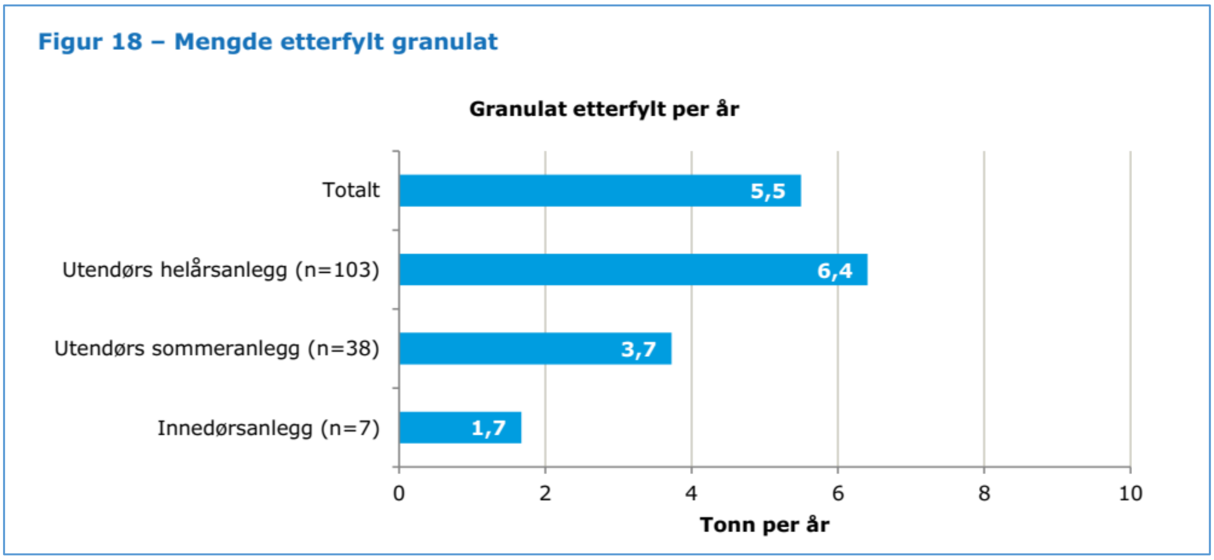


Figure 17 Granulate annual refill (Rambøll 2017)

The use of annual refill of granulate is closely connected to operation. While a summer operated field needs in average 3.7 t/year, the fields operated year around needs 6.4 t/year as shown in Figure 17 Granulate annual refill (Rambøll 2017). The reason for the difference is not clear, but some factors with impact may be:

- Snow moving will cause removal of granulate, and recovery of this fraction is difficult or just not done.

- Winter operated fields will most likely have more operational hours, and the use of the turf causes wear and tear of the field, in particular the granulate which will be degraded due to mechanical impact. Cold climate may enhance the degradation of frozen granulate particles.
- Operation equipment is in many cases based on single operator's experience and supplier's capacity to develop products and applications. The industrial range of products for these purposes is limited, and knowledge on operation and maintenance is limited accordingly
- Purchase of turf systems normally is by the general contractor, or directly by the owner/club/municipality. Execution of system design and demand analysis are limited, or based on standard guidelines from the Football Federation. There is a subsequent knowledge gap with respect to specification of the turf, equipment for maintenance and training of operators.

Calculating the loss of granulates from a sports field is a very complex process, and methodology for execution of the analyses is limited. Loss of granulate are assumed to follow some major tracks:

- By players, (textiles, shoes etc.)
- Rain water runoff
- Drain system
- Snow moving

In order to get an understanding of the magnitude, Figure 17 Granulate annual refill (Rambøll 2017) shows the refill rate. Studies made in SIAT indicates that granulate degrades due to wear and tear, forming a dust-like layer at the bottom of the turf. New granulate holds a particle size distribution range of 0.8-3.5mm. Analysis of particle distribution in the years after construction shows a growth in number of particles <0.8mm, which only may be explained by degradation of larger particles. The reduction in average particle size will cause a subsequent reduction in volume, i.e. the height of the granulate layer. The loss of these smaller particles is difficult – if possible – to detect clearly. The environmental impact is subject to further studies, as these particles are in the lower size range of the micro plastics. Consequently, the need of refilling the field is as much a compensation of the degradation process as the loss of granulate from the field. The need of refilling is the solution for protecting the fibres, as an increase in free fibre height may cause the fibres to bend or break. This results in different response to ball roll and shock absorption. Accordingly, the lifetime of the turf is reduced substantially if the maintenance including replacement of infill is not performed properly.

The less developed part of the value chain is the end of life stage. The only known company in Scandinavia who is set up to receive and process turf waste is Re-Match in Denmark. This company is able to fraction the waste into plastics, rubber and other substances. The objective is to process the rubber and plastic for further reuse. In Sweden, RagnSells is running a processing facility for car tires, with rubber granulate (SBR) as one of the outputs. In Denmark, Genan is running an equal processing plant for car tires.

The only known present option for the turf waste except reuse is incineration, and this fact calls for more R&D on the subject.

The users and the usage

From literature, it seems clear that the development of turf systems has mainly had senior male athletes as the user model. Less information is available on the design of turf system to children and young athletes. In Norway, it is estimated that 375 000 persons are playing football (The Norwegian Football Association 2017). Among these, around 2 000 are players on level 1-3, including junior teams. The bulk part of the players are thus children and youngsters, the majority aged 14 years and below. In order to prepare best possible conditions for training and improvement of performance, the turf properties should be better fit to the users. In this respect, the discussion on turf design should have a wider perspective than artificial turf with infill or not. With the new 4G systems available, it may be possible to reduce the environmental impact of artificial turf just by taking the infill-based concepts out of the market for the majority of fields.

The age distribution among members differs from one club to another. When a club is in process of building an artificial turf, the users should be in focus. Are the user group children and youngsters or elite? Elite clubs will have different demands on the quality of the turf than a small local club, where children and youths are the most frequent users. One example from a sports club in Trondheim may explain the topic:

Players age	No of players
8-16 years	650
Junior, senior	100 (level 2-3)

Figure 18 Byåsen Sports Club, Trondheim: Members of the football department (Rasmus Hugdal 2018)

With the growing diversity in sports demanding an all-weather field, there may in future be a need of developing multisport turfs for the typical users, i.e. all the players except the top level athletes. Design of the artificial turf field should welcome all users, not only organized sports. The vast majority of users are just playing football, they are on flat sole shoes or maybe pupils at the school close by, doing their gym exercises.

Environmental impact

A number of reports on the environmental impact of artificial turf, are issued. Tests and measurements are executed, with the aim of describing leachate containing metals, rubber granulate loss and traces in sediments, impact on downstream water system including beaches and ocean.

The properties of the main products used in a turf system is fairly well described and declared. The big, pending issue is how to categorise the sports field in an environmental context. Over the years, a framework for the use of fertilizers, pesticides and biocides in the agricultural industry are developed, modified and enhanced. Use of wastewater sludge on land with respect to possible polluting agents is subject to approval against an equal framework. Pollutions from road traffic, which may affect ambient water or air, are subject to continuous research and analysis. Building materials are undertaken certifications and test procedures as to comply with health, safety and environmental requirements.

Coming to sports fields, there seems to be a gap. Neither the client (sports clubs) nor the suppliers fits in with the above-mentioned environmental impact framework. Operation is in many cases based on club members in voluntary positions. Training, equipment and reporting of the services are less developed. Guidelines for design and construction of the fields also lack the environmental impact factor. The suppliers and the sports federations are in possession of the power to define the standards with respect to the sport's requirements, product properties and performance declarations.

Product

The definition of micro plastics are plastic particles below 5mm in diameter (Mepex 2016). According to the Norwegian football association (NFF) and the Ministry of Culture in Norway, the granulate used in football turfs should have a size between 0,8 - 3mm (The Norwegian Ministry of Culture 2015).

The total amount of micro plastics in nature from artificial turfs is not known, but an estimate of 3000 metric tonn/year was made by Mepex on behalf of the Norwegian Environmental Agency (Mepex 2016). A Swedish report estimates a loss of 1 640-3 510 tons of rubber granulate every year from 1 336 turfs in Sweden (Magnusson, Eliasson et al. 2016). A similar study has been performed in Denmark where a total of 380 – 640 tons/year are expected to be lost from the 254 turfs in 2015 (Lassen, Hansen et al. 2015). Possible pathways to the environment are through storm water and drains, mechanical snow removal and granulate sticking on clothes, skin and shoes, which brings granulate off the turf. The quantities of granulate in each pathway is not fully explored. In a survey on 141 fields in Norway, it is stated that winter operation may cause an increase in granulate loss of around 70% (Rambøll 2017).

The most commonly used granulate is styrene butadiene rubber (SBR) granulate (Eunomia 2017). SBR-granulate is shredded tire components containing a large variety of chemical components. The following indicative figures regarding composition of tires (by weight) are 40 - 45 % rubber, about 20 % carbon black, 5 - 6 % silica, 15 - 25 % metal (highest amount in truck tires), 1 % sulphur, 2 % zinc oxide, about 6 % stearic acid, 0,5 % accelerators, 1 % antioxidants and about 5 % textiles. The content of heavy metals in tires constitutes of four metals that are recognised as possibly toxic in elevated concentrations, where the distribution is 0,005 % lead, 0,001 % cadmium, 0,02 % copper and about 1 % zinc (COWI 2012).

SBR - granulate consists of several organic toxins and heavy metals, zinc being the most prominent (Bocca, Forte et al. 2009, Menichini 2011, COWI 2012) . During the vulcanization, the rubber is heated, and sulphur, zinc oxide and carbon black are added. Zinc is an essential metal that, in large concentrations, could give toxic effects (Klaasen 2013). Other possible toxic components are polycyclic aromatic hydrocarbons (PAH) due to the addition of carbon black (COWI 2012). Several PAHs are labelled as toxic and possibly carcinogenic (Klaasen 2013).

SBR-granulate can contain phthalates, especially DEHP (COWI 2012). Phthalates are a group of organic substances that could cause reproductive toxicity (Kemi 2015). Other substances that could have an environmental and health effect are latex, amines, phenols and volatile organic components, amongst others (COWI 2012).

A large focus has been on the possibility of cancerous effects on humans through contact with SBR-granulate. ECHA concludes that there is a low or neglectable risk of health impact for booth children, youths, adults and operators of artificial turfs (ECHA 2017) This issue subject to further research, as present reports are based on a variety of approaches with respect to methodology and scope.

From the report, the following advises are given (ECHA 2017):

Based on its evaluation, ECHA recommends the following:

1. Consider changes to the REACH Regulation to ensure that rubber granules are only supplied with very low concentrations of PAHs and other relevant hazardous substances.
2. Owners and operators of existing (outdoor and indoor) fields should measure the concentrations of PAHs and other substances in the rubber granules used in their fields and make this information available to interested parties in an understandable manner.
3. Producers of rubber granules and their interest organisations should develop guidance to help all manufacturers and importers of (recycled) rubber infill test their material.
4. European sports and football associations and clubs should work with the relevant producers to ensure that information related to the safety of rubber granules in synthetic turfs is communicated in a manner understandable to the players and the general public.
5. Owners and operators of existing indoor fields with rubber granule infills should ensure adequate ventilation.

In addition, ECHA recommends that players using the synthetic pitches should take basic hygiene measures after playing on artificial turf containing recycled rubber granules. For example, they should always wash their hands after playing on the field and before eating, quickly clean any cuts or scrapes, take off their shoes/cleats, sports equipment and soiled uniforms outside to prevent tracking crumb rubber into the house, and any players who accidentally get crumb rubber in their mouths should not swallow it.

Figure 19 Recommendations, (ECHA 2017)

Other common alternatives, that are used as granulate in artificial turfs, are ethylene propylene diene monomer (EPDM), Thermo Plastic Elastomer (TPE) and organic cork (SIAT 2017).

Eco toxicological analysis of SBR - granulate in the environment is lacking. Studies have shown some effect on terrestrial organisms. A study from 2017 showed decreased growth in earthworms living in earth containing SBR-granulate (Pochron, Fiorenza et al. 2017). Toxicological analysis on marine organisms and biota should be investigated further, with respect to possible effects on algae and marine organisms, such as Daphnia Magna (water flee), which is an important indicator used in marine toxicology.

Findings

Plastic is known to degrade slowly over time and a complete degradation of plastics to CO_2 and other molecules could take decades, possibly even centuries (Magnusson, Eliasson et al. 2016). The degradation process of granulate is not fully explored, but several impact factors are mentioned. (Cheng 2014):

- Ozone, attacks the particle surface, resulting in cracks
- Oxygen, causes oxidative degradation
- Water and soil, causes leaching of the soluble components
- Heat, accelerate the degradation
- UV radiation, promoting oxidative degradation
- Mechanical degradation due to wear and tear

The degradation process will change the chemistry of granulate and could have an impact on the local environment (Klaasen 2013).

Due to the factors mentioned above (Cheng 2014), the polymeric structure of rubber is gradually decomposed (Verschoor 2007). During ageing, released zinc from the polymer and could be present as dissolved zinc species or as ZnS precipitates. The report from Verschoor (2007) concludes that there is an increased emission caused by leaching. As the chemical and physical properties of the granulate change over time, due to degradation to smaller particles, the leaching of zinc increases. The risk assessment performed in this study identified a potential eco toxicological impact in surface water, groundwater and soil. Further, the report indicates that the rubber crumbs does not meet the critical load standards in the Building Materials Decree and that the criteria for the discharge of wastewater (CIW) is not met (Verschoor 2007). Leachate analysis performed, shows a high zinc leaching in only 24 hours, with concentrations as high as 2300 µg/l, which is above the limits for German standard limits (DIN) set for content of substances in soil and ground water. With regards to zinc, 44 % of all samples were above the specified standard (Bocca, Forte et al. 2009). According to another research studying leachates of heavy metals, including zinc, 4-5 times higher concentrations were detected in leachates from two year old SBR, compared to virgin samples (Li, Berger et al. 2010)

According to the Danish Environmental Agency, zinc from artificial turfs could oppose a threat to groundwater quality where SBR infill is used. Potential risk depends on the depth of the groundwater and the mobility of zinc. The mobility is highly dependent on pH and the local geology (COWI & The Ministry of Environment and Food of Denmark 2017). There is a need of further research in order to quantify the risk.

Eco toxicity could occur from the drainage with elevated levels of zinc, which adversely affects the growth, survival and reproduction of aquatic plants and other marine organisms, including fish, at concentrations as low as 10-25 µg/L (Cheng 2014). Since heavy metals are non-degradable in nature and SBR-rubber contains some heavy metals, although in small concentrations, possible accumulation and toxic effects on marine organisms should not be underestimated.

A typical artificial football turf can as a new site contain 1 000 – 1 500 kg of zinc, embedded in the SBR granulate infill. According to this study, under natural conditions 10 – 40 % of the zinc could be released from the granulate over a 10 year lifetime of the system (Cheng 2014).

DHI analysed in 2013 and 2017 the water quality from several artificial turfs in Denmark. **Fel! Hittar inte referenskälla.** The yellow line describes the environmental limit of dissolved zinc in fresh and marine water (7,8 µg/l). The orange line describes the limit for groundwater quality (100µg/l), while the red line describes the limit for drain water in treatment plants (3000 µg/l).

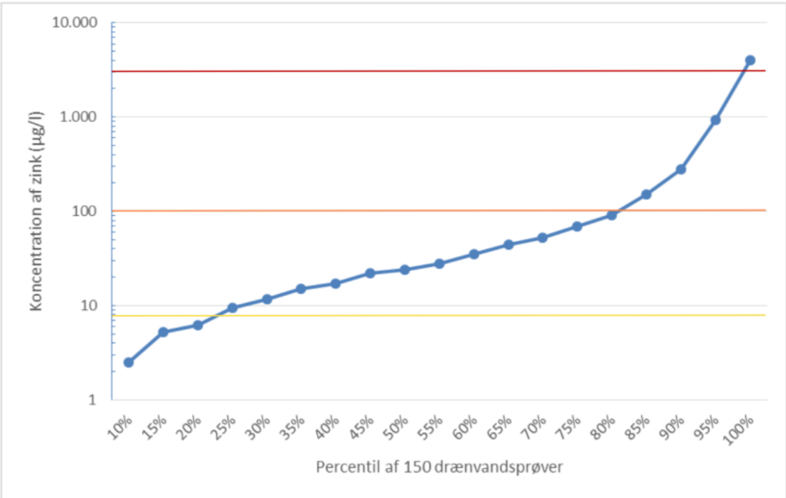


Figure 20 Concentration of zinc in drain water (DHI 2017)

The source of zinc could be SBR – granulate, but other sources, such as drainage mats and SBR – pads, could affect the total concentration (DHI 2017).

Use of salt as an ice-breaker on artificial turfs is common in Nordic countries. Different salts are usable, but all contains chloride. Chloride in large quantities could affect adjacent plants and trees, possibly affect groundwater or other vulnerable recipients (Andersen and Kjær 2016).

The impact of salt use is not explored, but to set the topic in perspective, the amount of salt applied on a typical winter-open football field in Norway counts up to 10x the amount used on highway, quantified as kg/m^2. (SIAT2017).

Sports halls with artificial turf

Turf in indoor facilities represents a special case. As the turf is inside, there is no runoff caused by rain, snow moving or operational reasons, and there is no UV-impact. On the other hand, using turf with sand or granulate infill (any product) may cause formation of dust. Studies have shown increase of VOC and PAH in indoor facilities, and concludes that the use of rubber infill made from SBR is not recommended. (Dye, Bjerke et al. 2006) .

Another issue is the possible growth of bacteria in the turf. The rubber granulate acts as a biofilm carrier, where fair temperature levels, humidity from air, water from turf flushing, sweat and fibres from body all together create an environment for growth of bacteria (Mcnitt and Petrunak 2008).

It is learned from field visits, that the turf may frequently be flushed with water in order to avoid dust exposure during use, and to give the turf better usage properties.

There are to the author's knowledge no known guidelines on design of ventilation systems for sports hall with artificial turf. To conclude, the fresh air demand from the users may easily be calculated, while the impact of materials is more difficult, not to say beyond present knowledge. At SIAT, a study is conducted this year in order to figure out the dust component, including characterisation of sizes and development of a guideline for design of ventilation systems (Ressem 2018) . Analysis of the dust with respect to organics/inorganics are subject to further studies.

The framework

In Europe, the EN 15330-1 is a reference for design and performance of sports turfs for different purposes. The standard is implemented in Norway as NS-EN15330-1.

As for football pitches, FIFA has taken the position as regulator of the market with respect to test procedures as well as performance indicators. The following code of quality applies:

Certificate	Scope	Comments
Nordic certificate	Level 3 and below	Approved for public funding (Norway)
FIFA Quality	Level 3 and below	As above
FIFA Quality Pro	Elite level	As above

The Nordic certificate is identic to the EN-15330-1, except the skin abrasion and surface friction parameters, which are not included. Subsequently, the use of the Nordic certificate – or even better – the EN standard as is – may be a solution to reach an independent level of quality for the broad numbers of football fields in the Nordic countries.

Knowing that use of the majority of artificial turf fields are not only for football – but also as the playground close to the school – there is a need of implementing performance codes and test procedures that fits best to the real usage.

Field contractors and turf assemblers

From the Norwegian market, the findings are:

Civil construction of sports fields is performed by contractor specialized in ground works like roads, pipework for drain, sewage or water etc. The typical picture is that the number of contractors is limited, and they seems to form regional submarkets.

Specialised contractors perform assembly of the turf system. Some of them are working independently; some are more or less an extension of the distributor. Typically, they have a nationwide market approach, but they are small companies, in some cases just the owner and maybe some short time staff depending on the workload. Assembly of the turf system of climatic reasons is seasonal, and completion of the work to be made accordingly.

Field operation and maintenance

Artificial turf fields need a rather sequential style of maintenance, with weekly, and monthly tasks to be performed. Additionally, a more in deep cleansing of the turf may be required on regular basis. Scope of maintenance as well as intervals follows the season, opening hours and more important, winter season use or not.

The skilled clubs and the municipalities normally perform the regular maintenance by own workforce and equipment.

As for the assembly of the turf, there is a special group of contractors doing the frequent maintenance. Field maintenance is very seasonal, with a rush during the spring. The contractors have normally a regional market approach, as transport time and costs limits the capacity and price policy. Again, these contractors are small enterprises, where the knowledge base is on more on experience than education. In many cases, the contractors are importing their own equipment, and modifying details based on own experience.

Knowledge gap

With the described "thin lines" in the value chain from manufacturer to contractors, there is always a risk of knowledge transfer constraints. These days, there is a shift in the market towards turfs without the traditional infill, and this shift calls for knowledge update on the turf assemblers as well as the maintenance contractors and the suppliers of their equipment.

The 4G systems will require new approach for turf design, where the PAD plays a more important role. As there is no granulate to manage, maintenance intervals, style of equipment and procedures of the work, is subject to further research and development. The regular need of harvesting and refreshing granulate to avoid packing is not an issue, and both intervals and duration of the maintenance works must be revised. An expected outcome is far less need of maintenance, which will be to the benefit of the owner with respect to lifetime costs.

A solution may be to establish knowledge hubs where the different parties are present and agree on a coordinated effort to share knowledge and improve quality of the value chain, to the benefit of the end users. The short-term burden is on the maintenance contractors, while the manufacturers are challenged, if their products fails with respect to expected lifetime of the system.

Of particular importance is the manufacturer's guidance in selection of equipment and procedures for execution of the works in order to comply with product properties.

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