Green Power and Energy Efficiency Investments Community-Financed for Football Buildings

Deliverable 4.1:

Summary of best practices in EE and RES installations in sports buildings

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Executive Summary

Most of the current sport facilities in Europe were built between the 1960s and the 1980s, and at those times energy efficiency was generally not a design consideration. Additionally, in the last few decades there have been radical changes in the use of stadiums and football buildings. These facilities should be renovated and maintained in light of new end-user requirements and energy technologies. Currently, renovations in the building sector are lagging, with an estimated renovation rate of less than 1% of building stock per year. Thus, sports buildings represent both significant opportunities and challenges for improved energy usage.

Currently, energy efficiency renovations and, in particular, RES installations in sport buildings are becoming more common and more required by the building managers and a few excellent and successful examples have been developed. Deliverable 4.1 aims to support energy efficiency renovations in football buildings of all types, from large stadiums to small training centres, encouraging good practices and providing technical solutions based on the experiences of specialists involved in energy efficiency. It provides a comprehensive and accessible Technical Catalogue for football buildings, collecting suitable solutions already recognised as effective and largely used for several building typologies (residencial, commercial and industiral) to enhance energy efficieny, reduce GHG emissions and produce renewable energy on-site.

Designers and building managers can use this report to select strategies and technologies that will save energy over the lifetime of the football buildings and ensure appropriate renovation plans.The deliverable is structured starting from the understanding of football buildings' main features and typical energy conspumption, moving to the identification of the main areas for improvements and then ending with a synthesis of recommended solutions collected within dedicated and easy-to-read technical sheets. The solutions have been analysed under the technical and economic points of view, while also providing some qualitative information about the potential links and adapability with crowdfunding schemes. Further developments, specifically on the Candidate Buildings, will be carried out in next WP4 activities within Task 4.2.

List of acronyms and abbreviations

BMS: Building Management System
CCHP: Combined cooling heat and power
CHP: Combined heat and power
DHW: Domestic Hot Water
DoA: Description of Actions
EE: Energy efficiency
EEB: Energy-efficient Building
EED: Energy Efficiency Directive
EPBD: Energy Performance Buildings Directive
D: Deliverable
HVAC: Heating Ventilation Air Conditioning
IAQ: Indoor Air Quality
IEQ: Indoor Environment Quality
KPI: Key Performance Indicator
LED: Light Emitting Diode
MEP: Mechanical Electrical Plumbing
nZEB: Nearly Zero-Energy Buildings
PV: Photovoltaic
RES: Renewable Energy Source
SHGC: Solar heat gain coefficient
TLCI: Television Lighting Consistency Index
VT: Visible transmittance
WP: Work Packaged

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1 Introduction

Deliverable 4.1 documents all the activities carried out within Task 4.1 in the first six months of GREENFOOT project. The following paragraphs provide a brief description of the deliverable's content and of the target group that the document is addressed to.

1.1 Description of the deliverable content and purpose

The purpose of this deliverable is to synthesize knowledge regarding best practise and important factors for energy efficiency (EE) renovations and renewable energy sources (RES) installations in sport buildings. In general, there is a wide range of solutions for building energy efficiency retrofit. This report identifies a summary of the most suitable EE actions and RES that can be used for the development of engineering plans for each candidate building (activities linked to task 4.2).

Since there is a wide variety of buildings under the definition of sport/football buildings, together with a wide variety of needs and areas of improvements, to set the basis for the analysis and to identify the most suitable interventions, a concise overview of the building main features and an initial clustering into different "sport building type" has been carried out. Three main building typologies have been identified taking into consideration the three candidate buildings types pre-selected within the Description of Action (DoA) and extending the analysis to other relevant case studies. An important link has been made with the studies carried out in the framework of the European Commission founded project SPORTE2.

Then for each sport/football building type, a wide range of applicable energy efficiency renovation solutions have been analysed together with their potential impacts. The objective is to provide an easy-to-read Technical Catalogue (Appendix 1) collecting a set of suitable solutions for each building category, completed with technical features, detailed information, analysis under the point of view both of energy savings and of adaptability with crowdfunding schemes. Strengths and barriers were summarized in order to facilitate informed decision-making during the development of plans for the candidate buildings. The selection and integretion of the prosoped solutions within each candidate building renovation plan will be deeply evaluated in task 4.2.

To strengthen the linkages with sport associations and bring work closer to the real needs of the sector and of the project, the complete version of the Technical Catalogue has been shared among relevant stakeholders within the GREENFOOT project in order to collect their feedback on the solutions proposed. A preliminary questionnaire, documented within Appendix 2, has been shared among the main stakeholders involved in GREENFOOT project. The feedback will be used to address the preliminary steps for the development of the activities of Task 4.2.
To conclude the work done within T4.1, general considerations have been provided in order to extend the utility of the Technical Catalogue to building managers across Europe.

1.2 Target group and link to other activities

The main target group of this deliverable is made up of planners, designers, building managers and any other stakeholders who are directly involved in the technical aspects of renovation process of football buildings. Task 4.1 is directly related to Task 4.2 since it provides technical solutions and general recommendations for the subsequent development of engineering plans for each candidate building. Substantially this document provides developers and designers a technical basis for the identification of the suitable solutions that can be applied in each candidate building in order to improve energy efficiency. From the technical side, this document is also a relevant starting point in the replication strategy and the potential applicability of GREENFOOT concept to different sport/football facilities in various EU countries.

2 Analysis of the current sport building stock

Buildings cause a significant amount of greenhouse gas emissions, mainly CO_2, altering our planet's climate. The European sport building stock accounts for approximately 1.5 Million buildings representing ~8% of the overall building stock while the overall energy consumption is ~10% of the building sector.[1] A similar analysis can take place with respect to CO_2 emissions. Football facilities, with about 465,000 facilities, represent up to 30% of the entire European sport building stock. The projection made with available statistical data and taken from the EU funded project SPORTE2 highlights the EU dimension of the Sport and Recreation Building Stock and football facilities in particular.

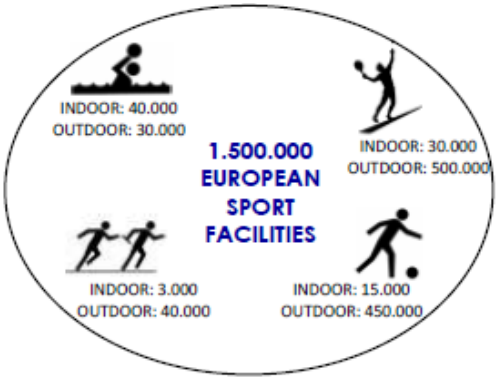


Figure 2-1: EU dimension of the Sport and Recreation Building Stock[2]

Most of the current sport facilities were built between the 1960s and the 1980s and at those times energy efficiency was generally not a design consideration. These facilities must be renovated and maintained.
A recent survey conducted on football managers within the Life TACKLE project[3], highlighted that 9.4% of football clubs and stadiums already started to implement certain environmental practices (includicng those related to the reduction of energy consumption) but their implementation levels vary greatly as shown by Figure 2-2.

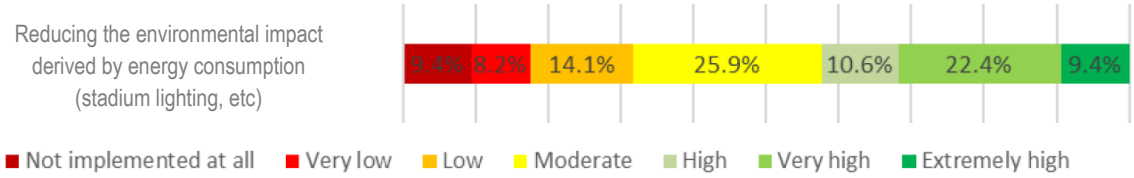


Figure 2-2: Result of Life TACKLE survey[3]

From the same survey, it appears that 30% of the respondents (football managers) follow improvements from other stadiums or football clubs. Hence, it is important to have early efficient clubs and examples able to show the way forward to other clubs and football building managers.
Up to now, only a small percentage of buildings have been deeply renovated and the sector represents both significant opportunities and challenges. Currently, renovations in the building sector lag behind with an estimated renovation rate of less than 1% of building stock per year.[4] GREENFOOT has the stated goal to boost this annual

[1] SPORTE2 D7.1 Market Analysis. 2013.
[2] SPORTE2 D1.1 Performance criteria and Requirements. 2013.
[3] The environmental management of professional football events: A survey of football managers, 2021 – Life TACKLE project available at *www.lifetackle.eu*
[4] EC Energy Efficiency Directive, Article 5 https://ec.europa.eu/energy/content/setting-3-target-public-building-renovation_en

replication rate up to 1% per year in the case of European sports building. Case studies, best practices and EU funded projects highlight that energy consumption in these buildings can be reduced by up 30% in many cases[5].

Football buildings and related sport facilities are part of a complex and heterogeneous sector, especially compared to the residential building stock, and vary enormously in size and in use. In general, they include indoor and outdoor spaces and some of the internal spaces share characteristics with offices, industrial, and commercial building categories. A football centre may consist of a single unit or, as in case of a large integrated complex, a site encompassing several buildings, outdoor spaces and parking areas, providing a set of different facilities that support sport practice including dry ports, fitness facilities and in some cases also swimming pools.
Football buildings can be classified as:

- Competitive sports buildings: in which official and competitive activities can take place.
- Exercise sports buildings: in which regulated activities, not intended for competition, can take place as preparatory and training activities.
- Complementary sports buildings (as offices, commercial areas, guest houses or even hotels): in which all support and complementary activities can take place.

Often competitive sports buildings as football stadium can be shared between more than one club and are used with less frequency, while non-competitive sports buildings for training are used more often. Depending on the type of football buildings there are different requirements, needs and priorities based on the actual building conditions, the user needs and commercial considerations. This section provides a description of the most common football building types with an analysis of the spaces and the related main features.

2.1 Main building typologies and energy uses

In general, football buildings and related sport facilities are unique by their physical nature (characteristics), their energy consumption profiles, the usage patterns (long periods of low use and then short periods of high use), ownership (public and private) and comfort requirements. Additionally, a whole host of factors causes each renovation project to be unique.

Achieving energy savings in buildings is a complex process. Reducing the energy demand requires at first to understand the key characteristics of building structures and systems. Since there are a wide variety of football buildings, the process of mapping buildings and facilities into main typologies represents the first step for the definition and the targeting of suitable EE solutions. Football buildings vary in size and structure, from small local centres to large stadiums with a capacity for tens of thousands of people. Each building poses different challenges in terms of energy efficiency and a tailor-made solution is almost always needed. In line with the purpose of GREENFOOT, and with the first selection of candidate buildings, three main football building typologies have been identified and analysed:

- Football stadiums, as competitive sports buildings.
- Sport and training centres, as exercise sports buildings.
- Clubs headquarters, as complementary sports buildings.

Each typology is characterized by different needs, which have great influence on the energy behavior of the building. The requirements of each building type, together with its related facilities, vary depending on the activity carried on and on the number of practitioners or occupants in general. Additionally, football buildings must comply with specific national and local regulations, and health and hygiene regulations (requirements such as minimum

[5] EU funded project SPORTE2

temperature, humidity, ventilation rates and lighting levels), which can have a strong influence on the energy demand.
To identify areas with the greatest savings potential, designers and energy experts need to know where energy is being used and which processes consume the most energy. Following paragraphs provide a quick overview of the main football building types features and energy uses.

2.1.1 Football stadiums

Modern stadiums are extremely different from older versions, in terms of size and comfort for spectators and teams, the services offered to the public, environmental sustainability and safety. For the Italian scenario for example, the average age of professional football stadiums is about 60 years[6], and in recent years, the average use of the facilities vis a vis their capacity has decreased in all categories. Stadium use ranges from 58% of Serie A to about 20% in the Lega Pro of capacity on gameday[7].

The range, number and size of stadium facilities and temporary arrangements available inside the building depend on the competition category for which the stadium is intended to be used. For instance, to host an official stage of one of the two European competitions, Champions League or Europa League, the stadiums must have specific minimum requirements. UEFA currently classifies the studiums in four categories, according to UEFA Stadium Infrastructure Regulations[8], based on the level and type of competition that will take place. Each category requires a specific set of standards and regulations to be fulfilled, in addition to the fulfillment of certain structural and design criteria. The following table summarises the characteristics and the minimum requirements of each UEFA category.

Table 2-1: UEFA stadium categories

Criteria	Category 1	Category 2	Category 3	Category 4
Field of play	100 to 105 m long, 64 to 68 m wide		105 m long, 68 m wide	
Min. size of referee's dressing room	N/A		20 square metres	
Minimum floodlighting .	to suit broadcaster	800 E_h(lux) horiz. Illum. uniformity ratios U1h >0.4 and U2h >0.5	1200 E_h(lux) horiz. Illum. uniformity ratios U1h >04and U2h >0.6	1400 E_h(lux) horiz. Illum. uniformity ratios U1h >0.5 and U2h >0.7
		350 E_v(lux) vertical illuminance uniformity ratios U1h >0.35 and U2h >0.45	750 E_v(lux) vertical illuminance uniformity ratios U1h >0.4 and U2h >0.45	1000 E_v(lux) vertical illuminance uniformity ratios U1h >0.4 and U2h >0.5
Spectator standing allowed	Yes	No		
Min. Seating capacity	200	2500	4500	8000
Turnstiles and electr. ticket control system	No	1 turnstile per 660 seats		
Min. total VIP seats	50	75	100	100
VIP parking	20	50	100	150

[6] Gli Stadi italiani nel panorama europeo, Monitor Deloitte, 2020 available at: http://www.legaseriea.it/uploads/default/attachments/documentazione/documentazione_m/1502/files/allegati/1702/gli_stadi_italiani_nel_panorama_europeo_pov_monitor_deloitte.pdf
[7] GUIDA UEFA AGLI STADI DI QUALITÀ, Edition 2011, UEFA
[8] UEFA Stadium Infrastructure Regulations Edition 2018, UEFA

VIP hospitality area	Yes	Yes	Yes	Yes
Closed-circuit telev. system (CCTV)	N/A		Yes	
Control room	N/A	Yes	yes, with equipped colour monitors connected to CCTV system and displaying live data from ETCS	
Minimum media working area	10 working positions	20 working positions	30 working positions	
Photographers' working area	N/A		15 working positions	20 working positions
Minimum media seating	10, 5 with desks	20, 10 with desks	30, 15 with desks	60, 30 with desks
Minimum space for main camera platform	2 m × 2 m for 1 camera	4 m × 2 m for 2 cameras		6 m × 2 m for at least 3 cameras
Additional camera platforms	N/A		2 platforms 2 m × 2 m for 1 camera each on the 16m lines	category 3 + 1 platform on the opposite stand from main camera platf and 2 platforms 2 m × 2 m behind each goal for 1 camera each
Min. n° of commentary positions	1	3	5	10
Min. n° of TV studios	1		2	2, at least 1 with a view of the pitch
Min. post-match interview positions	N/A		4, each 4 by 3 metres	
Min. outside broadcast van area	300 m^2	400 m^2	600 m^2	1,000 m^2
Min. n° of seats in press conference room	N/A	20	30	50
Min. size for mixed zone	N/A			large enough for at least 50 media representatives

Depending on the size of the building, the following facilities are likely to be present in a stadium:

- Playing field with seating for players and coaching staff.
- Spectators' areas: bowl, bleachers, VIP and hospitality areas with different configurations.
- Pitch-side advertising, photographers, TV cameras and security staff spaces.
- Player and referee facilities (as dressing rooms, warm-up areas).
- Media facilities (flash interview areas, conference room, broadcast compound).
- Commercial areas (club shops, food and beverage facilities).
- Security and emergency services.
- Medical and first aid facilities.

- Toilets and circulation spaces.
- Administration facilities/offices.
- Support facilities and technical rooms.
- Circulation spaces.
- Parking: VIP, players, match officials and delegate and public parking areas.

2.1.1.1 Typical energy uses and consumption

Under the energy aspect, stadiums are very energy-intensive buildings. According to the data presented by Smulders and Imtech Building Service about European sports infrastructures, more than 4,000 stadiums exploit up to 40 TWh/year, which are mainly generated from conventional fossil fuels[9]. A modern medium-sized stadium (55,000 spectators) reaches an energy use of 10,000 MWh/year, which equals 3,600 tCO2/year, on average[10]. During a 90-minute match, a stadium with a capacity of 40,000-80,000 spectators can consumes up to 25,000 kWh. The power used in those 90 minutes could keep more than a dozen average European homes electrified for an entire year.

The increment of the stadiums' energy demand is also due to extended opening hours of the facilities. Indeed, contemporary stadiums do not open only on match day, but also host museums dedicated to the home-team, sports stores, which promote the home-team's brand, restaurants and playgrounds for younger supporters. However, in general, most of the football stadiums, regardless of size, are characterized by an intermittent use of the premises and of a variable number of people using them over the day, with occupancy ranging between time intervals without use and time intervals with the maximum capacity. Precisely for this reason, very often the energy systems and infrastructures of stadiums are oversized and run at appropriate levels only for periods of maximum use.

Often, stadiums are used by more than a sport club but only fully used one day every other week for approximately half of the year (during the season when the football matches are active). In some cases, stadiums also host a range other sporting and cultural events throughout the year.

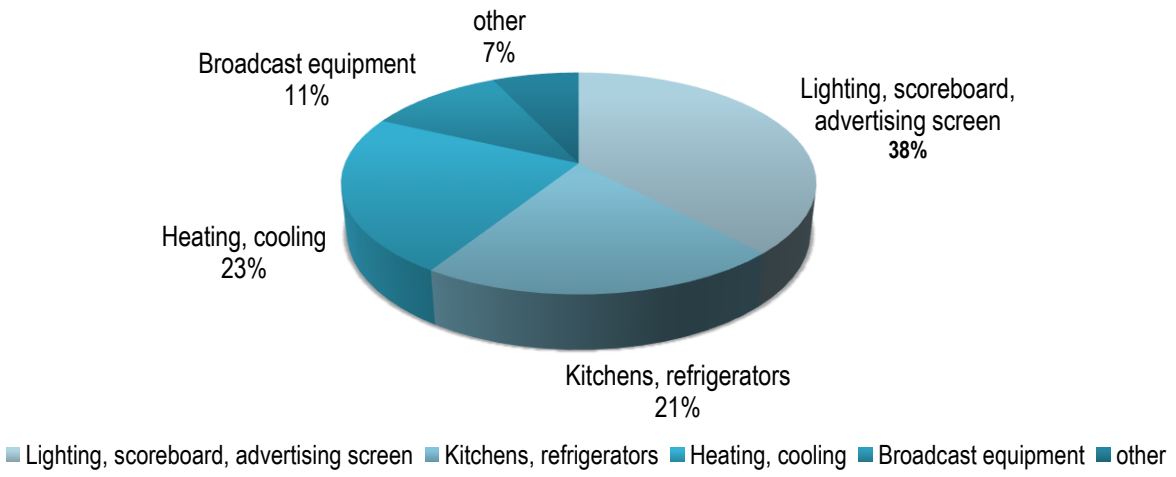


Figure 2-3: Estimated stadium energy consumption[11]

[9] Green Stadium: As Green as Grass. Smulders, Graus, van Rossom, Noordermeer, Master's Thesis, University Utrecht, Utrecht, The Netherlands, 2012.

[10] Towards Zero Energy Stadium: The Case Study of Dacia Arena in Udine, Italy, Manni, Coccia, Nicolini, Marseglia, Petrozzi, 2018

[11] https://selectra.co.uk/energy/news/world/world-cup-2018-stadium-energy-use

In general, energy consumption is due to:

- Lighting, scoreboards and advertising screens, about 38% of the total.
- Heating, cooling and mechanical ventilation, which account for 23% of the total.
- Consumption of commercial areas (e.g. kitchen, refrigerators), for about 21% of the total.
- Broadcasting equipment (powerful satellite transmitters, countless HD cameras and purpose-built editing suites), ~11% of the total.
- Others (e.g. maintaining & cleaning service, etc..), for about 7% of the total.

In addition to the more standard energy consuming services listed above, there are a few specific services which can have a considerable impact on energy consumption such as:

- Under-soil heating.
- Pumps for the irrigation system.
- Artificial lighting for grass growth.

2.1.2 Sport and training centres

Training centres are the places where professional or non-professional teams train performing fitness activities. There is a wide variety of training facilities, from small amateur centres to training ground of main football associations and of course, size and facilities offered vary greatly. Generally, a sport and training centre is characterised by:

- Outdoor spaces consisting in one or more playing fields, with natural grass or synthetic pitches, where players play and train.
- Indoor spaces which host a whole range of services such as players' changing rooms and toilets, medical and first aid facilities, conditioning and therapy rooms, and are usually placed in the immediate vicinity of the playing areas.
- Administrative units, offices, support facilities, equipment deposits and technical rooms.
- Parking areas.

Larger centres also host additional facilities such as recreational spaces, fitness and rehabilitation gyms, swimming pools and hydrotherapy areas, bars, kitchens, dining rooms, meeting rooms, press rooms and laundry facilities. There are also training centres with guest houses where players can live. Many of these are for youth developemtn where young players can attend school in the morning and train in the afternoon.

2.1.2.1 Typical energy uses and consumption

In a typical sport and football training centre, as reported in the sports and leisure sector overview guide[12], energy costs are second only to labour costs, accounting for as much as 30% of total operating costs. Unlike stadiums, the use of sport and training centres is more constant throughout the week and the year. Energy consumption is strictly dependent on facilities included in the centres and can vary greatly between a small amateur centre and a high-class football team training centre.

[12] CTV006 - Sports and leisure introducing energy saving opportunities for business, Carbon Trust - UK, 2006 available at: http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=CTV006

Figure 2-4 gives an overview of a typical energy cost breakdown within a sport facility with a pool. There are a number of common services where typically energy is wasted or not used efficiently: heating, ventilation and air conditioning, lighting and electrical equipment.

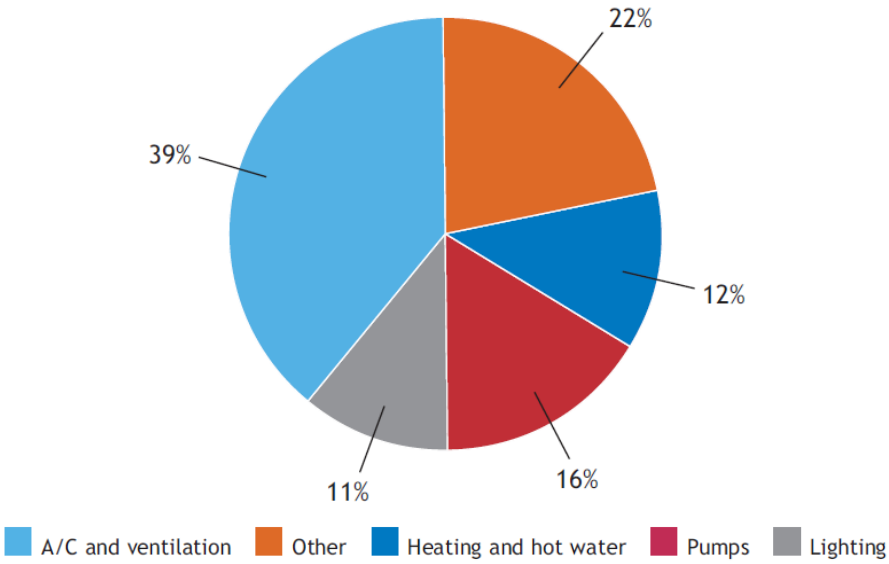


Figure 2-4: Energy cost of a typical sport centre with a pool[13]

The HVAC systems for heating, cooling, ventilation and domestic hot water (DHW) production accounts for a large proportion of energy use in sports centres. The related energy cost accounts for up to 50% of the total energy costs of the centres with a pool (up to 67% considering also the electrical consumption of circulation pumps). Facilities may have centralised units or smaller individual units for the different parts of the building/complex. Lighting is also a relevant item for energy costs, it can account for up to 20% of total energy costs in dry sport centres and around 10% in centres with a pool. Remaining energy costs are due to equipment and other facilities that can be present in the football centre as electronic gym equipment and irrigation systems.

2.1.3 Club headquarters

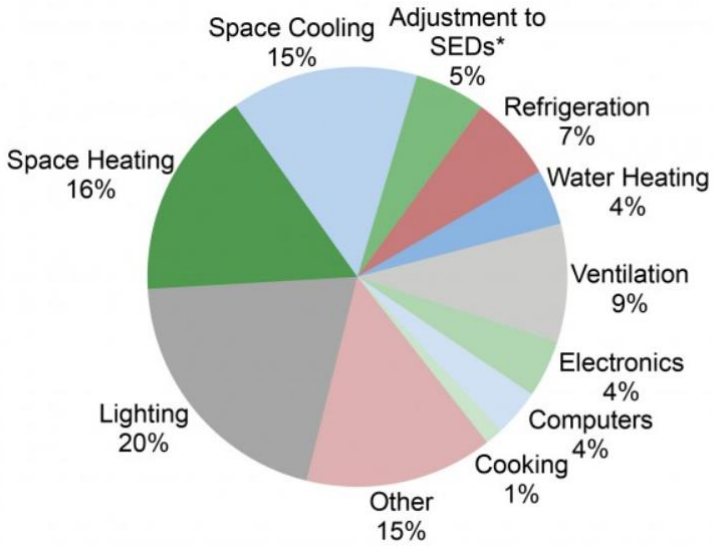
Club headquarters are considered as buildings housing the club's management and administrative staff. Often, in addition to the offices, there are dedicated commercial areas with merchandising sections and ticketing facilities, a fan club area and a museum in which to collect trophies, prizes and team uniforms. Usually there are also large spaces dedicated to media and communication with conference rooms and interviews areas. Since these buildings represent the image of a football club and the power of the team, they are more often targeted with aesthetic renovations and a particular interest is reserved to the prestigious international LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) sustainability certifications.

2.1.3.1 Typical energy uses and consumption

Clubs headquarters are typical office buildings with usage patterns, energy demands and consumption similar to any other commercial and office structures, with a stable use pattern throughout the week and the year.
As shown in

[13] CTV006 - Sports and leisure introducing energy saving opportunities for business, Carbon Trust - UK, 2006

Figure 2-5, the most consistent energy use is represented by space heating and cooling, up to 30% of the total energy uses (40% when mechanical ventilation is also included). Depending on the climate context and on the building characteristics electricity use for cooling can be significant. Another high end-use of electricity is due to lighting. Consumption depends on office type, utilisation of daylight, illuminance levels and hours of use. Generally, computers and other electronic devices account for up to 8%.



*State Energy Database System (SEDS) is an energy adjustment that EIA uses to relieve discrepancies between data sources. Energy in this case is attributable to the commercial sector, but not to specific end uses.

Figure 2-5: Energy cost of a typical commercial building (including offices)[14]

[14] U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) (2012) 2011 Buildings Energy Data Book

3 Areas of improvements

As confirmed by the analysis of the current building stock, sports buildings are highly energy-intensive structures due to their structural characteristics and use. Apart from statistics and estimations, it is a fact that stadiums, arenas, and football training centres of all types consume massive amounts of energy and can be extreme consumers, especially with regards to electricity (lighting, cooling, pumps, specific equipment and hospitality needs during match days, etc.).
Reducing existing building energy consumption consists of two synergistic approaches:

- Reduce the need for energy through implementation of energy efficiency measures.
- Offset the remaining building energy needs through use of renewable energy systems.

In general, to develop advanced energy-retrofitting plans and to tailor suitable interventions, a detailed assessment of the energy performance of the buildings is of primary importance in order to identify the weak points and the most promising aspects to be renewed and improved.

This chapter, based on previous analyses of benchmarks and relevant energy uses and consumption in football buildings, provides an overview of the areas of improvements on which building owners, energy managers and designers should focus for the energy renovation of football buildings emphasizing the opportunities to increase EE and implement crowdfunding schemes.
The most relevant areas of improvements observed have been reported and divided within 6 thematic groups:

- Technologies to exploit RES (renewable energy sources).
- Improvement of the lighting system.
- Modernisation of HVAC systems, plant and equipment.
- Implementation of BMS (Building Management Systems).
- Renovation of the building envelope.
- Upgrade of electrical equipment and specific technologies.

3.1 Renewable energy sources

In football buildings, energy sources are mostly traditional and fossil fuels, or coming from the electrical grid. Fossil fuels are a finite resource and big contributors to climate change while renewable energy can be obtained from natural resources such as sun, wind and geothermal heat, which are naturally replenished. It is therefore sensible to lower the football buildings consumption and find more sustainable energy sources. Consistent with trends across the building sector, there is an increasing interest to exploit renewable energy sources in sport facilities and especially in retrofit scenarios. Generally, football facilities exhibit high electrical consumption and the use of RES as photovoltaic solar panels and co-generation systems to generate energy are two of the most promising areas of improvement.

Additionally, football facilities are in many cases well postured to adopt RES technologies due to the great availability of large outdoor surfaces and roofs to install solar thermal collectors and photovoltaic systems, making these increasingly popular among the forms of energy that are being used to power sports facilities. Several recent examples as the Johan Cruijff Arena (Amsterdam), the Ashton Gate Stadium (Bristol) and the Kaohsiung National Stadium (Taiwan) demonstrate the efficacy of the adoption of RES in terms of energy and cost savings. The following array of solutions based on renewable energies can be implemented and tailored in all types of football and sports buildings.

3.1.1 Photovoltaic systems

Photovoltaic systems (PV systems) use solar panels to convert sunlight into electricity. PV panels installed in football buildings' roofs provide a simple and environmentally-friendly means of generating electricity. In a football building, a small PV system may provide energy to a single service or device (e.g. a lamp in outdoor areas or parking) while large grid-connected PV systems can provide the energy needed by multiple and consistent electrical services. The use of PV systems suits well also with the intermittent use of most of the football facilities, such as stadiums, with occupancy ranging between time intervals without use and time intervals with the maximum use. In particular, through an intelligent demand side management it is possible to:

- Dedicate energy to the facility when needed.
- Store energy, through efficient and cost-effective energy storage systems.
- Exchange energy with the grid when it is not needed on site. In this case the energy produced by the PV array can be sold back into the main electricity grid in a net metering agreement.

Allowing a structure such as a stadium, extremely energy-intensive during a sporting event, to become more autonomous from an energy point of view would make the power grid of the whole district more stable by avoiding these peaks in consumption. While solar panels are still an expensive option in the short term, the economic benefits will be realised over a period of time. Additionally, many countries now have grants and subsidies that make them a viable and even attractive proposition over the longer term.

3.1.2 Solar thermal panels

Solar thermal technology allows the production of heat through sunlight and the conversion of solar radiation to thermal (heat) energy. In football facilities these forms of energy can be used to provide the heating or pre-heating of the water used in baths and changing rooms. Solar thermal systems can be efficiently used for different applications:

- Domestic hot water (DHW) heating.
- Space heating: solar thermal systems can contribute to the heating of internal spaces as well as to the hot water heating. This use is best applied to under-floor heating systems as they work at lower temperatures.
- Swimming pools: the heating of the pools is one of the best-established applications of solar water heating. In some cases, collector efficiencies of greater than 75% can be achieved.

It is advisable to implement a solar thermal system for all those facilities where there is a high demand of domestic hot water (e.g. for changing rooms in stadiums and training centres) and where it has a large impact on energy bills. This system is also recommended for swimming pool heating, where applicable.

3.1.3 Biomass heating system

Biomass is a term that covers different types of organic materials such as trees, construction wood, agricultural, forest, urban and industrial residues and waste (e.g. corn husks, rice hulls, peanut shells, grass clippings, leaves, crops, sewage sludge and manure) that can be processed and burned to produce energy with less effect on the environment than fossil fuels. Biomass heating systems for thermal applications generate heat from two main forms of biomass: woody materials and gas or liquid biofuel.

This type of energy production has a limited long-term effect on the environment because the carbon in biomass is part of the natural carbon cycle, while the carbon in fossil fuels is not, and permanently adds carbon to the environment when burned for fuel[15]. Implementing a biomass heating system in a football building simply means to

[15] http://www.esru.strath.ac.uk/EandE/Web_sites/07-08/Biomass_feasibility/overview/carbon.html

replace the existing fossil fuel boiler with a new biomass boiler and connect it to the system. Biomass may offer a few advantages in terms of energy cost reduction:

- It can be significantly cheaper.
- It can generate significant annual payments for heat generated and used from national incentives dedicated to RES.

The types of facilities for which biomass is usually a good investment include those football buildings where hot water use results in high load for all seasons (e.g. not for stadiums). To provide heating to football facilities, the use of hybrid systems linking biomass with solar thermal systems is considered ideal.

3.1.4 Geothermal systems

Geothermal systems take advantage of the thermal energy generated and stored inside the Earth. Geothermal heat pumps are the common application to exploit geothermal energy by utilising the constant temperature of the earth as an exchange medium for heat, irrespective of seasonal changes in the atmospheric temperature. They represent one of the most cost-effective heating and cooling systems available. Geothermal systems are capable of heating and cooling spaces by transferring heat from or into the heat exchanger. In winter, heat is removed from the heat exchanger and pumped into the indoor air delivery system; in summer, heat is removed from the indoor air stream into the heat exchanger. Implementing geothermal heat pumps in football buildings can be an opportunity to renovate the HVAC systems exploiting renewable resources, increasing the efficiency of the heating and cooling systems and reduce the energy costs.

3.1.5 Micro wind turbines

Wind is a major source of energy in many parts of Europe, and wind turbine technology is advancing rapidly. Depending on the wind resource availability, a small wind energy system can lower the electricity consumption and therefore may be viable to install a series of small wind turbines in the proximity of a stadium or a training centre to produce electricity for internal use, or to feed into the local grid if there is a surplus. Generally small wind turbines can be well-integrated with urban landscapes and with PV systems, representing an iconic technology to promote energy efficiency and a new image of sustainable sports.

3.2 Lighting

Having good lighting levels in contexts where a sport is practiced at a competitive or pre-competitive level is extremely important. Lighting systems of football buildings must meet requirements in terms of illuminance, uniformity, glare control and chromatic properties of the sources used. These may vary based on the level of the competition. In Europe, EN 12193 defines the requirements for three different competition classes.

Additionally, to comply with UEFA's requests for high-definition broadcasts (slow motion shooting minimising flickering) it is needed to set up an ad hoc lighting system able to assure an uniform lighting level (at least 2000 lux) and a brilliant colour rendering (CRI 86, TLCI>80) over the whole field in order to avoid any shadow on the football players. To achieve these targets, in a medium-sized stadium, up to 300 floodlights may be needed. Since energy consumption for lighting is a considerable part of football buildings' energy costs, its improvement represents a strategic key aspect. There are many simple ways to reduce the energy consumption and costs associated with lighting without compromising comfort, the most important ones are:

- Converting existing lighting systems to LED with High-Efficiency LED Light.
- Partializing the system to allow multiple scenarios (e.g. for the playground 3 or 4 scenarios can be set for different purpose: training sessions, matches and television footage).

- Introducing an automated lighting management system including the actual monitoring of lighting levels, occupancy and daylight sensors.

Of course, the amount of energy and cost savings will be higher the more fixtures that are replaced and if hours of use or costs of electricity are higher. In case of stadiums, powerful floodlights and outdoor lighting used to light up the entire stadium structure on match nights are frequent and can have an intrusive impact on the immediate neighbourhood, i.e 'light pollution'. Since these lights have a major impact on the area around the stadium, contingencies need to be put in place to limit visual contamination and minimize disruption to the local community. The deep renovation of the lighting systems offers many benefits such as:

- **Massive reduction in energy spent** converting a 1000-Watt metal halide which actually consumes an additional 15% for the fixture ballast and accounts for a total of 1150 Watt to a 400-Watt sport LED light reduces energy consumption up to 750 Watt per fixture. This means about 65% energy saving per fixture.
- **Cut down on regular maintenance spent for replacement**: a metal halide suffers significant lumen degradation quickly. It is not uncommon for a metal halide to lose half of its initial lumens within the first 7500 hours of life, or the half-life of the bulb. At some point, as the bulb gets older, its effectiveness becomes limited, and it should be replaced, and that is frequently well before the bulb had completely failed. It does not make sense to light a football field with metal halide bulbs that are 80% through their lifespan. Even though the lights are still 'on', the field is dim. Best practice is to replace the bulbs at half-life, which makes maintaining stadium and training centre lighting systems a chore. The replacement of bulbs in a stadium or training centre is not easy and cheap, as in case of offices or traditional building (the lights are generally mounted high). Therefore, it may make sense to upgrade stadium lights to LED to eliminate this costly time expenditure. LED lighting systems normally maintain 70% of their initial lumens even after 100,000 hours of use.
- **Obtain higher quality of light**: the Colour Rendering Index (CRI) is a quality scale of a light source, a range between 0 and 100, with 100 being the best score. With LED light, it is rare for the CRI to be below 70, compared to High Pressure Sodium Lighting HPS, whose score is less than 30. With LED lights on the playing field everything appears sharper and brighter. Colours appear as they should and are not discoloured by the light source itself. In the case of the HPS light, it is necessary to compensate the poor quality with more quantity.

Table 3-1 summarises the benefits of LED lights compared to conventional technologies:

Table 3-1: Comparison between LED lights and conventional technologies

Item	Benefits of LED lights compared to conventional technologies
Service life	Lifespan of LED lights is 4 or 5 times higher than other technologies. They also lose their lumen efficiency much slower over time when compared to MH HID technology, offering better performances for a much longer lifespan. This translates into lower maintenance and material replacement costs, as well as less waste for disposal.
Energy efficiency	LED fixtures offer excellent light performance with low power. Replacing conventional lamps with modern LED floodlights and lamps can lead to up to 35% energy savings.
Costs	LED systems generally cost more than other solutions, but they offer a better return on investment during the lifespan of the system thanks to energy savings and the reduction in maintenance costs and need of replacement.
Color	LED lights offer higher Television Lighting Consistency Index (TLCI) than other technologies. Color rendering is especially important in sports facilities that host HD TV footage and broadcasts.

Operating times	Unlike other technologies, LED solutions emit 100% of the luminous flux, directly upon switching on. They don't take time to warm up.
Focus	HID and other technologies emit omnidirectional light, they tend to illuminate beyond the specific area, even with spotlights, which means that much of the light emitted is scattered and wasted. The LED lights, on the other hand, are very localized, where ~100% of the emitted light can be specifically directed towards the area to be illuminated.
Light pollution	The directional lighting capability of LED lights naturally helps to minimize light pollution. Additionally, the use of reflective visors can further reduce light scattering and its negative impact on the environment around sports facilities.
Environment	In addition to minimizing light pollution, LED solutions require significantly less energy to operate than other technologies. As a result, they create fewer greenhouse gas emissions.

3.3 HVAC systems, plants and equipment

The wide variety of football building types and size is also reflected in a large number of HVAC systems serving them. Since most of the current sport facilities were built between the 1960s and the 1980s, often their HVAC systems are outdated. Their replacement with more efficient systems or the modernisations of some equipment offers a big opportunity to reduce energy consumption and costs. The refurbishment of an HVAC system should always be completed by interventions on the building envelopes.

Typically, in small football buildings (both training centres and more often club headquarters) natural gas boilers are used for hot water production and heating demands. The existing boilers can be replaced with:

- New condensing boilers.
- High efficiency heat pumps.

Both systems can be used in connection with solar thermal systems which can provide preheating and hot water to shower facilities. Because of the volumes of water utilised in sport facilities the energy savings could be relevant. In general, big and medium-sized stadiums, training centres and large club headquarters can implement, additionally to big-size condensing boilers and heat pumps, also the following production systems:

- Cogeneration systems (a.k.a Combined Heat and Power system, CHP) able to generate simultaneously both electricity and heat for heating purposes or DHW production.
- Tri-generation systems (a.k.a Combined Cooling, Heat and Power systems, CCHP) able to generate simultaneously electricity and heat for heating, cooling or DHW production. Tri-generation differs from cogeneration in that the waste heat is used for both heating and cooling, typically in an absorption chiller. CCHP systems can attain higher overall efficiencies than cogeneration and traditional plants.

HVAC systems must also guarantee adequate thermal comfort and air quality levels. A frequent change of air can involve an excessive waste of energy, which may be limited by the installation of an Air Handling Unit (AHU) with a heat recovery system, which could achieve constant temperature and constant humidity with heat recovery up to 90%.

The creation of thermal zones with separated regulations allows to define spatial requirements zoning the internal spaces of a building into different areas where it will be possible to set different conditions (temperatures, air changes, etc). A good rule for zoning a building is that perimeter spaces should be zoned separately to core spaces. This is because of the effect of façades and so the external condition can affect the perimeter areas differently than the internal areas. Moreover, for perimeter spaces, spaces with different orientations and substantially different

façade types (e.g. an opaque wall and a glazing wall) should be zoned separately as they are subjected to solar gain differently and/or at different times.

3.4 Building Automation

In general, most of the football buildings, regardless of size, are characterized by an intermittent use of the premises and of a variable number of people using them over the day, with occupancy ranging between time intervals without use and time intervals with the maximum use. This feature of intermittency may decrease the energy efficiency of the facility. It is also the case that the energy infrastructure may be oversized or run at levels only appropriate for periods of maximum use. Currently, most of football buildings are not yet equipped with building automation systems although, in some cases, they are energy-intensive buildings.

The adoption of appropriate and smart building automation systems, in particular in large football buildings with extensive HVAC and electrical systems, leads to major improvements and energy savings. In fact, it is well-know that a Building Management System (BMS) can play a major role for reducing overall energy consumption, optimizing end-uses of energy and reducing operative and maintenance costs while maintaining comfort, safety and security. Through a building automation system, it is possible to monitor and control building HVAC systems, indoor and outdoor lighting as well as security, fire alarms, and basically everything else that is electrical in the building. Where storage systems are installed it will be possible to define how to manage thermal energy or electricity to balance the energy peaks. Renewable energy systems can be monitored and connected to the server through standard protocols, allowing to:

- Verify the hourly production.
- Plan maintenance actions when the production data exceed the efficiency threshold: an alarm will be sent automatically to the energy manager or electrician for timely interventions.
- Introduce a simple management protocol and integration with the grid.

3.4.1 Smart metering and controllers

Football facilities are unique buildings for energy consumption with a wide composition of functional areas. The adoption of an appropriate and well-designed metering and control system is essential to support the building management system to meet energy efficiency goals and assess energy savings. Due to the specific features of football buildings (e.g. very large spaces, very high energy peaks concentrated during limited time intervals, very large variation in occupant numbers, need of particularly healthy air quality, etc.), specific smart metering systems and data handling solutions are required. Modern independent sensors and wireless sensor technology allow a deep monitoring with high frequency, and are able to provide an automatic and instant distribution of tailored and pre-processed information.

3.5 Building envelope

The building envelope, considered as the boundary between the conditioned interior of a building and the outdoors, plays a key role in determining levels of comfort, natural lighting and ventilation, and thus how much energy is required for heating and cooling. Energy performance of building envelopes are relevant, especially in the case of club headquarters, as they are comparable to typical office buildings, where the comfort of the occupants over long periods is critical and can even improve working efficiency and worker retention. More generally, the performances of the building envelopes are always relevant where there are heated or cooled internal spaces.
Energy loss through the building envelope is highly variable and depends on numerous factors such as building age and type, climate, construction technique, orientation, geographical location and occupant behaviour. For this

reason, the solutions to improve performance are also varied and highly dependent on the specific case. A general approach implies that to improve energy performance in winter, solar gains should be maximised, and thermal losses minimised mainly using thermal insulation. Similarly, during summer, internal and external gains should be minimised to not overcharge the cooling system using thermal mass, efficient glazing, insulation, shading, reflective surfaces and natural ventilation. Both needs should be carefully balanced based on the actual needs of the building. Following, a quick overview of the most common solutions to renovate building envelopes and improve energy efficiency:

- Continuous external insulation (walls, roofs, external floors) with the correction and minimisation of thermal bridges to reduce heat losses in cold climates.
- Installation of high-performance windows (e.g. low-e glasses) with low thermal transmittance, appropriate solar heat gain coefficients (SHGC) and shading devices to reduce glare and unwanted solar heat gain.
- Installation of highly-reflective membrane on the roofs in hot climates, in order to reduce heat island effects and the cooling demand.
- Installation of green vegetative roofs able to reduce heating and cooling costs and air pollution.

A high-performance envelope provides cost savings for heating and cooling, protection from wind and moisture, occupant comfort, and durability.

3.6 Electrical equipment and specific technologies

Specific technologies and equipment, with relevant energy consumption, could be present in stadiums or training centres. Their replacement with new advanced technologies offers challenges and opportunities to improve the system's energy efficiency. In general, where possible, any features or equipment that require extensive or costly maintenance should be avoided. Severe weather conditions or failure to undertake adequate maintenance could make it necessary to use technologies such as undersoil heating and artificial lighting to growth grass. Both systems are extremely energy intensive and represent a field in which to investigate opportunities and solutions for energy improvement and financial savings.

3.6.1 Soil heating systems

For professional and international stadiums, a very high standard of playing surface is required. Under these circumstances it is important to eliminate risks of poor playing conditions or event cancellation, particularly associated with poor weather conditions, e.g. heavy rainfalls or ice and snow. According to the FIFA's Technical recommendations and requirements[16], in cold climates, the playing field should be equipped with an underground heating system to prevent it from freezing in extreme winter conditions. In the first and second Bundesliga (DFB) in Germany, undersoil heating is already standard. To prevent the pitch from freezing a few solutions are available:

- Installation of an undersoil heating system.
- Use of a heated pitch cover consisting of a layer of plastic sheeting that conceals a system of ventilators producing warm air. This solution protects also the pitch in the event of heavy rain or snow fall.
- Adopt fully covered stadiums; in this case, additional artificial lighting may be needed.

3.6.2 Artificial lighting for grass growth

In order to guarantee a playable field with adequate grass growth throughout the season, even under certain climatic conditions where the amount of natural light and ventilation is critical, a grass-growing artificial lighting is

[16] Football Stadiums, Technical recommendations and requirements, 5th edition, 2011, FIFA

needed. Since certain wavelengths of light (400-500 nm and 650-680 nm wavelength) can enhance the photosynthesis of the plants, adopting a system capable of emitting a beam of homogeneous light within the above spectrum represents a smart solution to increase the parameters of grass growth and reinvigorate the root system. Lighting systems to help promote grass growth have been available for a number of years and their combination with hardware and control systems can support their efficient use.

4 Technical EE and RES solutions Catalogue

There are several solutions available on the market that can be easily implemented to increase energy performance and the thermal comfort of football buildings. To synthesize knowledge regarding best practices and relevant technical solutions to be adopted to improve energy efficiency and RES installation in football buildings, a dedicated Technical Catalogue (Appendix 1) has been developed in order to provide an easy-to-read tool to be used for the development of engineering plans. The purpose is to provide a wide range of solutions, suggest energy efficiency options and technical features to inform the development of detailed plans, at first for each GREENFOOT candidate buildings (Task 4.2), and then to all other football buildings interested in energy renovation. The challenge is to enhance energy efficiency in football buildings, reduce CO_2 emissions, produce cost savings and provide good examples for the whole sports community and beyond.This section introduces the GREENFOOT Catalogue structure and general design considerations.

4.1 Structure of the Technical Catalogue

The Technical EE and RES solutions Catalogue for football buildings (Appendix 1) has been developed based on the initial analysis of the current football building stock and the identification of its weak points and areas for improvements. The findings are based on information collected from literature review, from RINA Consulting expertise as engineering firm, from the experiences of the partners involved in GREENFOOT, and from relevant existing examples.

The Technical Catalogue consists of a collection of 20 sheets documenting specific design solutions and technologies to guide the designers during the development of renovation plans and facilitate an informed decision-making process. For the catalogue structure, a pragmatic approach has been proposed and the technical solutions have been organised according to the following 6 categories, which refer to the main areas of improvements identified in chapter 3:

- Renewable Energy Sources and Smart Grid.
- Lighting.
- HVAC systems, plants and equipment.
- Building Management System.
- Building envelope.
- Electrical equipment and specific technologies.

Each category starts with a brief introduction including a general description of main purposes and best practices. Opportunities and guidelines to reduce energy uses are briefly described, while technical details will be reported within subsequent dedicated sheets. Each category contains a bundle of different solutions, each with its own technical details. The information for each technical solution is structured as follows:

- **General description** with an explanation of main functions (what is it, and what does it consist of?) and the football building typology that it can be applied to.
- **Technical features and design parameters**: What are the main technical considerations?
- **Conditions for implementation**: What on-site conditions should be considered?
- **Strengths and barriers**: What are the benefits and limits of the solution?
- **Performances and potential impacts**: What are the impacts of the solution both from under the point of view of energy and cost savings, and of adaptability with crowdfunding schemes? Performances and potential impacts are dependent on geographic, climate and social conditions and therefore require more accurate evaluations on the specific cases. Within this document a generalized approach has been adopted and general information provided.

- **Relevant examples** (if exemplary for the technology): successful implementations of the solution proposed are provided as reference.

To be effective, the sheets integrate also preliminary information about the adaptability with crowdfunding schemes as introduced in the following paragraph.

4.1.1 Adaptability with crowdfunding schemes

Crowdfunding is a process by which several people ("crowd") finance different kind of initiatives or projects ("funding"), even with modest amounts of money, and sometimes receiving a reward in exchange (the reward could be of a financial nature, such as an equity participation or an interest rate, or-non financial in the case of more tangible benefits). In fact, it is a method of collecting contributions in small amounts accumulated by a multitude of individuals that shifts emphasis on the attractiveness of ideas rather than on return on investment. The appropriateness of each solution for crowdfunding is evaluated based on the best practice examples and data presented in GREENFOOT's Deliverable 2.1.

Within the technical sheets of the Catalogue proposed in Appendix 1, for each solution, a preliminary evaluation of the potential impacts on the adaptability with crowdfunding has been provided. For the purpose of this report, the preliminary assessment is focused specifically on the business proposition of financial solutions (or just crowdlending) while a more in-depth analysis of the other options will be carried out as part of Task 2.3 where the technical solutions highlighted will be combined with the results of the work done in Deliverable 2.1
Since crowdfunding adaptability is due to a complex set of conditions associated with different socio-economic contexts, to explore how much a solution may fit with crowdfunding schemes a dedicated matrix, shown in Table 4-1, has been developed taking into account 4 aspects capable of positively or negatively influencing the adaptability with crowdfunding:

- The return of investment: for which 3 levels have been identified less than 3 years, from 3 to 10 years and over 10 years.
- The visibility and image return for club and fans: with high, medium and low impact.
- The carbon footprint reduction: with high, medium and low impact.
- The experience improvement for fans and users: with high, medium and low impact (e.g during the match or the use of the building).

Table 4-1: Matrix for the adaptability with crowdfunding schemes

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
from 3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

Crossing the levels (high, medium, low) of each aspect with the return of investment a partial score is associated using a scale from 0 to 4, 4 represents a solution which best fits with crowdfunding and 0 a solution which does not fit well with crowdfunding. Adding all the partial scores for each aspect (visibility and image return, carbon footprint reduction, experience improvement) a total score is obtained. Based on the total score calculated as above, it is possible to classify each of the solution proposed in the Catalogue with 3 different levels of adaptability:

- **High level** (score between 8 and 12): the solution proposed fits very well with a crowdfunding approach.
- **Medium level** (score between 4 and 8): the solution proposed fits somewhat with a crowdfunding approach, some improvement could be evaluated.

- **Low level** (score between 0 and 4): the solution proposed fits poorly with a crowdfunding approach, tailored expedients and measures are needed to enhance the adaptability with crowdfunding.

More details on crowdfunding schemes will be deeply evaluated within WP3 tasks with a focus on financial infrastructure (Task 3.1), regulatory barriers (Task 3.2) and investment opportunities at every test site (Task 3.3), and within the socio-economic assessments in WP2 (Task 2.1 - 2.3).

4.2 General considerations

To get reliable renovation scenarios, it is important to analyse and understand the peculiarities and the real behaviour of each case with a focus on the requirements, the objectives, the current and further needs and the priorities of the specific football building. These may vary depending on the actual state of the building, on commercial considerations and expected cost savings. As each football building is its own special case, the identification of a solution or set of solutions must start from an analytical analysis of the current-state-of-the-art of the building and its needs, and must involve energy experts to assess the energy performance of the building and evaluate all the energy related information such as:

- Thermo-physical characteristics of the envelope and energy performance of windows in order to characterise the energy flows of walls, roofs and slabs.
- Space use and features to identify homogeneous thermal zones with similar thermal loads, ventilation rates and set point temperatures.
- HVAC systems including equipment and operating schedules.
- Characterisation of all the energy sources utilised at the facility, including renewable energy sources possibly installed.
- Lighting configurations and all the relevant electrical equipment.

Due to the different nature of the football buildings, not all the solutions proposed are suitable for all the buildings. A suitable data collection on site is an essential pre-requisite to develop reliable advanced energy-retrofitting plans and to tailor suitable interventions. The clear understanding of the actual state of the building allows to identify and define the parameters of what is feasible. Besides, a balance should also be established between the proposed technical solutions, the real needs and the finance reality together with the type of energy contract in place with the energy suppliers.

All the technical solutions, to be implemented and adopted in a renovation project, must also be compliant with all the design, construction, health and safety national and/or local requirements. Additionally, all the competitive structures, with reference to the activity level, must be complaint with technical and approval requirements of the international and national football associations (e.g. CONI). EE football building renovations should provide also good levels of comfort, incorporating the latest technological advances to maximise the commercial potential by incorporating a broad range of facilities and usages.

5 Conclusions and future works

The document provides technical information and best practices for the implementation of EE solutions and RES technologies in football and sports buildings. In particular, it will serve as a basis for the development of the engineering plans for GREENFOOT Candidate Buildings (Task 4.2).

The analysis on the football building stock revealed that there is a wide variety of buildings each with its own features, peculiarities, weather and site conditions and needs, which all have great influence on the energy consumption. Starting from the analysis of most promising areas of improvement, such as the exploitation of RES, the improvement of lighting and HVAC systems, the implementation of Building Automation systems and advanced specific technologies and equipment, as well as the renovation of the building envelope, the deliverable has introduced a range of suitable EE solutions and RES technologies, which are analysed and collected within the Technical Catalogue (Appendix 1). A large part of the solutions proposed are suitable to each football building typology as they can be scalable to building features and needs from larger stadiums to small training centres.

In order to provide an easy-to-read and immediate-use tool, the Technical Catalogue has been organised through 20 technical sheets including a general description of the function performed, technical details and design parameters, conditions for implementation, strengths and barriers, energy performances and costs savings as well as preliminary information on the adaptability with crowdfunding schemes. For some solutions, relevant examples have been provided in order to give guidance and be investigated in the following GREENFOOT technical activities. For each area of improvement and thematic group of the Technical Catalogue, general considerations have been provided in order to extend the utility of the document to building managers from across Europe and not limit it only to the development of the renovation scenarios of the GREENFOOT Candidate Buildings.

The analysis performed and the data collected establish a starting point for the GREENFOOT project under the technical and engineering point of view and fit in a wider context in order to meet Work Package 4 objectives and support other further GREENFOOT activities. The implementation of EE solution and RES technologies depends of course on the dimension of the interventions.

In general, there are two predominant perspectives on the relative importance of the building envelope and heating and cooling equipment. The passive design approach supports high levels of energy efficiency in building envelope components, with any remaining need for heating or cooling met by basic, efficient mechanical equipment. The smart technology approach promotes high energy efficiency in mechanical equipment because it is routinely replaced, and installing it is easier than retrofitting old, inefficient building envelopes. Either approach can be appropriate. The balance between advanced envelopes and advanced equipment needs to be established on the specific building considering product availability, cost, climatic conditions and energy prices.

More in-depth analysis on the Candidate Buildings' needs, requirements and opportunities for energy efficiency improvements will be carried out within the subsequent Task 4.2, in which suitable renovation scenarios and engineering plans will be developed. To develop suitable renovation plans able to reduce energy consumption and increase cost savings, detailed energy audits will be needed to analyse the state-ot-the-art of each Candidate Building and to evaluate in detail all the potential impacts both under the energetic and economic points of view.

To conclude the task activities, the final draft of the Technical Catalogue has been shared among relevant stakeholders within the GREENFOOT project, including the 3 football federations (AFFA, FAI and FFF), the European Football for Development Network (EFDN) and the European Crowdfunding Network (ECN), in order to communicate the range of solutions, to define the renovation scenarios, and collect their feedback on the solutions

proposed. Appendix 2 show the questionnaire and the feedback collected so far. No adjustments and additional implementations of the Technical Catalogue has been required at this point of GREENFOOT project. Nevertheless, this preliminary survey will be included in the first steps of Task 4.2. The results will help to complete the initial analysis and to start the development of the activities on the Candidate Buildings.

The Technical Catalogue can be easily updated with new solutions throughout the GREENFOOT project if adjustments and implementations are needed. Additionally, to energy efficiency measures, renovation projects of existing football buildings should take into account a series of interventions aimed to enhance flexibility and facilitate functions and activities that can make the venture more economically viable. Although most of the geometric aspects are fixed, there are a few functional space layouts that can be optimised. To conclude with the further steps for the implementation of the solutions, there is a usual sequence of steps which are broadly summarised within Figure 5-1 and which will be implemented in the following workflow of the WP4.

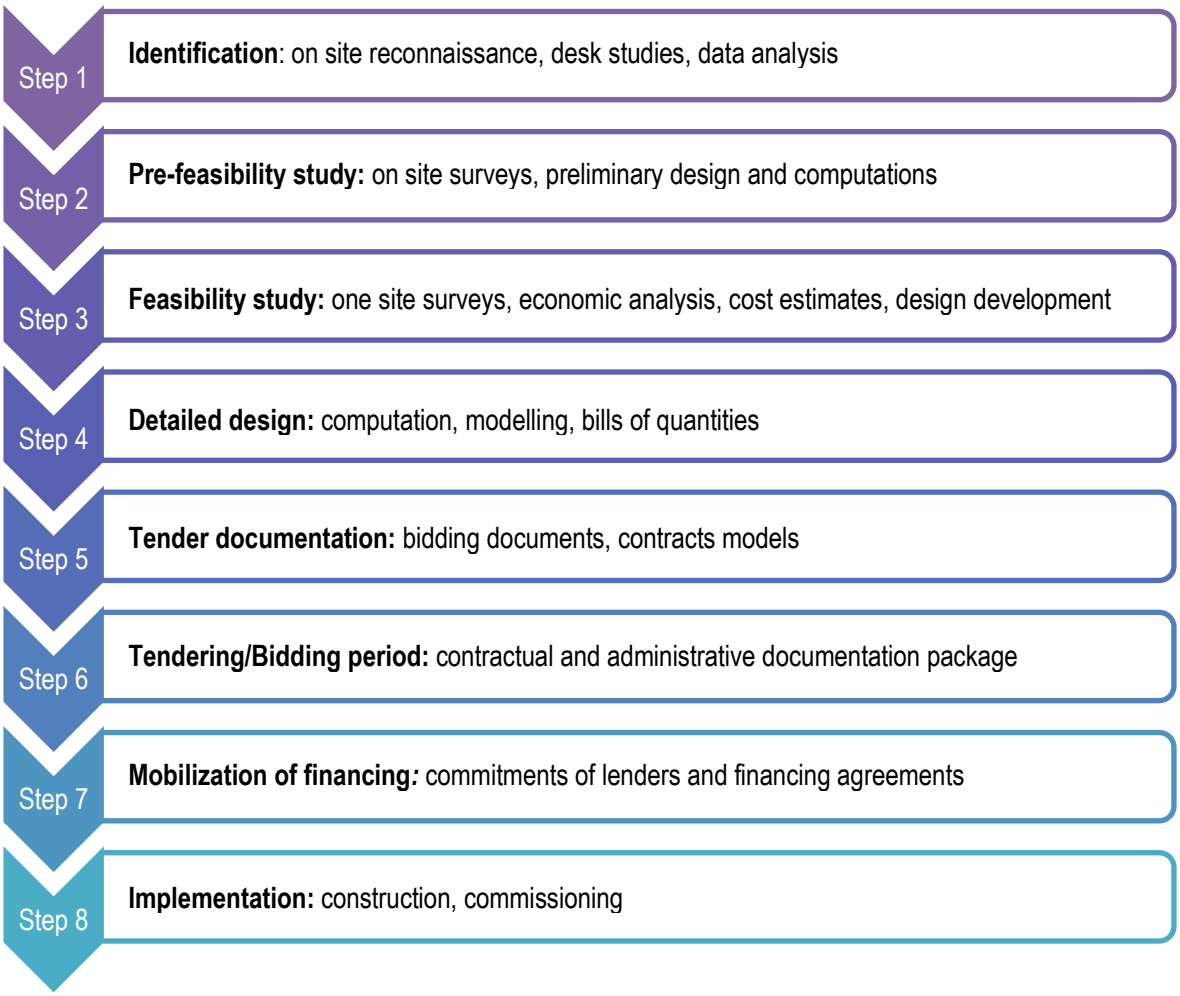


Figure 5-1: Complete workflow for the implementation of EE and RES solutions in Candidate Buildings

6 Further Reference Material

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7 APPENDIX 1 – Technical Catalogue

Comprehensive sheets, informing about technical specifications, impacts and savings opportunities have been provided and divided into 6 categories:

- C.1 – Renewable Energy Sources.
- C.2 – Lighting.
- C.3 – HVAC systems, plants and equipment.
- C.4 – Building Automation.
- C.5 – Building envelope.
- C.6 – Electrical equipment and specific technologies.

List of EE and RES solutions

Ref. Code	Category	Category 2
C.1	Renewable Energy Sources	C.1.1 – Photovoltaic systems (PV)
		C.1.2 – Solar thermal panels
		C.1.3 – Biomass heating systems
		C.1.4 – Geothermal systems
		C.1.5 – Small wind turbines
C.2	Lighting	C.2.1 – LED technology for floodlighting
		C.2.2 – LED technology for internal lighting
		C.2.3 – Lighting controls
C.3	HVAC systems, plants and equipment	C.3.1 – High efficiency Heat Pumps
		C.3.2 – High efficiency Condensing Boiler
		C.3.3 – High efficiency Air Handling Units (AHU)
		C.3.4 – Cogeneration systems
		C.3.5 – Trigeneration systems
C.4	Building Automation	C.4.1 – Building Management Systems
C.5	Building envelope	C.5.1 – Thermal insulation
		C.5.2 – High-performance windows
		C.5.3 – Cool roofs
		C.5.4 – Green roofs
C.6	Electrical equipment and specific technologies	C.6.1 – Under soil heating
		C.6.2 – Artificial light for grass growth

C.1 - Renewable Energy Sources

An improvement opportunity to optimize the EE, reduce utility costs and building's carbon footprint is given by the implementation of RES that allows electricity production for self-consumption, sale into the grid, and the exploitation of thermal heat collected both from solar radiation and the ground. The use of renewable energy systems for meeting football buildings energy needs is also a means for demonstrating leadership in environmental sustainability and resource conservation, increasing the reliability of on-site electrical and thermal energy supplies, addressing energy security issues, and other benefits.

For every type of football building, the biggest economic benefit of renewable energy technologies is represented by the generation of electricity that can be used directly, stored for deferred uses, or sold to the grid. The following technical sheets have been provided:

- C.1.1 – Photovoltaic systems (PV)
- C.1.2 – Solar thermal panels.
- C.1.3 – Biomass heating systems.
- C.1.4 – Geothermal systems
- C.1.5 – Small wind turbines.

Before selecting an appropriate renewable energy technologies to apply to an existing football building retrofit project, it is important to first consider a number of factors, including:

- Available renewable energy resources at or near the building site.
- Available area for siting of the renewable energy technology.
- Cost of energy purchased from the electrical or thermal energy provider for the building.
- Available incentives for offsetting the installation cost of the renewable energy system.
- Local regulations affecting renewable energy systems.
- Desire to preserve or alter existing architectural features.
- Characteristics of the energy profiles to be offset by the renewable energy installation.

C.1	Renewable Energy Sources (RES)

C.1.1 Photovoltaic Systems (PV)

i. General description

Main function	Photovoltaic systems (PV) are made of PV modules consisting of many solar cells which convert solar light into electricity. PV technology can be used on a variety of scales, from an integrated solar cell in a single lamp/device, to a battery-operated solar system or even a large grid connected solar power plant with capacity of several MW. PV systems can be used as principal or ancillary source of electrical power.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.

ii. Technical features and design parameters

Technical features	Several types of PV technologies have been developed and can be classified as follows: ⚽ **Mono or multi-crystalline silicon cells**: may be mounted into framed panels or frameless panels suitable for roof or façade integration. For commercial PV panels highest cell efficiencies are about 20% for mono crystalline cells and 18% for multi crystalline cells ⚽ **Thin-film cells**: minor amount of material required in creating the active material of solar cells but most thin-film solar cells are sandwiched between two panes of glass to make a frameless module and therefore they are approximately twice as heavy as crystalline silicon panels. The majority of thin-film panels have 2% to 5% lower conversion efficiencies than silicon. Cadmium telluride (CdTe), copper indium gallium selenide (CIGS) and amorphous silicon (A-Si) are three thin-film technologies. ⚽ **Concentrating photovoltaic technology (CPV)**: utilise optical devices, such as lenses or mirrors, to concentrate direct solar radiation onto very small, highly efficient multi-junction solar cells. Commercial CPV modules with silicon-based cells offer efficiency in the range of 20% to 25%. ⚽ **Organic photovoltaic (OPV)**: uses organic semiconductors and are potentially cost-effective for photovoltaic applications. The main disadvantages associated with organic photovoltaic cells are low efficiency, low stability and low strength compared to inorganic photovoltaic cells. Currently, the market only has a few manufacturers.
Main components	⚽ PV modules: to convert sunlight directly into electricity. ⚽ Solar cables: to connect solar modules and other electrical components in the PV system. ⚽ Support structure: to mount or install the PV modules and other component.

	⚽ Batteries: to store electricity and provide energy on demand. ⚽ Inverters: required to convert the DC power produced by the PV module into AC power, if grid-connected or used as 230 V system. ⚽ Controllers: to manage the energy storage to the battery and deliver power to the load.
Design parameters	Relevant key elements for PV system design are: ⚽ Demand of electricity of the building. ⚽ Availability of spaces on which to install the PV system and roof covering materials. ⚽ Location and irradiance levels. ⚽ Orientation and angle of inclination of the panels
iii. Conditions for implementation	
Site conditions	It is necessary to identify appropriate sites for installing the PV modules without any shading. Generally, roof tops offer suitable opportunities to place the systems (also for their low visual impact). Optimum exposure is coincident with the south direction as this orientation offers the highest productivity for an azimuth of 0 degrees.
Recommended applications and best practices	⚽ **Roof-top solar PV systems** integrated with football building: either mounted on top of the roof or nearby on auxiliary structures ⚽ **Small PV modules** combined with single efficient lamps (mostly LEDs), charge controllers and efficient batteries. Only a few watts essential services can be provided, such as lighting. ⚽ **Battery backup inverters**, special inverters design to draw energy from a battery, manage the battery charge via a charge controller and export excess energy to the utility grid. It is advisable to have a system connected to the grid and equipped with batteries to storage electricity. The advantage is that the energy produced during the operating hours of the PV system can be used simultaneously or stored on site to maximise self-consumption. The residual energy that cannot be stored in batteries can be sent into the grid and can be enhanced through on-site exchange contracts Additionally, with the grid connection, the supply of energy is always guaranteed (even in the event that the PV system fails to produce energy).
Maintenance	⚽ Cleaning of the panels – visual control done regularly ⚽ Checkup of cables and fixation – visual control done regularly

iv. Strengths	**v. Barriers**
⚽ Saving of fossil fuels and carbon footprint reduction ⚽ Consolidated technology. ⚽ Technology scalable according to the real needs of the building. ⚽ Easy maintenance of PV system. ⚽ Most commercial PV modules are capable of producing electricity for at least 20 years. Good quality panels are expected to have a life period up to 30-35 years.	⚽ Inefficient financial support in a few cases. ⚽ Relatively low prices of electricity in some countries (e.g. Azerbaijan) that make the investment less convenient with long pay-back periods. ⚽ Complex regulatory framework to obtain administrative authorizations and to sell energy to the grid. For a direct sale of electricity, it is compulsory to be registered as an electricity supplier and therefore paying all taxes on the electricity sold.

vi. Performance and potential impacts	
Energy production	The performance of PV systems depends on many factors: size (installed capacity), efficiency of the technology, irradiation at the site, cleanliness of the surface, system configuration. An installed capacity of 1 kWp (typically 4-6 individual modules with a total surface of approx. 8 m^2) can generate more than 2000 kWh annually. In moderate, cloudy climates, the modules may reach only 50% or less of this output (e.g. 1000-1500 kWh annually in North Italy).

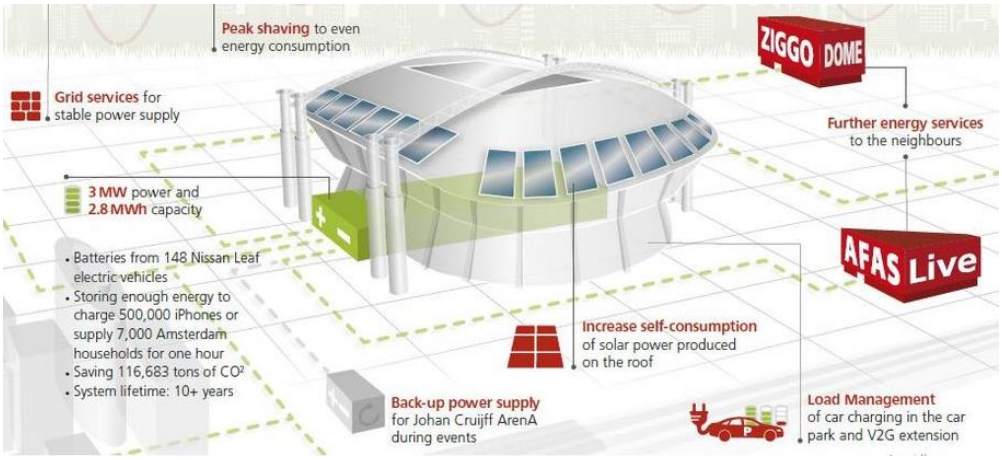
Cost savings/ Payback time	The cost saving of a PV system depends on the electricity price and on the amount of electricity produced (linked to solar irradiation, technology efficiency and system configuration) as well as the availability of financing incentives. For these reasons, the return of investment (ROI) must be evaluated specifically for each case. Average cost per kWp installed: ⚽ With battery banks: 2500-3000€ ⚽ Without battery banks: 1500-2000€ Typical payback times PBT (without energy storage systems) are between 1-3 years.
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score 10)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

vii. Relevant examples

Johan Cruijff ArenA (Amsterdam) [17]

The stadium hosts around 15 league home games a season as well as international ties, European cup encounters and a range of non-sporting events throughout the year.



https://www.johancruijffarena.nl/en/over-ons/duurzaamheid/

More than 4,200 solar panels (about 1MWp) have been installed on the roof in 2014 to supply green energy to the ArenA providing about 930 MWh/year (10% of current electricity consumption) with 117,000 tons of CO_2 saving. The ArenA is also equipped with the largest European energy storage system using second life and new electric vehicle batteries installed at a commercial building. Batteries from 148 new and used Nissan LEAF cars provide 3 MW of storage with a capacity of 2.8 MWh.

The battery, charged to 100%, can be called on to provide full power to the ArenA for one hour during a major event with maximum energy intake or three hours if dispensable consumers (e.g. kitchen facilities) are disconnected.

For the energy storage system, there is an intelligent hard and software solution that manages the battery in multiple use cases. Linked to the PV intervention also up to 200 electric vehicle chargers have been installed.

[17] https://www.johancruijffarena.nl/en/over-ons/duurzaamheid/

	A sophisticated management system balances the differences in energy supply and demand. The system can provide backup during a power failure and reduces the use of diesel generators. Storage capacity outside the stadium means the battery contributes to a more stable Dutch electricity grid. A return on investment is expected within 10 years (due to the complex storage system), although this is said to be a conservative estimate.
Bentegodi Stadium, (Verona) [18]	Bentegodi Stadium is a sports facility in Verona with a total of 39,211 seats (it is the eighth Italian stadium for capacity). https://www.stadi.online/stadio-bentegodi-verona/ Between July and December 2009, a photovoltaic system was installed on the roof of the Bentegodi with a value of approximately 4 million euro and a nominal power of approximately 1 MW (9591 m² of panels for a power of 999 kWp), thus becoming the first solar stadium in Italy and the largest photovoltaic system in Italy on a sports facility, thanks to the installation of 13,328 solar panels; with the proceeds from the energy produced, the maintenance costs of the sports facility are amply covered.

[18] https://www.comune.verona.it/nqcontent.cfm?a_id=48635

C.1	Renewable Energy Sources (RES)

C.1.2 Solar thermal panels

https://www.cordivari.it/Sistemi_termici_solari_integrati/Sistemi_termici_solari_per_acqua_calda_sanitaria

i. General description

Main function	Solar thermal collectors collect heat by absorbing sunlight. The thermal energy produced from the solar thermal collectors is gathered and stored in well-insulated tanks and used both for domestic hot water (DHW) production or in larger combined systems to assist space heating requirements. Solar thermal collectors can be used on a variety of scales to meet specific building requirement.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.

ii. Technical features and design parameters

Technical features	There are two main types of solar thermal panels: ⚽ **Flat-plate collectors** composed of a dark absorbing surface, a transparent cover, a heat insulating backing and a fluid that transport heat from the absorber to a water tank. The absorber can be made of different materials, namely polymers, copper, aluminum or steel. Copper is the most expensive, but it's also a better, more durable conductor. Polymer collectors are indicated for colder climate since materials such as silicon are much more freeze-tolerant than metal ⚽ **Evacuated (or vacuum) tube collectors** made up of several glass tubes through which the transfer fluid flows. This system is more efficient than flat-plate panels, especially in cold climates but loses efficiency in warm weather duo to the risk of overheating.
Main components	⚽ Solar thermal collectors: to collect heat form sunlight. ⚽ Support structure: to mount or install the solar thermal panels modules and other component ⚽ Pipes where transfer fluid flows: to transfer heat from the panels to dedicated tank. ⚽ Insulated buffer tank: to store the heated water. ⚽ Controllers: to manage the heated water and the systems.
Design parameters	Relevant key elements for solar thermal system design are: ⚽ Demand of domestic hot water (and space heating, if combined) of the building. ⚽ Location and irradiance levels. ⚽ Availability of spaces on which to install the panels and roof covering materials ⚽ Orientation, angle of inclination of the panels

iii. Conditions for implementation

Site conditions	First, it is needed to identify appropriate areas for installing the solar thermal panels without any shading. Generally, roof tops offer suitable opportunities to place the systems (also for their low visual impact). Optimum exposure is between the south-west and south-east directions as this orientation offers the highest productivity for an azimuth of 0 degrees.
Recommended applications	⚽ **Roof-top solar systems** integrated with football building: either mounted on top of the roof or nearby on auxiliary structures. It is advisable to have a solar thermal system for all those facilities where there is a high demand of domestic hot water (e.g. for changing rooms in stadiums and training centres) and where it has a large impact on energy bills. For heating purposes, the system can be successfully applied to under-floor heating systems. The system is recommended for swimming pool heating where applicable (e.g. in large training centres). The heating of the pools is one of the best-established applications of solar water heating. In some cases, collector efficiencies of greater than 75% can be achieved.
Maintenance best practices	⚽ Cleaning of the panels – visual control done regularly ⚽ Check-up of pipes and fixation – visual control done regularly

iv. Strengths	v. Barriers
⚽ Saving of fossil fuels and carbon footprint reduction ⚽ Consolidated and cheap technology. ⚽ Technology scalable according to the real needs of the building. ⚽ Easy maintenance of the system. ⚽ Expected lifespan up to 25 years.	⚽ Relatively low DHW demand that make the investment less convenient with long pay-back periods.

vi. Performance and potential impacts

Energy production	The performance of a solar thermal system depends on many factors: size (installed capacity), efficiency of the technology, irradiation at the site, cleanliness of the surface, system configuration. A small (domestic) solar thermal installation produces between 1000kWh and 2500kWh.
Cost savings Payback time	The potential savings offered by solar thermal systems are difficult to calculate exactly and depend on a large range of factors. These include: ⚽ Initial system cost (depending on size, quality of parts and installation). ⚽ The energy source that they are replacing (gas, electricity, etc.) ⚽ The efficiency of the systems and the solar resource ⚽ Availability of financing incentives ⚽ The cost of the fuel used for backup water heating system, if present and the energy needs. The return of investment (ROI) must be evaluated specifically for each case.
Adaptability with crowdfunding schemes	Level of adaptability: **Medium** (total score between 5 and 8)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples	
Allianz Stadium (Torino) [19]	The stadium has been inaugurated on September 2011 and has a capacity of just over 41,000 spectators. The new built stadium incorporates advanced environmentally sustainable technologies to ensure a low environmental impact, to reduce energy consumption from non-renewable energy sources reducing waste and optimising the resources available. https://mole24.it/2020/10/14/lallianz-stadium-di-torino-la-casa-della-juventus/ The DHW production is supported by two solar thermal systems, dedicated to the athletes' changing rooms and restaurant kitchens, which cover about 60% of DHW demand. The flat type collectors are composed by 8 modules each system and located on the rooftop of the two service blocks roof.

[19] https://docplayer.it/19248334-Gli-impianti-dello-juventus-stadium.html

C.1	Renewable Energy Sources (RES)
C.1.3	**Biomass heating systems**

https://industriale.viessmann.it/guide/guida-impianti-biomassa

i. General description	
Main function	Biomass heating systems use organic materials such as woody materials and gas or liquid biofuels to generate heat for heating purposes or DHW production. Biomass plants can be sized on the needs of the specific football building.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	Several configurations of biomass systems are available: ⚽ **As part of an integrated/hybrid heating system**: this configuration allows for the use of a biomass boiler alongside a traditional boiler to be implemented in greatest plants. The traditional heating can act as a backup. ⚽ **With another renewable heating system**: this configuration allows to go fossil fuel free. ⚽ **As a standalone heating system**: often biomass boilers are used as a standalone system. They can create enough heat all year round, without any production drop in winter (frequent problem with the other renewable sources).
Main components	⚽ Fuel store: it can be automatically fed by delivery truck. Fuel store can be a converted building or a shipping container and should large enough so that only 3 or 4 fills per year are required. ⚽ Biomass boiler ⚽ Buffer tanks: they store hot water that is distributed around the central heating system. The boiler boosts tank temperature rather than starting from cold water, making the whole system a far more efficient.
Design parameters	Relevant key elements for biomass heating systems design are: ⚽ Demand of thermal energy of the building. ⚽ Availability of spaces to install the biomass boiler and to store the biomass. ⚽ Resource assessment, planning and procurement. It is important to research cost and availability of biomass fuel in the area or region.

iii. Conditions for implementation

Site conditions	The first condition for the implementation of a biomass heating system is the availability of spaces for the installation of the boiler, the buffer tanks and the fuel store.
Recommended applications and best practices	The type of system best suited to a particular application depends on many factors, including: availability and cost of each type of biomass (e.g. chip, pellet or logs), competing fuel cost, thermal peak and annual load, building size and type, space availability, operation and maintenance staff availability and local emission regulations. The types of facilities for which biomass is usually a good investment include those football buildings where hot water use results in high load for all seasons. For buildings or training centres with more than 10,000 sqm in a moderately cold climate, a system fuelled with wood chips will be probably be the most economical, assuming that there is a stable local chip supply. For buildings or training centres with less than 10,000 sqm in a moderately cold climate, a wood pellet system might be the best option. For large systems it is advisable to have pellets delivered in bulk (not bagged). These systems usually use pellet silo or bunker to store large quantities of pellets. As a result, the pellets can be automatically conveyed from the silo to the pellet stove, furnace or boiler. Source https://www.wbdg.org/resources/biomass-heat
Maintenance	⚽ Regular and consisting maintenance interventions

iv. Strengths

- ⚽ Cheaper fuel and running costs compared to standard boilers.
- ⚽ Carbon neutral heating.
- ⚽ Consolidated technology.
- ⚽ Technology scalable according to the real needs of the building.

v. Barriers

- ⚽ Complexity of determining available biomass resources: biomass fuel could be not available in the region.
- ⚽ Needs to fuel store.
- ⚽ Capital costs higher than the costs for fossil-fuel plants
- ⚽ Maintenance of biomass boilers requires greater interventions rather than fossil-fuel boilers

vi. Performance and potential impacts

Energy production	The performance of biomass heating systems depends on many factors: size (installed capacity), quality of biomass fuel used and system configuration. A typical biomass system operating has a net efficiency of about 70-77%. Best performing boilers and systems could arrive up to 90% net efficiency.
Cost savings/ Payback time	The cost saving of biomass heating systems depend on the biomass fuel costs and the energy sources that they are replacing. Additionally, to evaluate the return of investment (ROI) also the initial system costs and the availability of financial incentives must be taken into account and evaluated case per case. Typical fuel cost savings are[20]: ⚽ Wood pellets: 20-40% saving on fuel cost ⚽ Wood chips: up to 50% saving on fuel cost
Adaptability with crowdfunding schemes	Level of adaptability: **Medium/Low** (total score between 1 and 5)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

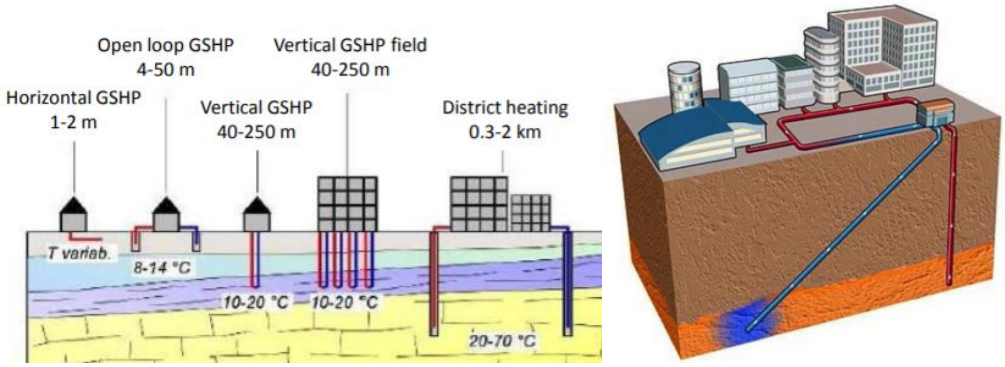
*return of investment to be evaluated on the specific case, it can vary.

[20] https://www.treco.co.uk/news/article/what-is-biomass-heating

vii. Relevant examples	
Pride Park Stadium (Derby County)	With a capacity of 33,597, it is the 16th-largest football ground in England and the 20th-largest stadium in the United Kingdom. https://www.bdfutbol.com/en/e/e2007.html The installation of a biomass boiler at the Pride Park Stadium of Derby County Football Club is one of the first example of carbon-neutral heating at a professional football club. The 600 kW STU boiler from Hoval meet the base heating loads of the stadium. It is supported by existing gas-fired boilers (separate Hoval SR-Plus boilers using natural gas) to meet peak loads. Payments under the Renewable Heat Incentive exceed £600 000 through the period of the grant. Also at Moor Park training ground (the reference training centre) a 110 kW Hoval BioLyt wood-pellet boiler has been integrated with solar-thermal heating to provide heating loads and DHW.

C.1	Renewable Energy Sources (RES)

C.1.4 Geothermal systems



i. General description

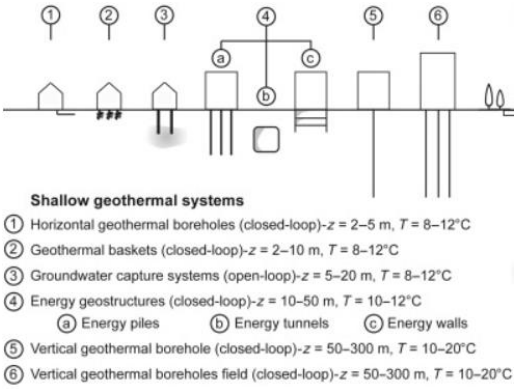
Main function	Geothermal systems exploit the heat retained within the ground to produce both heating and cooling. For larger volumes, dedicated heat pumps can be combined in parallel or connected to other systems to fit the building needs.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.

ii. Technical features and design parameters

Technical features	There are two main types of geothermal systems: ⚽ **Shallow geothermal systems** can be used to provide heating, cooling and hot water using temperatures available underground of less than 25°C. These systems are suitable for small-scale systems and can be used in almost any geographical location. ⚽ **Deep geothermal systems** can be used to provide heating and hot water as well as electrical power using temperatures available underground greater than 25°C and up to 200 °C. These systems are suitable for medium-to large-scales uses but can be applied in more particular locations than shallow geothermal systems.
Main components	⚽ Geothermal heat pump ⚽ Liquid heat exchange medium (Horizontal or vertical open/closed loops) ⚽ Hot and cold buffer tank
Design parameters	Relevant key elements for geothermal systems design are: ⚽ Demand of heating, cooling and hot water of the building. ⚽ Soil composition and groundwater level ⚽ Borehole thermal resistance, depth and spacing

iii. Conditions for implementation

Site conditions	Availability of space for the installation of geothermal probes. Drilling permits and authorizations are needed.
Recommended applications	It is advisable to implement shallow geothermal systems using multiple heat pumps connected in parallel between hot and cold buffer tanks. If heating and cooling loads are balanced the system does not require the ground loop to add or take away energy with the result of an increase in efficiency.

	However, most of the time there is an imbalance in the heating/cooling loads and the system circulating fluid is routed to the ground loop field to absorb or reject energy as required to balance the system. Because there is both a hot and cold buffer tank, this system allows both heating and cooling to take place at the same time. In larger centres, different thermal zones with different activities might be present: certain parts of the building (for example the north side) could require heating while other parts (such as the south side) could require cooling. 
Maintenance best practices	Checkup of refrigerant levels, electrical connections – visual control done regularly

iv. Strengths	v. Barriers
⚽ Saving of fossil fuels and carbon footprint reduction ⚽ Not dependent on sun or weather conditions ⚽ Technology scalable according to the real needs of the building. ⚽ Easy maintenance of the system. ⚽ Expected lifespan up to 30 years for the heat pumps and up to 50 for the underground infrastructure ⚽ Free thermal energy except the electricity consumption of the heat pumps	⚽ High capital costs compared to other systems ⚽ Not always allowed (drilling permission) ⚽ Geothermal potential is scarcely known with little awareness of its potential: limited qualified designers and contractors

vi. Performance and potential impacts

Energy production	Most of the geothermal heat pumps have Coefficient of Performances (COPs) of 3-4.5. This means that while a fossil fuel furnace has an efficiency of about 78-90%, a geothermal heat pump has an efficiency of about 300-450%. The energy production of a geothermal systems depends on many factors: size of loops and heat pump, efficiency and system configuration.
Cost savings/ Payback time	The cost saving due to the implementation of a geothermal system is linked to the amount and the cost of electricity/fuel saved that would be produced with the existing traditional system. The return of investment (ROI) must be evaluated specifically for each case. The payback period of a typical geothermal heat pump system is between 5 and 10 years.
Adaptability with crowdfunding schemes	Level of adaptability: **Medium** (total score 7)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

C.1	Renewable Energy Sources (RES)

C.1.5 Small wind turbines

Horizontal axis wind turbine

Vertical axis wind turbine

i. General description	
Main function	Small or micro wind turbines are small wind turbines used for the microgeneration of electricity available for small scale interventions suitable for urban context.
Applicable to	⚽ Stadiums. ⚽ Training centres.
ii. Technical features and design parameters	
Technical features	There are two main types of small wind turbines: ⚽ **Horizontal axis wind turbines** have a horizontal shaft with the turbine rotor placed on the top of the turbine tower. A wind sensor with servomotor keeps the axis of the turbine along the path of the wind. ⚽ **Vertical axis wind turbines** use vertically aligned rotating shaft. Because of the vertical axis they do not have to align with the wind path and therefore they are more suitable where the direction of wind significantly varies.
Main components	⚽ Small wind turbine ⚽ Support structure ⚽ Generator connected to the electrical plant.
Design parameters	Relevant key elements for small wind turbines design are: ⚽ Wind direction, frequency and average speed. ⚽ Availability of spaces on which to install the turbines
iii. Conditions for implementation	
Site conditions	It is needed to verify the wind conditions of the site. Proper wind speed, direction and frequency must be carefully evaluated.
Recommended applications	Small wind turbines are suitable for urban applications. They require little space and can be well integrated with the urban environment. Horizontal axis wind turbines have a higher efficiency in the conversion of wind into electricity than those with vertical axis and require an average wind speed of about 6m/s. Vertical axis wind turbine does not require a specific orientation and are suitable for urban wind regimes which are usually turbulent, with variable wind direction and flow. They work with winds from 3 m/s up.

Maintenance best practices	Regular easy maintenance of the equipment is needed.

iv. Strengths	v. Barriers
⚽ Saving of fossil fuels and carbon footprint reduction. ⚽ Relatively cheap technology. ⚽ Can be well-integrated in urban context. ⚽ Easy maintenance of the system. ⚽ Expected lifespan up to 20 years.	⚽ Site conditions. ⚽ Low availability of wind (frequency or speed).

vi. Performance and potential impacts

Energy production	In general, a system up to 20kW, can produce annually from 1 MWh to 1.8 MWh for each kW of nominal power. The performance of small wind turbines of course depends greatly on the wind conditions of the site.
Cost savings/ Payback time	The cost savings due to the implementation of a small wind turbine system is linked to the amount of electricity produced and used within the sport building. The return of investment (ROI) must be evaluated specifically for each case.
Adaptability with crowdfunding schemes	Level of adaptability: **High/Medium** (total score between 7 and 9)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

Lincoln Financial Field (Philadelphia)

Lincoln Financial Field is an American football stadium that represent a good example of implementation of small wind turbines in football buildings as stadiums and training centres.

https://inhabitat.com/14-uge-wind-turbines-turn-philadelphia-eagles-home-field-into-nfls-greenest-stadium/

Fourteen micro wind turbines are located in two sets of seven at opposing ends of the field and connected to the stadium's grid, reducing energy consumption during the day, and putting power back into the grid at night. The fourteen wind turbines are a standard commercial model, each turbine is approximately 15 feet tall and features a vertical-axis design. Together, the turbines and solar panels will annually produce about six times the amount of power used during all Eagles home games. Thanks to their strategic placement, the new energy-producing equipment do not interfere with the fans' experience on game day.

C.2 Lighting

Lighting represents one of the main consumption areas for many football buildings. LED fixtures, both for external and internal applications, have enormous cost saving potential reducing energy usage, waste and maintenance costs. Additionally, LED lights have a variety of benefits beyond cost savings. When replacing lighting installations, every football facility is different, from large stadiums to small training centres, indoor halls to outdoor complexes. Every venue generally requires an individual lighting solution that must be carefully evaluated and designed.

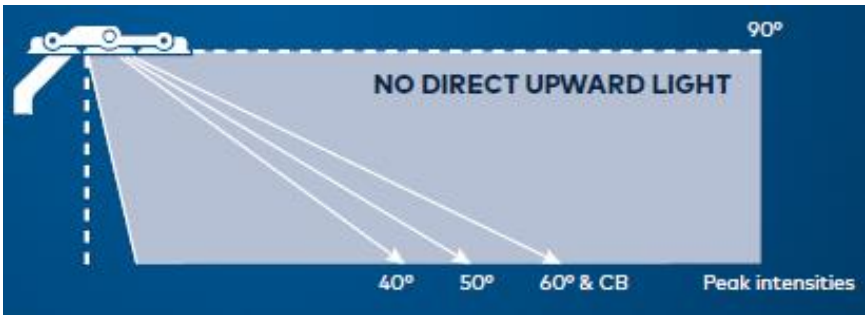
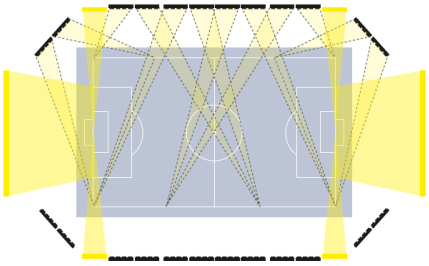
- Pitch: precision LED lighting installations with flexible controls.
- Seating: balanced lighting to maximise visibility for spectators.
- Indoor areas: controls and sensors are recommended to avoid energy wasted and fit user needs
- Outdoor areas: adequate lighting to provide safety.

The following technical sheets have been provided:

- C.2.1 – LED technology for floodlighting.
- C.2.2 – LED technology for internal lighting.
- C.2.3 – Lighting controls.

C.2	Lighting
C.2.1	**LED technology for floodlighting**

i. General description	
Main function	Pitch and bowl lighting of a stadium or a training centre.
Applicable to	- Stadiums. - Training centres.
ii. Technical features and design parameters	
Technical features	An LED, or a Light Emitting Diode, is semiconductor device that emits light due to the electroluminescence effect. LED floodlights are highly energy efficient and have a higher lumen per watt output than any other conventional lighting system. A huge variety of different LEDs are available on the market with different lighting parameters and design solutions, each type with its own datasheet and specifications. In terms of light quality, results are excellent, with temperatures ranging from 3000K to 6000K (for all the LED lamps, from warm to cool lights) and a colour rendering of up to 90 CRI (very high quality). In general, the key features of LED are: - Low power consumption. - Small size.

	⚽ Fast switching. ⚽ Physically robust. ⚽ Long lasting. LED floodlights can be equipped with optical equipment to minimize dispersion of light and glare avoiding direct upward light. 
Design parameters	To achieve desired results in accordance with standards, precise calculations and measurements should be made for vertical and horizontal camera illuminance, for grid points and glare ratings, flicker and limiting angles.  Relevant key elements for pitch and bowl lighting design: ⚽ Identification of the different configurations/uses of the facility (e.g. UEFA category, national league, concert, maintenance, emergency, etc.). ⚽ FIFA and UEFA lighting requirements. ⚽ TV broadcast requirements.
iii. Conditions for implementation	
Site conditions	No specific site conditions are required.
Recommended applications	It is advisable to install modular LED floodlights than can be used even in dual or triple configurations, with different power outputs and light distributions. ⚽ Illuminance levels must be configured for each camera position. ⚽ Artificial light sources should simulate natural daylight. ⚽ Colour rendering greater than 80 and TLCI rating should be above 80. ⚽ Implement a continuous LED light level adaptation. ⚽ Flicker factor under 6% is highly recommended. Adequate lighting control technologies ensure long-term installation performance and easy maintenance.
Maintenance best practices	Low maintenance is required.

iv. Strengths	**v. Barriers**
⚽ Long lifespan	⚽ Higher capital cost than conventional lighting

- Excellent light performance with low power (high energy efficiency and high color rendering)
- Light pollution reduction
- Low maintenance and replacement

vi. Performance and potential impacts

Energy performance

In general, LED bulbs require a lot less power to light up a space delivering the same output in lumens.

Energy savings can vary widely, depending on how often a light is used, how bright that light needs to be. Usually LED light bulbs yield considerable energy saving every year.

Cost savings/ Payback time

Cost savings can vary widely, depending on energy savings and on the actual cost of energy. The return of investment (ROI) for the implementation of LED floodlights must be evaluated specifically for each case.

Adaptability with crowdfunding schemes

Level of adaptability: **High** (total score between 9 and 11)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

Griffin Park, UK (Brentford Football Club)

Brentford Football Club is a professional football club playing in the Football League Championship.

www.thornlighting.com

- Four-2kW LED floodlights were installed on the four existing 40m masts
- 92 LED floodlights with a symmetric distribution provide the bulk of the illumination
- 8 LED floodlights provide asymmetric lighting with a low tilting angle to illuminate the corners.

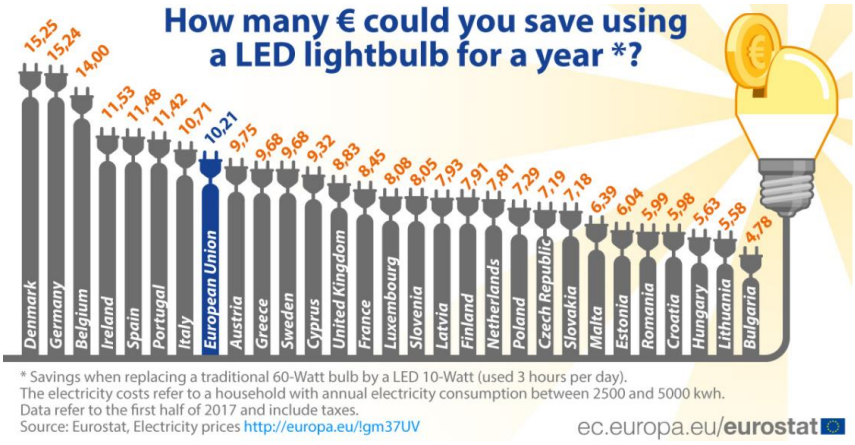
The floodlights were selected on the basis of providing the best solution from a lighting design aspect as well as the geometry of the stadium. An average lux level of 1,200 has been achieved.

C.2	Lighting
C.2.2	**LED technology for internal lighting**

i. General description	
Main function	Artificial lighting for internal spaces of the football buildings
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	An LED, or a Light Emitting Diode, is semiconductor device that emits light due to the electroluminescence effect. LED bulbs are highly energy efficient and have a higher lumen per watt output than any other conventional lighting system. A huge variety of different LEDs are available on the market with different lighting parameters and design solutions, each type with its own datasheet and specifications. LED lighting systems can be equipped with controls and sensors.
Design parameters	To achieve desired results in accordance with standards careful design of internal lighting shoud be carried out by specialists. Relevant key elements for lighting design of internal spaces are: ⚽ Identification of lighting level required by the specific use of the space and according to tasks and human factors and considering the availability of daylighting. ⚽ Considerations on surfaces characteristics and glare control measures. ⚽ Lifespan of the lamp and the percentage of lumen depreciation. ⚽ Color of the lamps, taking into account CCT (correlated Color Temperature) and CRI (Color Rendering Index) index
iii. Conditions for implementation	
Site conditions	No specific site conditions are required.
Recommended applications	It is advisable to install proper control systems using smart swathes, daylight controls and motion sensors able to avoid the use of lights when not needed. ⚽ Illuminance levels must be configured for each space needs. ⚽ Artificial light sources should simulate natural daylight. ⚽ Colour rendering greater than 80 and TLCI rating should be above 80. Adequate lighting control technologies ensure long-term installation performance and easy maintenance.
Maintenance best practices	Low maintenance is required.
iv. Strengths	**v. Barriers**

⚽ Long lifespan ⚽ Excellent light performance with low power (high energy efficiency and high color rendering) ⚽ Low maintenance and replacement	⚽ Higher capital cost

vi. Performance and potential impacts

Energy performance	In general, LED bulbs require a lot less power to light up a space delivering the same output in lumens. Energy saving can vary widely, depending on how often a light is used, how bright that light needs to be.
Cost savings/ Payback time[21]	Cost savings can vary widely, depending on energy savings and on the actual cost of energy. The following image shows potential savings achievable replacing a traditional 60-Watt bulb by a 10-Watt LED used 3 hours/day. Savings vary across the Europe depending on the electricity price of each country. The return of investment (ROI) for the replacing of LED lights must be evaluated specifically for each case. 
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score between 9 and 11)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

Riverside Stadium, UK Middlesbrough FC

www.thornlighting.com

The Riverside Stadium is a football stadium in Middlesbrough, England has a capacity of 34,742. To comply with requirements of TV broadcasters a significant refurbishment of the lighting system was needed. The design had to be modern, flexible and energy efficient.

A variety of LED luminaires have been installed at Middlesbrough FC to elevate the facility to Premier League standards following the club's promotion to the English Premier League. The new lighting reduces energy consumption and provides much better color rendering.

[21] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20180110-1

C.2	Lighting

C.2.3 Lighting controls

i. General description

Main function	Lighting controls to automatically manage lights to save energy.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.

ii. Technical features and design parameters

Technical features	The most common types of lighting controls include: ⚽ **Dimmer controls** which provide variable indoor lighting, reducing their wattage and output when a full artificial lighting level is not needed. LED bulbs and fixtures must be designed for dimming. ⚽ **Occupancy sensors controls** detect indoor activity within a certain area. They provide convenience by turning lights on automatically when someone enters a room and save energy by turning lights off soon after the last occupant has left the room. ⚽ **Timer controls** can be used to turn on and off lights at specific times. ⚽ **Daylight sensors** read available light and send a signal to the control system.
Design parameters	Relevant key elements for lighting control system design of internal spaces are: ⚽ Identification of spaces and relevant lighting levels required. ⚽ Considerations space usage, frequency of use, type of users. ⚽ Analysis of the internal geometry of spaces and daylight levels.

iii. Conditions for implementation

Site conditions	No specific site conditions are required.
Recommended applications	Specific guidelines have been developed for the proper installation and layout of each sensors. Designer and installers should follow the detailed instructions of the manufactures. At first it is needed to identify where lighting controls will cost effectively save energy
Maintenance best practices	Low maintenance is required.

iv. Strengths v. Barriers

⚽ Low maintenance and replacement ⚽ Increase energy savings of LED lights	⚽ Wiring more difficult and expensive

vi. Performance and potential impacts

Energy performance	According to the Lawrence Berkeley National Laboratory, common lighting control strategies can reduce lighting energy consumption by an average 24 to 28% [22]
Cost savings/ Payback time	Dimmers are inexpensive and increase the service life of lightbulds significantly. Cost savings can vary depending on the actual cost of energy which is different in each EU country.
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score between 8 and 10)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

[22] A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings, 2011 – Energy Analysis Department Lawrence Berkeley National Laboratory Berkeley

C.3 HVAC systems, plants and equipment

Heating and cooling followed also by ventilation and domestic hot water (DHW) production represent a consistent area of improvement for any buildings. The introduction of mandatory minimum energy performance standards and minimum levels of renewables in buildings to decarbonise heating and cooling are pushing the designers and building owners to implement very highly efficient HVAC systems.

A complete renovation of the HVAC system, in the case of large and complex buildings, can represent a huge and expensive intervention that should be evaluated carefully. Moreover, HVAC systems installed in the existing buildings are often difficult to retrofit and an entire system renovation, since the components are spread through the whole building in different spaces, can require a deep refurbishment. Nevertheless, single equipment can be replaced more easily with good results in terms of energy efficiency improvement, for example HVAC generators. The selection of type and capacity of HVAC generators must be carefully evaluated considering the heating and cooling systems, their operating temperatures, the insulation provided to the building envelope and the availability of a suitable heat source.
The following technical sheets have been provided:

- C.3.1 – High efficiency Heat Pumps
- C.3.2 – High efficiency Condensing Boiler
- C.3.3 – High efficiency Air Handling Units (AHU)
- C.3.4 – Cogeneration systems
- C.3.5 – Tri-generation systems

Detailed design of HVAC systems and key components depend on particular building cases, local characteristics and national codes, and therefore must be evaluated carefully for each case. In general, to make correct sizing of a new HVAC system, the characteristics and the main parameters of all elements should be correctly calculated and assessed (e.g. maximal airflow of ventilation units, maximum capacity of heating and cooling equipment, ducts and pipes diameters, etc.).

C.3	HVAC systems, plants and equipment
C.3.1	**High efficiency Heat pumps**

i. General description	
Main function	Heat pumps can be used to provide space heating, cooling and DHW production in one integrated system. Heat pumps use electricity or gas (less frequent) to operate and transfer heat from an external

	source to the internal environment and represent an excellent solution in refurbishment of existing building systems.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	There are a variety of heat pumps depending on the heat source: ⚽ Air-Source Heat Pumps: extract heat from outside air ⚽ Ground-Source Heat Pump: extract heat from the ground ⚽ Water-Source Heat Pump: extract heat from water (e.g. aquifer, pond) The heat extracted is then transferred to inside air or water. Outdoor air is the most common source in refurbishment as drilling is often prevented by the existing buildings and infrastructure. If a mechanical ventilation system is provided, then a suitable source can be the recover on the exhausted air.
Design parameters	The following parameters should be carefully evaluated to size heat pump capacity correctly: ⚽ Heating and cooling building demand as a function of the outdoor temperature. ⚽ Design loads (winter and summer loads) of the building. ⚽ Availability and external conditions of the heat source. ⚽ Heating and cooling distributing devices characteristics. ⚽ Assumed trend and amount of DHW demand.
iii. Conditions for implementation	
Site conditions	Availability and properties of the heat source for the heat pumps.
Recommended applications	The selection of the most appropriate heat pumps should consider the available sources. Electrical heat pumps and the related efficiencies are particularly sensitive to the temperature difference between the heat source and the thermal useful effect. The optimal temperature range for conventional air source heat pumps operation is above -5°C. Heat pumps begin to lose efficiency once temperatures dip to 4°C and are no longer the most efficient heating option once temperatures fall to -5°C and below. When outdoor temperatures reach the point where heat pumps are no longer able to operate efficiently, many systems utilize backup heating systems. Installing a backup heating system (e.g. condensing boilers) is a smart option that ensures efficient, constant heating also in colder periods. A DWH storage must be provided as the heat pump does not allow the instantaneous production.

iv. Strengths	**v. Barriers**
⚽ Lower running costs: provision of heating, hot water and cooling with less energy consumption ⚽ Less maintenance required than combustion heating systems ⚽ Average lifespan up to 15-20 years	⚽ High capital costs ⚽ Issues in very cold climates that can reduce efficiency and damage the system

vi. Performance and potential impacts	
Energy performance	Performance of heat pumps are expressed with: ⚽ Coefficient of Performance (COP) for heating: typically, between 3 and 5. ⚽ Energy Efficiency Ratio (EER) for cooling: typically, between 3 and 5. For comparison, other forms of heat generation have the following efficiencies: ⚽ Condensing gas/oil boiler: 0.9 - 0.96 efficiency

	⚽ Conventional gas/oil boiler: 0.7 - 0.8 efficiency
Cost savings/ Payback time	Heat pumps prices are usually high, taking into account the installation of the entire system, however the costs will vary for different heat pumps. The payback period of typical heat pumps are: ⚽ Between 2 and 7 years for air-source heat pumps. ⚽ Between 5 and 10 years for water-source and geothermal heat pumps.
Adaptability with crowdfunding schemes	Level of adaptability: **High/Medium** (total score between 5 and 8)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

C.3	HVAC systems, plants and equipment
C.3.2	**High efficiency Condensing boiler**

i. General description	
Main function	Condensing boiler can be used to provide space heating and DHW production.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	Condensing boilers have higher thermal efficiency compared to traditional boilers, which results in energy savings and a reduction of fuel consumption. A condensing boiler will generate additional heat from the boiler flue gas by means of condensation of water vapour contained in the exhaust pipe, thus recovering its latent heat and thus allowing energy saving and a better thermal efficiency. The market offers a wide variety of choices of condensing boilers: from the smallest suitable for small buildings and limited services to the largest suitable for large football buildings and demanding services (clubs headquarter, stadiums, training centres). Modulating condensing boilers are usually the best option to meet efficiently the heating demand of the building.
Design parameters	To correctly size the capacity of the boiler, an accurate heat load evaluation is strongly required as function of the outdoor temperature. The building demand for heating and DHW and the characteristics of the distributing system must be analysed.
iii. Conditions for implementation	
Site conditions	Dedicated space for the installation of the boiler (and the storage if present) is needed.
Recommended applications	Heating systems should operate in a way that the return temperature to the boiler is lower than 55°C in order to allow the condensation of water vapour. Without condensation of flue gases, the highest combustion efficiency that a gas or propane boiler can achieve is about 88%. Common errors that must be avoided are: ⚽ Oversizing the boiler for the heat load: when the boiler is oversized it spends most of the heating season cycling on and off rather than ramping the system temperature and firing rate up and down in response to outdoor temperature changes with nearly continuous burns. ⚽ Oversizing the boiler for the radiation (and micro zones): to keep the boiler from excessive cycling on calls for heat from the zones, there has to be sufficient radiation on each zone to elicit the minimum fire output of the boiler, at condensing temperatures.

	Small condensing boilers can be installed for changing room of small training centres for DHW production replacing traditional or electrical boilers where present.
Maintenance best practices	Condensing boilers require routine maintenance.

iv. Strengths	v. Barriers
⚽ Increased energy efficiency compared to traditional boilers ⚽ Well-known technology ⚽ Easy replacement of a traditional boiler with a new condensing boiler ⚽ Average lifespan up to 15-25 years	⚽ Existing distributing and emitting systems that do not allow suitable return water temperatures for condensing

vi. Performance and potential impacts	
Energy performance	Condensing boilers can ensure a 96% efficiency rate. Generally conventional boilers can only reach 70-80% efficiency. The lower the temperature of the water entering the condenser (approximately 55°C), the more efficient the gas cooling process will be ensuring the maximization of the energy efficiency of the boiler.
Cost savings/ Payback time	The cost saving is linked to the amount of fuel saved with respect to existing system and to the price of the fuel in the specific country. The initial capital cost of the condensing boilers varies depending on the size (capacity) required to be installed. The return of investment (ROI) must be evaluated specifically for each case. The payback period of a small-medium condensing boiler is between 5 and 15 years.
Adaptability with crowdfunding schemes	Level of adaptability: **Medium/Low** (total score between 1 and 5)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

C.3	HVAC systems, plants and equipment
C.3.3	**High efficiency Air Handling Units (AHU)**

i. General description	
Main function	Air Handling Units (AHUs) are used to re-condition and circulate air as part of heating, ventilation and conditioning systems. The basic function is to take in outside air, re-condition it according to the desired needs and supply it as fresh air to internal building spaces in order to provide acceptable indoor air quality.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	AHUs connect to ductwork that distributes the conditioned air through the building and returns it to the AHU. A heat/cooling recovery exchanger is normally fitted to the AHU for energy savings and increasing capacity. There are different types of AHUs for use in various applications, from small to larger buildings (e.g. Variable Air Volume (VAV) or Constant Air Volume (CAV), single duct or dual duct terminal units, etc.) that can be connected to different terminal devices such as fan coils. Normally AHUs are designed for outdoor use, typically placed on roofs.
Design parameters	The design of an AHU within an HVAC system is dependent on: ⚽ Specific building and system requirements. ⚽ Maximum and minimum airflow required. ⚽ Indoor air quality (IAQ) and thermal comfort requirements. ⚽ Energy use.
iii. Conditions for implementation	
Site conditions	The building must already have a mechanical ventilation system. Implementing an AHU with all the air ducts can be extremely difficult and not feasible.
Recommended applications	It is advisable to have a good mechanical ventilation in particular for large buildings and in all those spaces where a good quality of air changes cannot be adequately provided by natural ventilation. Appropriate location for intake air, far from sources of pollution, must be found. To increase the energy efficiency of the whole HVAC system is it advisable to implement a heat recovery ventilation system able to recover the residual heat and pre-heat (or pre-cool) the fresh air entering in the AHU.
Maintenance best practices	One of the most important components of AHU is the filter that perform the function of removing dust and other undesirable components of air to make it clean and fresh. Filters should be cleaned frequently.

iv. Strengths	v. Barriers
⚽ Better air quality ⚽ Improved comfort	⚽ Integration not always feasible in existing buildings and HVAC systems ⚽ Lack of available space for new installations in existing buildings ⚽ Many existing buildings are not designed for new installations of air ducts

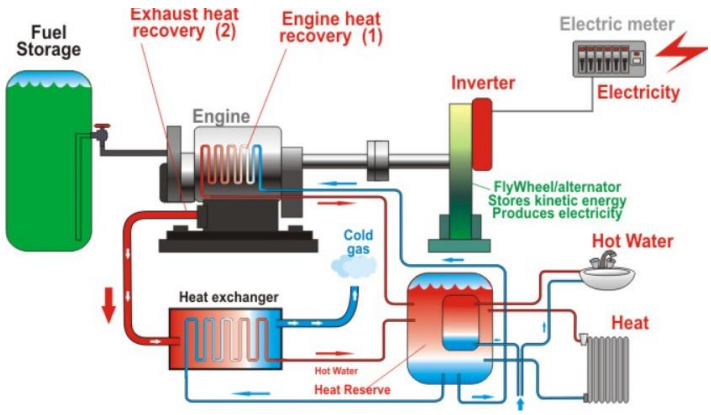
vi. Performance and potential impacts	
Energy performance	Replacing existing old AHUs with new and more efficient AHUs provides energy saving. These savings can be increased by implementing a suitable heat recovery system used to reduce the heating and cooling demands of the football building. Heat recovery systems typically recover about 60-95% of the heat in exhaust air.
Cost savings/ Payback time	Cost savings and payback time must be carefully evaluated considering the whole HVAC system and specifically for each case.
Adaptability with crowdfunding schemes	Level of adaptability: **Medium/Low** (total score between 2 and 8)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

C.3	HVAC systems, plants and equipment

C.3.4 Cogeneration systems (CHP - Combined Heat and Power systems)



http://me1065.wikidot.com/small-scale-cogeneration-including-automotive-applications

i. General description

Main function	In a cogeneration system, a fuel-burning turbine drives a generator to produce electrical power. The heat produced from that process is captured and used (up to 90%) to produce heat and hot water. In this way both electrical power and heat can be provided simultaneously to the football building.
Applicable to	⚽ Stadiums. ⚽ Large scale training centres. ⚽ Large scale club headquarters.

ii. Technical features and design parameters

Technical features	Cogeneration is not a single technology, but an integrated energy system that can be adapted to the needs of the energy end user. Small scale CHP plants are an excellent example of decentralized energy. There are different types of cogeneration plants suitable for football building depending on prime movers: ⚽ Gas engines: used at small-scale applications (200 kW_e – 5 MW_e) ⚽ Micro turbine: used at smaller scales (30 kW_e – 0.5 MW_e) Additionally, steam turbines are used for large-scale applications (> 5 MW_e) suitable not only for single football building but also for the whole neighbourhood.
Design parameters	In the optimum design of a cogeneration system, monthly heat and electricity load profiles are needed. Demands of heating and electricity are covered in varying rates with different capacities of the cogeneration system. The design of CHP systems will depend on the individual application. In general, the cogeneration system capacity selection is made according to the electricity loads. Then, for the selected cogeneration capacities technical and economic calculations are made. Among other considerations the following parameters should be considered: ⚽ Electrical and thermal load capacities of possible configurations. ⚽ Load variations, monthly, daily and diurnal. ⚽ Flow temperatures in the supply network related to pipe diameter required.

iii. Conditions for implementation

Site conditions	A cogeneration facility should be located at or near the building or facility using the produced heat so that transport distance is minimised. It is also important to consider noise levels and accessibility.
Recommended applications	Balance between how much electrical power should be produced and how much hot water should be available must be carefully evaluated and designed. In order to be economically viable, it is essential to

	exploit every possibility of minimising cost by a fully logical approach both in the area of generation and in the transport and distribution of heat. Cogeneration systems generate electricity and the heat is a useful by-product (solution suitable for football buildings where electricity demand is higher than heating and hot water demand). Micro CHP systems can be also driven by heat demand and deliver electricity as a by-product (solution suitable for clubs headquarters where heating demand could be relevant).
Maintenance best practices	Higher maintenance costs are foreseen rather than other traditional systems. Most cogeneration plants contain mechanical rotating equipment which requires periodic maintenance.

iv. Strengths	v. Barriers
⚽ Primary energy costs reduction up to 60% [23] ⚽ Carbon emission reduction up to 66% [17] ⚽ Increasing reliability for the facility and the grid ⚽ Increasing fuel efficiency ⚽ Lifespan around 20 years	⚽ High capital costs ⚽ Complex system ⚽ Higher maintenance costs

vi. Performance and potential impacts

Energy performance	The overall efficiency of producing both heat and power using cogeneration is typically 85% (to be compared to 58% for conventional separate production of power and heat) [24].
Cost savings/ Payback time	Costs vary depending on the ratio of cogeneration system to meet the energy needs. Generally, capital costs are higher than other systems. Simple paybacks typically range from 2 to 10 years [24].
Adaptability with crowdfunding schemes	Level of adaptability: **High/Medium** (total score between 7 and 9)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

Continassa, Juventus training centre	Continassa area is an example of a training centre served from an energy point of view by the integration of different high efficiency systems, district heating, cogeneration and heat pumps. Here a series of technologies will be available: natural gas cogeneration plant for the combined production of electrical and thermal energy; heat pumps for the production of chilled water; heat exchanger powered by city district heating.

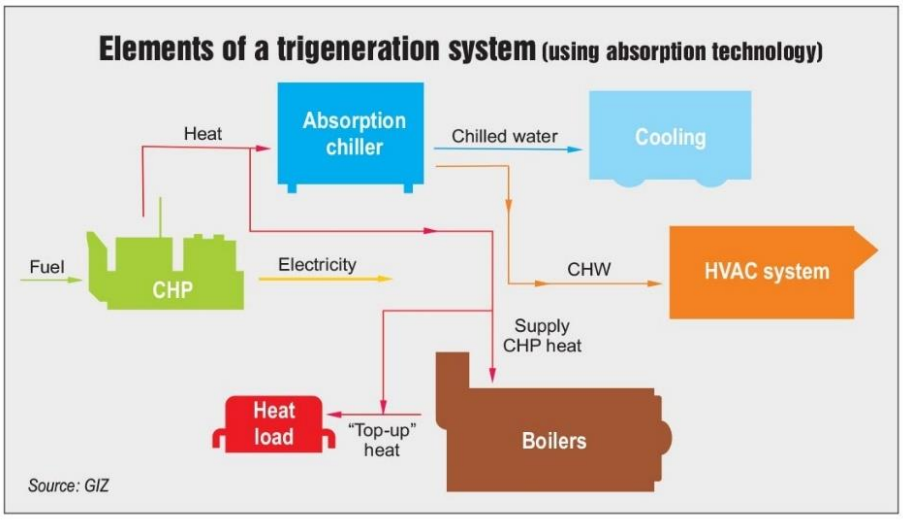
https://www.calcioweb.eu/2016/11/juventus-continassa-lavori-jvillage/10055773/

[23] Cogeneration feasibility guide, September 2014 - Office of Environment and Heritage NSW available at: www.environment.nsw.gov.au

[24] KTH Industrial Engineering and Management, Stockholm - Master of Science Thesis "Simulation of Tri-generation Systems with application of optimization", 2016, Javier Galvan Villamarin

C.3	HVAC systems, plants and equipment

C.3.5 Tri-generation systems (CCHP - Combined Cooling, Heat and Power systems)



https://powerline.net.in/2019/02/02/triple-benefits/

i. General description

Main function	In a tri-generation system, a fuel-burning turbine drives a generator to produce electrical power. Unlike cogeneration, the heat produced from that process is used for both heating (and hot water production) and cooling.
Applicable to	⚽ Stadiums. ⚽ Large scale training centres. ⚽ Large scale club headquarters.

ii. Technical features and design parameters

Technical features	Like cogeneration systems, also CCHP systems integrate different energy systems. An absorption chiller that converts the waste heat into chilled water for cooling is linked to the combined heat and power (CHP) plant.
Design parameters	In addition to the design parameters that need to be evaluated for CHP plant design, for trigeneration systems demand for cooling must also be analysed, according with monthly and daily load variation.

iii. Conditions for implementation

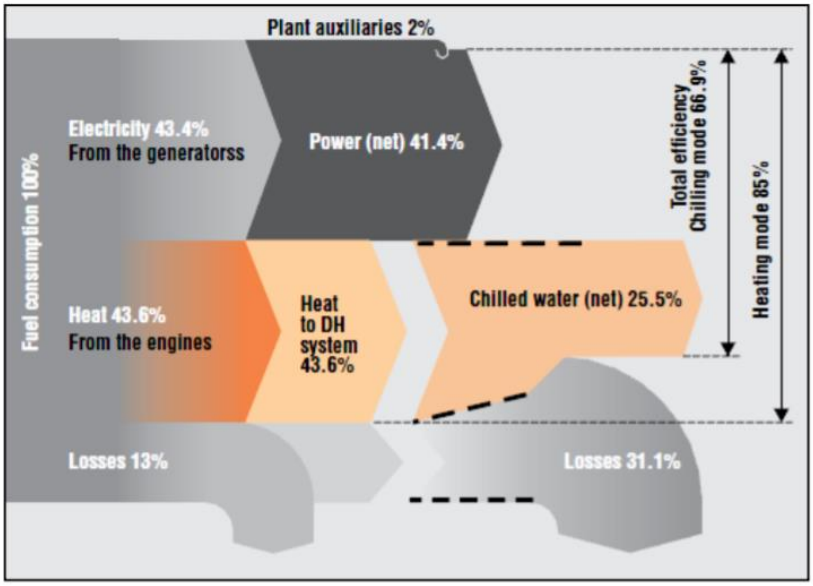
Site conditions	As required for cogeneration systems, also tri-generation systems should be located at or near the building or facility using the produced heat so that transport distance is minimised. It is also important to consider noise levels and accessibility.
Recommended applications	Same as cogeneration systems.
Maintenance best practices	Higher maintenance costs are foreseen rather than other traditional systems. Most cogeneration plants contain mechanical rotating equipment, which requires periodic routine maintenance.

iv. Strengths	v. Barriers
⚽ Primary energy costs reduction	⚽ High capital costs
⚽ Carbon emission reduction	⚽ Complex system
⚽ Increasing reliability for the facility and the grid	⚽ Higher maintenance costs
⚽ Increasing fuel efficiency	⚽ Low awareness of the benefits
⚽ Lifespan around 20 years	

vi. Performance and potential impacts

Energy performance

The overall efficiency of producing both heat and power using cogeneration is typically 85% (to be compared to 58% for conventional separate production of power and heat) and operating in a cooling mode, the CCHP system efficiency could be up to 66%[25]



Cost savings/ Payback time

Costs vary depending on the ratio of tri-generation system to meet the energy needs. Generally, capital costs are higher than other systems. In can be assumed that, as for cogeneration systems, simple paybacks typically range from 2 to 10 years[25]

Adaptability with crowdfunding schemes

Level of adaptability: **High/Medium** (total score between 7 and 9)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

[25] KTH Industrial Engineering and Management, Stockholm - Master of Science Thesis "Simulation of Tri-generation Systems with application of optimization", 2016, Javier Galvan Villamarin

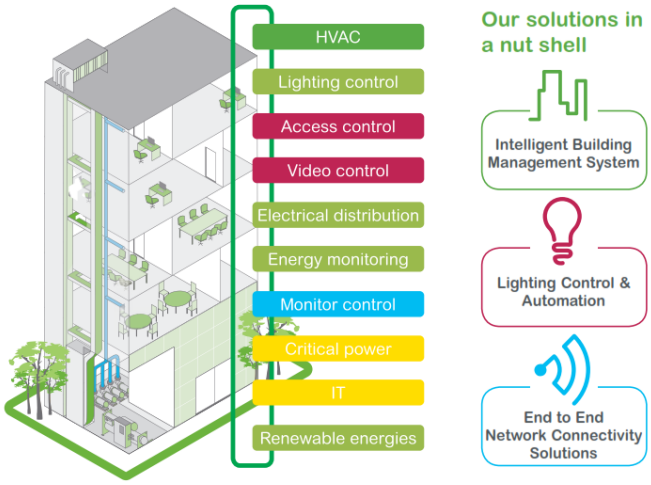
C.4 Building Automation

A Building Management Systems (BMS) is one of the most powerful tools in building engineering services, which is primarily used to monitor and control electro-mechanical systems, extra low voltage systems, elevators, lighting etc. Building management system also ensures efficient utilization of resources, energy efficiency, improved comfort and safety for the users. A BMS includes subsystems for managing its various components, including:

- System for commercial accounting of heat consumption.
- Automatic equipment for heating and cooling supply systems.
- Water supply and plumbing systems.
- Automatic equipment for lightning and electric power supply systems.
- Smoke removal, fire alarm system and other emergency warning systems.
- Security-burglar signaling system.
- Access monitoring and control system.
- Other low current systems.

Typically, systems linked to a BMS represent 40% of a building's energy usage and up to 70% if lighting is included. The potential energy and costs savings may be therefore considerable.

C.4	Building Automation
C.4.1	**Building management system (BMS)**



http://www.microtechbd.net/bms-solution-bd.php

i. General description	
Main function	Building management systems (BMS) also known as building automation systems (BAS) refers to a computer-based control system installed in buildings to monitor and regulate the building's electrical and mechanical equipment such as power systems, lighting, heating, cooling and ventilation.
Applicable to	Stadiums. Training centres. Club headquarters.
ii. Technical features and design parameters	
Technical features	BMS systems are "Intelligent" microprocessor-based controller networks installed to monitor and control a building's technical systems and services such as air conditioning, ventilation, lighting and hydraulics. More specifically, they link the functionality of individual pieces of building equipment so that they

	operate as one integrated system. Current generation BMS systems are based on open communications protocols and are WEB enabled allowing integration of systems from multiple system vendors and access from anywhere in the world. A BMS has a three-level circuit: ⚽ **Upper level (management level)**: dispatching and administration as well as work with databases and statistical functions. At this level cooperation between personnel (operators, dispatchers etc) and the system is performed, which is implemented by means of computer devices and SCADA-systems. ⚽ **Middle level (automation level)**: automated management of functional processes. Basic components of this level are main controllers, signal input-output units, and various switching equipment. ⚽ **Low level (field level)**: level of terminals with input/output functions. This level includes sensors, actuating mechanisms, cabling between devices and low-middle levels. BMS includes the following components: ⚽ **Indoor and outdoor sensors** to measure temperature, relative humidity, air quality, movement, CO_2 and luminance. ⚽ **Direct digital controllers (DDC)**: switches, diaphragms, valves and actuators. DDC used for building automation can be grouped in three categories: programmable logic controllers (PLCs), system/network controllers and terminal unit controllers to control simple devices. ⚽ **Decision unit**: a real time decision support unit includes interaction with the sensors, the incorporation of expert and intelligent system techniques, and communicates with the building's controllers through a communication network ⚽ **Database** of the building energy characteristics and the knowledge database, where all essential information is recorded The output values from the field sensors and different switch states are monitored through the input ports (Digital/Analog) of DDC over a pre-defined time interval. Any change in the values/states will be immediately reported to the DDC. The direct digital control analyses these changes in values/states through the pre-written PID (Proportional Integral Derivative) program in the DDC and required control action would be initiated through Analog/Digital output ports of DDC. DDC also have communication ports like Ethernet, RS 485 through which DDC can communicate with other third-party devices for monitoring and controls through protocols like BACnet, MODBUS, LON Works, M-Bus, KNX, OPC etc. BMS software also will have a graphical user interface (GUI) installed in a computer through which the user can monitor and control the systems remotely. Nowadays, almost all the equipment and systems used in the building engineering industry comes with communication ports or hardwired potential free contacts, to enable the user to interface with BMS, to remotely monitor and control the systems.
Design parameters	One of the most important aspects to be considered while designing a BMS refers to an adequate selection of the equipment with a careful evaluation of the equipment data sheet and the data given.
iii. Conditions for implementation	
Site conditions	Centralization of control and building utilities management can be arranged in different ways depending on the quantity of equipment and its functional use.
Recommended applications	⚽ All the coolers and heat pumps will have built-in temperature sensors for monitoring the temperature and hence it is not necessary to add additional temperature sensors. ⚽ Status of pumps also to be taken from mechanical side by installing DP Switches across pumps rather than relying on electrical starters, as starter will always show 'On' status when switched on, but sometimes the pump may not be really running due to some mechanical failure. ⚽ Instead of integrating the Main Fire Alarm Panel fully into BMS, it is better to assign 2 control relays, one for supervisory monitoring and one for fire alarm monitoring in the fire alarm system. By monitoring the status of these control relays, BMS operators could come to know the main 2 status.

	Apart from the integration of the above parameters/points, the BMS software should be customized to depict and process the data in a facility management perspective. Some of the specific functions required are: ⚽ Report energy consumption values from utility meters on a daily cut-off hour. ⚽ Report trends of parameters and status in HVAC Systems, Hot Water Systems, Ambient Conditions etc. ⚽ Trip/Fault and Stop status of equipment to be popped up in the BMS workstation with an Audio-Visual Alarm. ⚽ Automatic printing of alarms and events through a printer attached to BMS Workstation. ⚽ Preventive maintenance schedule alarms based on the operating hours of the equipment. The above functionalities in the software would enable the facility management team to analyze the energy usage patterns, variation of parameters at different operating conditions, and allow for proper planning and efficient utilization of energy and resources. Effective use of BMS depends on the accuracy of information available from the system and hence proper commissioning and validation of the system is very much crucial for the proper functioning and operational data analysis.

iv. Strengths	**v. Barriers**
⚽ Efficient utilization of resources. ⚽ Reduction of energy consumption and operating costs. ⚽ Improvement of internal thermal comfort. ⚽ Reduction of maintenance costs. ⚽ Real time monitoring building performance. ⚽ Flexible and user friendly.	⚽ Initial costs. ⚽ Incompatible communication with existing equipment.

vi. Performance and potential impacts	
Energy performance	The main objective for using a BMS in the building is energy saving and energy efficiency.
Cost savings/ Payback time	Sometimes the cost of installation in a building with normal function is higher than the amount of financial savings from energy savings. Thereupon, an overall analysis of the costs and other factors (such as the type and function of building, size and dimensions of the building and the number of indoor control system) should be done before installation. In case of large office buildings (similar to clubs' headquarters) BMS can reduce up to 50% energy consumption with a typical payback time of 1.7 years.[26]
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score 10)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

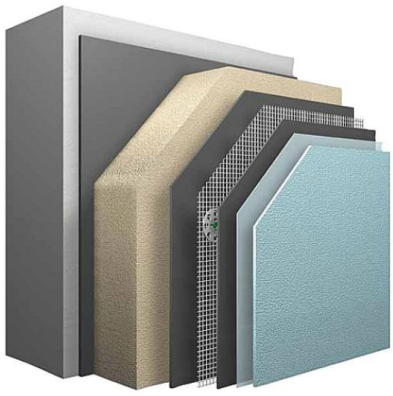
[26] Effect of Building Management System on Energy Saving, January 2014 A. Kamali, G. Khakzar, S. A. HajiAbadi,

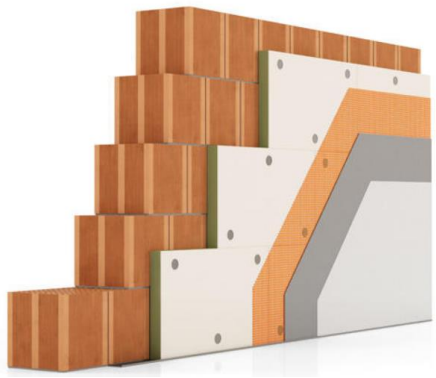
C.5 Building envelope

A complete renovation of a football building can start from an adequate renovation of the building envelope in order to reduce the energy demand of the building for both heating and cooling. The quality and energy performance of building envelops are the most important factors that affect the energy consumed by heating and cooling equipment. A general approach implies that to improve energy performance in winter, solar gains should be maximised, and thermal losses minimised mainly using thermal insulation. Similarly, during summer, internal and external gains should be minimised to not overcharge the cooling system using thermal mass, efficient glazing, insulation, shading, reflective surfaces and natural ventilation. Both needs should be carefully balanced based on the actual needs of the building. Building envelope improvements can improve not only energy performance but also occupant comfort through more stable temperatures and better control of lighting (e.g. glare reduction).
The following technical sheets have been provided:

- C.5.1 – Thermal insulation
- C.5.2 – High-performance windows
- C.5.3 – Cool roofs
- C.5.4 – Green roofs

C.5	Building envelope
C.5.1	**Thermal insulation**





i. General description	
Main function	Thermal insulation reduces heat gain/loss through the building envelope.
Applicable to	⚽ Stadiums (conditioned zones). ⚽ Training centres (conditioned zones). ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	Proper insulation reduces heat loss in cold weather, keeps out excess heat in hot weather and helps maintain a comfortable indoor environment. There are several common types of insulation: fiberglass, mineral wool, cellulose, polyurethane foam, expanded polystyrene (EPS), rigid foam board, and spray foam are just some examples. The type and the thickness of insulation needed varies considerably according the climate zone in which the building is located. High performance insulation products are characterised by low thermal conductivity coefficients (0,020-0,03 W/mK).

Design parameters	In most countries building codes include requirements to guarantee minimum acceptable insulation levels for building envelopes. Among other considerations the following parameters should be considered to achieve the minimum levels required: ⚽ Climatic parameters. ⚽ Material properties of the existing envelope. ⚽ Existing thermal bridges and possibilities to solve them. ⚽ Use of the internal spaces. ⚽ Thermal performances of the insulation (e.g. thermal conductivity, heat capacity, density of the material, etc)
iii. Conditions for implementation	
Site conditions	Generally, thermal insulation is applicable to a wide range of buildings and no specific conditions are required. Just for historical buildings external insulation cannot be permitted.
Recommended applications	The insulation must be continuous in order to avoid or limit thermal bridges. External insulation is recommended to achieve higher performances reducing thermal bridges with little risk of moisture problems. Internal insulation must be installed carefully and must not create a situation where the moisture levels in the wall can rise. When correctly installed with air sealing, each type of insulation can deliver comfort and lower energy costs. Complete insulation of walls, roofs and ground slabs is recommended in cold climates, while for warm climate may be more efficient to isolate only walls together with the implementation of cool roofs. The installation of thermal insulation requires detailed design, good workmanship and appropriate product selection in order to avoid and minimize thermal bridges and air leakage. To reduce carbon footprint, it is suggested to choose insulation materials with high percentage of recycled materials and select products with responsible sourcing certification over similar products without certification. Good options for eco-friendly insulation include stone mineral wool, cellulose, fiberglass, hemp and aerogel. To select the right insulation material, it is important to analyse how a material responds to moisture, weather it meets fire safety regulations and which thicknesses is needed to meet the national standards.
Maintenance best practices	Maintenance costs for thermal insulation products is low and not even required for many cases.

iv. Strengths	**v. Barriers**
⚽ Heat losses reduction. ⚽ Demand for heating and cooling reduction. ⚽ Improvement of internal thermal comfort.	⚽ External insulation not always allowed for historical building

vi. Performance and potential impacts	
Energy performance	Thermal insulation is an efficient solution to reduce energy consumption by preventing heat gain or loss through the building envelope. The energy performances achievable depend on the climatic conditions, on the state-of-the-art of the envelope and on the thermal characteristics and thickness of the applied insulation product. The energy savings achievable vary over a very wide range (e.g. from 22% to 79%)[27] and therefore must be evaluated for each building.
Cost savings/ Payback time	With adequate thermal insulation of the building envelope, energy costs can be dramatically reduced. Since there is a wide range of energy savings potential also payback periods can vary depending on energy performances and on fuel/electricity costs. Typical payback times are between 1 and 5 years[21].

[27] Determination of the Thermal Insulation for the Model Building Approach and the Global Effects in Turkey, August 2014, Cenk Onan, Department of Mechanical Engineering; Yildiz Technical University, Besiktas, Turkey

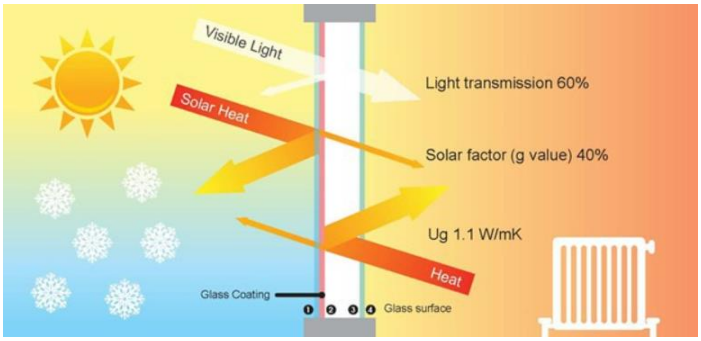
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score between 9 and 12)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

C.5	Building envelope

C.5.2 High-performance windows



https://www.specifiedby.com/guardian-glass/sunguard-high-performance-neutral-60-40

i. General description

Main function	High performance windows have the main function to improve thermal insulation of the envelope while ensuring appropriate level of natural lighting and ventilation.
Applicable to	⚽ Stadiums (conditioned zones). ⚽ Training centres (conditioned zones). ⚽ Club headquarters.

ii. Technical features and design parameters

Technical features	There is a wide range of high-performance windows based on different type of frames (aluminum, steel, PVC, hardwood and softwood frames), glass (insulated, with low-e coatings or solar control coatings, etc.), glazing (double or triple) and cavity fill (argon, krypton, xenon, vacuum). **Low-Emissivity (Low-E) glass** is specially treated with a transparent coating. The coating reflects heat back into the building, thereby reducing the heat loss through the window. Low-e glazing contribute in the reduction of the heating demand of the building. **Solar control glass** is a high-performance coated product that reflects and radiates away a large degree of the sun's heat while allowing daylight to pass through a window or façade. The indoor space stays bright and much cooler than if normal glass were used. Solar control glass incorporates invisible layers of special materials that have the dual effect of allowing sunlight in, while repelling solar heat. This technology is particularly beneficial in warmer southern climates where it can help to reduce the load on a building's air conditioning system, thus reducing energy demand, while maintaining a comfortable working environment. In addition, solar control glass units are typically double glazed and therefore combine both Low-E and solar control properties, to maximize insulation in cooler periods and solar control properties in summer. Other innovations such as triple glazing products can offer additional improvements in the window's insulating properties while the use of low-iron glass can increase light transmittance and free solar heat gain. These technologies offer additional benefits in terms of energy efficiency.
Design parameters	Similar to the opaque elements of the envelope, the following parameters should be considered for the selection of appropriate windows: ⚽ Climatic parameters. ⚽ Façade orientation and presence of external shading. ⚽ Inclination of the sun's rays throughout the year. ⚽ Existing thermal bridges and possibilities to solve them. ⚽ Use of the internal spaces.

iii. Conditions for implementation

Site conditions	No specific conditions are required. For historical buildings the replacement of windows could require a more careful design in order to comply with Cultural Heritage requirements.
Recommended applications	Appropriate choices of windows and shading devices are essential to balance the heat flows and natural light. It is recommended to choose windows and shading devices based on façade orientation balancing the thermal transmittance (U-value) with the solar heat gain coefficient (SHGC) and the visible transmittance (VT). In general, high U-value are recommended for north-façades while high SHGC are recommended for south-façades.
Maintenance best practices	Low maintenance is required for windows, but a proper installation is needed in order to avoid air leakage and moisture and guarantee high-insulation levels.

iv. Strengths	v. Barriers
Long lifespan 25-30 years. Solution relatively easily to install. Demand for heating and cooling reduction. Improvement of internal thermal comfort.	Payback times can be long. Relatively high capital costs.

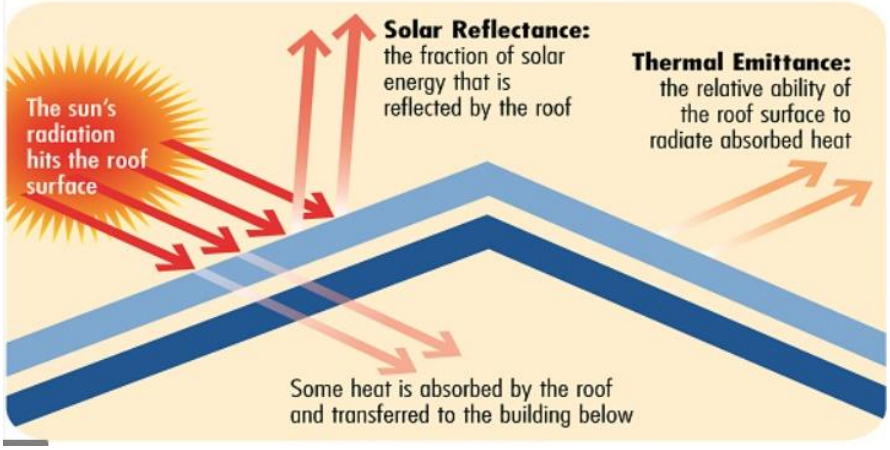
vi. Performance and potential impacts	
Energy performance	Energy performance of windows is highly dependent upon the design of the whole window: glazing, coating, spacers, internal gas. Selective and low-e coatings are able to reduce energy loss by as much as 30% to 50% in comparison with single-glass or simple insulated window.
Cost savings/ Payback time	Windows manufactured with low-e or selective coatings typically cost about 10% to 15% more than regular windows. Calculating the return on investment of upgrading complete windows is difficult as it depends on the type of glazing initially in place, the energy source and its prices, the energy needs, the energy-efficiency of other components of the building envelope, etc. It must also take into account potential financial incentives or fiscal rebates, which are often granted when choosing best performing glazing. Generally, the payback period of replacing complete windows can range between 3 to 9 years and the situation varies between countries[28].
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score 9)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

[28] Energy saving glazing solutions and a low carbon economy, 2011, Glass for Europe

C.5	Building envelope
C.5.3	**Cool roofs**



http://www.buildup.eu/sites/default/files/content/Cool%20Roofs_EN_1.pdf

i. General description	
Main function	A Cool Roof is a roofing system able to reflect solar heat and keep roof surfaces cool under the sun.
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.
ii. Technical features and design parameters	
Technical features	Cool roofs are characterized by reflective and emissive materials used to reflect solar radiation back into the atmosphere. As the roof stays cooler, the amount of heat transferred to the internal spaces of the building is reduced keeping a cooler and more constant temperature in the interior. The high solar reflectance and high thermal emittance of cool roof materials help roofs to absorb less heat and stay up to 28-33°C cooler than conventional materials during peak summer weather. Numerous roofing materials are rated with relatively high solar reflectance and thermal emittance values, including materials for low and steep sloped roofs (white, colored, photo-catalytic, etc).
Design parameters	Suitable materials for cool roofs should have the following properties: ⚽ High thermal emittance (describe how efficiently a surface cools itself by emitting thermal radiation), usually between 0.80 and 0.95. ⚽ High Solar Reflectance Index (SRI), usually higher than 0.65 for low sloped roof and 0.30 for steep sloped roofs.
iii. Conditions for implementation	
Site conditions	No specific site conditions are needed for the implementation of cool roofs.
Recommended applications	When correctly installed with air sealing, each type of insulation can deliver comfort and lower energy bills. To get the biggest savings, the easiest place to add insulation is usually in the attic
Maintenance best practices	Low maintenance is required.

iv. Strengths	**v. Barriers**
⚽ Energy savings and reduced energy costs. ⚽ Heat island effect reduction. ⚽ Improvement of occupant comfort and health.	⚽ Materials and colours not always allowed for historical building

⚽ Reduction of roof maintenance. ⚽ Reduction of air pollution and GHG emissions.	
vi. Performance and potential impacts	
Energy performance	Cool roofs can generate air-conditioning savings and peak demand reductions of 10-30% (measured in daily summer-time use).[29]
Cost savings/ Payback time	Typical payback time for non-residential buildings range between 0.6 to 3.3 years.[30]
Adaptability with crowdfunding schemes	Level of adaptability: **High** (total score between 9 and 11)

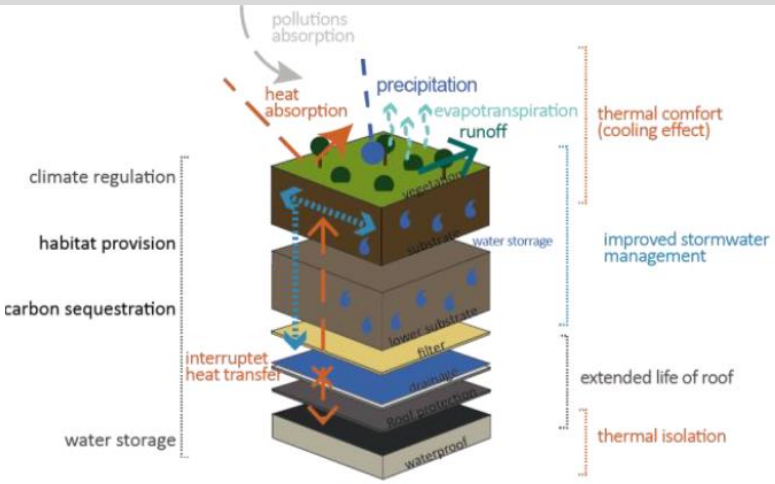
Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

[29] Cool roofs in Europe available at http://www.buildup.eu/sites/default/files/content/Cool%20Roofs_EN_1.pdf
[30] Costs and Benefits of Cool Roofs and Shade Trees in Kansas City region, 2018, Haley Gilbert and Ronnen Levinson, Heat Island Group, Energy Technologies Area, Lawrence Berkeley National Laboratory, Berkeley, CA

C.5	Building envelope

C.5.4 Green roofs



Source: Nature4Cities D5.1 NBS Technical Handbook

i. General description

Main function	Green roofs, also known as vegetated roofs, incorporate plants into the roof assembly adding insulating value, reducing storm water runoff, cool the building interior and the surrounding area, provide habitats for birds and insect
Applicable to	⚽ Stadiums. ⚽ Training centres. ⚽ Club headquarters.

ii. Technical features and design parameters

Technical features	Several types of green roofs with varying coverings, complexity and scopes can be established on rooftops. ⚽ **Intensive Green Roof**: complex and heavy greening systems often established on roofs that are accessible for public or recreation purposes and also for regular maintenance measures. Appropriate plants for intensive green roofs are mainly trees, shrubs and perennials. The growth media of intensive green roofs needs to be relatively deep and nutrient rich to support the growth of plants or bigger trees. ⚽ **Extensive Green Roof**: basic, light weight systems, characterized low vegetation surface that covers the buildings surface. Extensive green vegetation is often established on roofs that are not accessible or with limited access for public or recreation purposes (but annual maintenance) and partially characterized by steep slopes. Appropriate plants for extensive green roofs are low growing, rapidly spreading and shallow-rooting plants/hardy perennials (succulents such as sedums, herbs, wildflowers, grasses, mosses) that are able to survive with minimum nutrient uptakes and without additional nutrient supply. The selected plants for extensive green roofs are generally well adapted to alpine environments/climate and tolerate different climate conditions (e.g. drought) and temperature fluctuations.
Design parameters	Implementing a green roof on an existing building needs to be carefully evaluated under the structural and seismic point (e.g. evaluate the loadbearing capacity of the building and the need of structural modifications). Besides the following parameters should be taken into account for choosing the correct plants (trees, shrubs and perennials: ⚽ Weather data ⚽ Slope gradient of the roof

	⚽ Weight of the whole system ⚽ Water requirement and growing medium of the species ⚽ Water retention capacity
iii. Conditions for implementation	
Site conditions	Structures need to have an adequate loadbearing capacity (concrete structure are required). Roofs need to be flat or relatively flat and often an irrigation system is required for dry periods. Weather conditions and rainfall in particular should be adequate to support the growth of plants with low artificial irrigation needs.
Recommended applications	To protect the roof covering, it is recommended to apply an adequate protective cover under the trays. Depending on the climate zone in which the green roof is located, it is recommended to apply an irrigation system. To enhance the ecology of the site it is also recommended to select locally appropriate native species resistant to climatic agents and potential periods of drought.
Maintenance best practices	Green roof maintenance is crucial, especially in the first 5 years after establishment. ⚽ Intensive green roofs are characterized by a higher installation, maintenance, management effort (regular irrigation and fertilization) which leads to higher costs compared to extensive green roofs. ⚽ Extensive green roofs are characterized by minimum maintenance and management (artificial irrigation, fertilization) after establishment of the system. The installation and management/maintenance of extensive green roofs is less expensive than that of intensive systems.

iv. Strengths	**v. Barriers**
⚽ Energy reduction (increase of thermal insulation and reduction of cooling loads) ⚽ Storm water runoff reduction ⚽ Heat island effect reduction ⚽ Increase of natural habitats for birds and insects ⚽ Improvement of air quality	⚽ Inadequate roofs and structures ⚽ High capital costs ⚽ High maintenance costs ⚽ Limited space for rooting

vi. Performance and potential impacts	
Energy performance	Positive effects on building energy performance associated with green roofs are due to the increase of thermal insulation and evapotranspiration, which lead to a reduction of the roof temperature and the reduction of the cooling loads. To evaluate the energy savings, it is needed an accurate assessment of the building.
Cost savings/ Payback time	Green roofs represent an expensive EE solution especially considering the maintenance costs. Capital costs can vary widely depending on the type of roof and plants to be installed. Generally, they can range between 100-300 €/sqm. Payback times have to be evaluated on the specific building.
Adaptability with crowdfunding schemes	Level of adaptability: **High/Medium** (total score between 5 and 9)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	4	3	2	4	3	2	4	3	2
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

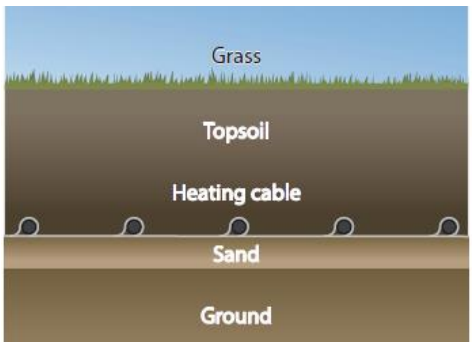
Barclays Centre, New York	Barclays Center is a multi-purpose indoor arena in the New York City borough of Brooklyn with a green roof of about 12000 m^2. https://www.westonsolutions.com/solutions/infrastructure-improvements/greengrid/greengrid-green-roof-system-on-iconic-sports-arena-ny/ The project features custom InstaGreen Sedum Tile vegetation installed over Hydrotech's GardNet technology to accommodate the steep slope of the roof. The slope of the project varies from at grade to 51 degrees at the steepest section. The green plant is especially hardy and does not need an elaborate irrigation system. (There are four hose bibs on the roof just in case of a drought situation) The Barclays' green roof helps to absorb sounds and lower high energy costs while providing environmental benefits such as stormwater retention.

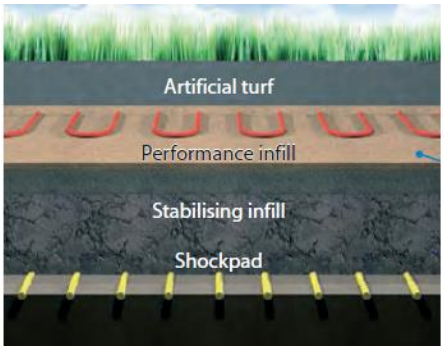
C.6 Electrical equipment and special technologies

Within sports buildings, there are also specific technologies with a very high consumption. All these technologies and systems represent a field in which to investigate opportunities and solutions for energy improvement and financial savings. The following technical sheets have been provided:

- C.6.1 – Under-soil heating
- C.6.2 – Artificial light for grass growing

C.6	Electrical equipment and special technologies
C.6.1	**Under-soil heating**

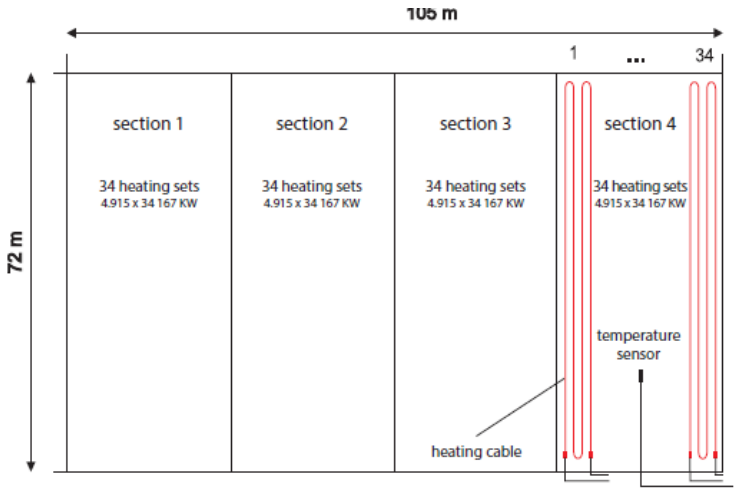




Source: Sport Field Heating – DEVI Application manual

i. General description	
Main function	Under-soil heating keeps the ground temperature at appropriate level and helps to maintain good quality of pitch during the whole season, avoiding any elements from bad weather, such as snow and ice, from building up and froze the field. Additionally, temperature maintenance of the soil around the grass roots ensures grass growth and prolongs the field usage by 3-4 months per year.
Applicable to	⚽ Stadiums. ⚽ Training centres.
ii. Technical features and design parameters	
Technical features	Under-soil heating system can utilize electric coils or a hydronic system that circulates hot water and possibly antifreeze through a piping system. It can be provided either by a piped water system or electrically heated flat cables or heating mats. ⚽ **Electric under-soil heating** uses electricity to heat the field. Heating cables pre-assembled into heating mats are put into the ground. A photovoltaic system in combination with battery storage can power the electric under-soil heating system. Normally, the recommended output for heating a natural grass field is 80-100 W/sqm (with maximum limit of 120 W/sqm depending on the geographic location) for system and 25 W/m for cables[31] ⚽ **Hydronic under soil heating** involves installing pipes underneath the playing surface and pumping hot water through them. Boilers are needed to heat the water (40°). Piping is placed across the field at specific intervals and depth. When the hydronic field heating system is turned on, the hot water in the pipes will keep turf and soil above freezing in most weather conditions. The heating elements installed just below the grass root zone together with temperature sensors must be controlled by a thermostat. Temperature sensors make sure that temperatures of the ground are kept steady creating a reliable frost protection.

[31] Sport Field Heating – DEVI Application manual

Design parameters	The following parameters should be considered for the selection and design of appropriate under soil heating: ⚽ Climatic parameters and area conditions (e.g. permanently shadowed or not, etc.). ⚽ Field type (artificial or natural) and size. ⚽ Power supply availability. ⚽ Drainage system. For medium weather conditions in order to heat a 1 m² surface outside up to 1 °C approx. power of 23 Watt is needed. Otherwise the heat exchange coefficient - approx. 23 W/(m²·K) should be used for the calculation. The possible temperature difference between the surface and the air for installed 100 W/ m² can be determined as follow: 100 W/m² /23 W/(m²·K) = 4°C. In means that 100 W/ m² ensures no freezing of the pitch surface (+1°C) under conditions of minimum air temperature up to -3°C. The heating system and the field should be split in zones with dedicated thermostat and temperature sensors. Minimum 4 zones are recommended.  Source: Sport Field Heating – DEVI Application manual

iii. Conditions for implementation

Site conditions	It is not recommended to install heating elements (electric under soil heating cables) at temperatures below -5 °C. At low temperatures, heating elements can become rigid and inefficient.
Recommended applications	⚽ The heating cables should be installed 25-30 cm (up till 35 cm) below the surface to avoid cable damage. Distance between the wires depends on the required W/m², and typically is about 15-25 cm. ⚽ An adequate drainage system is needed. Less water means less heating needs. ⚽ In order to keep the soil warm and moist, the area should be covered with plastic or a similar material when it is not in use. ⚽ To limit energy consumption, it is essential to adopt intelligent control systems that heat the under-soil heating only as long as it is necessary to prevent the soil from freezing. ⚽ A photovoltaic system in combination with battery storage can power the electric under-soil heating system, even at night, without expensive external power.
Maintenance best practices	For the hydronic system, glycol has to be replaced after 2 years (approximately 8000 liters, depending on the field size). In case of electrical undersoil heating maintenance is lower. A regular check is however needed.

iv. Strengths	v. Barriers
⚽ Reducing financial loss caused by postponing matches due to poor weather conditions	⚽ High installation costs ⚽ High operational cost

- Reducing risk of injuries for players
- In line with international standards (FIFA's Technical recommendations and requirements)
- Reliable system

In case of electrical undersoil heating also:

- Optimal combination with PV systems to reduce operating costs
- No antifreeze agents are necessary

vi. Performance and potential impacts

Energy performance

To limit energy consumption, it is essential to adopt intelligent control systems that heat the under-soil heating only as long as it is necessary to prevent soil freezing.

In case of an electric heating system, a good opportunity to improve energy efficiency is to exploit the electricity produced by a photovoltaic system.

Cost savings/ Payback time

Under-soil heating operating costs are highly dependent on weather conditions and external temperatures, and can range from 1000 to 3000 € per day. An optimization of the existing under soil heating systems is therefore highly recommended. Cost savings and payback times must be carefully evaluated.

Adaptability with crowdfunding schemes

Level of adaptability: **Medium** (total score between 4 and 5)

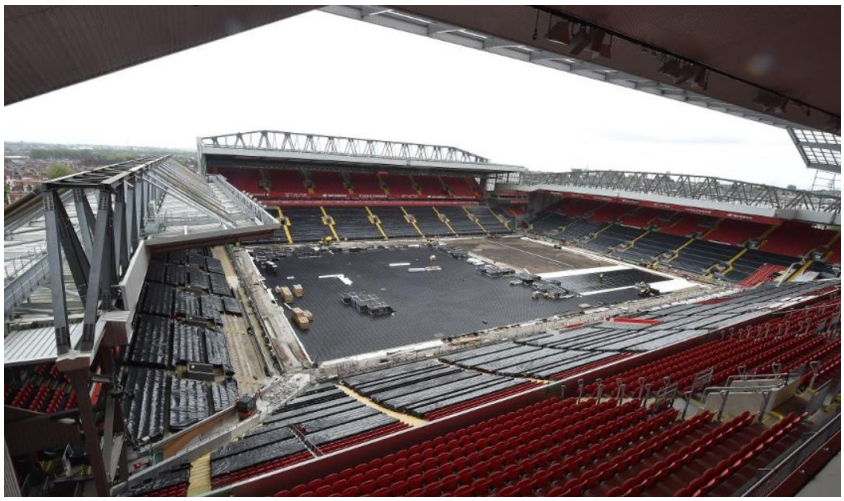
Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

Anfield Stadium (Liverpool)

Anfield is a football stadium in Liverpool, Merseyside, which has a seating capacity of 53,394, making it the seventh largest football stadium in England



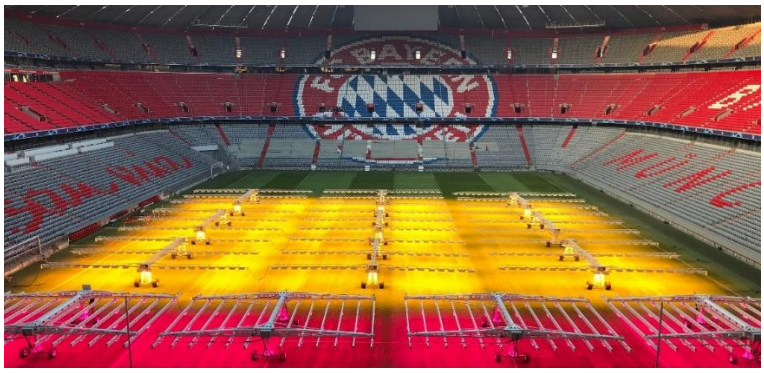
https://www.liverpoolfc.com/news/stadium/266257-photos-and-facts-anfield-pitch-renovation-underway

A new undersoil heating system has been put in place to help aid growth and prevent the ground from freezing during the winter months. As part of the undersoil heating system, over 19 miles of pipeline has been put in place to ensure optimum conditions for maintenance and grass growth. Eight heat and moisture sensors have been installed to help monitor the best growing environment for the pitch. Over 40,000 km

	of artificial grass fibres have been stitched into the layers of sand beneath the pitch, which will be composed of 97% organic grass and 3% artificial grass fibres.
Royal Sporting Club Anderlecht Stadium (Anderlecht)	RSCA Stadium is located within Parc Astrid in Anderlecht and can host up to 21.500 spectators. The RSC Anderlecht pitch is a semi synthetic field constructed in 2007. It is based on 90% sand and reinforced with 40 million PE fibers. The electrical system was chosen as: ⚽ The cables could be installed in a retrofit with a special machine without damaging more than 3% of the PE fibers and the field was playable after 4 weeks. ⚽ The power supply was already available, thus saving the cost, approval and operation of a 720 kW gas-fired boiler. ⚽ The control of the heating cables was included in the existing PLC control SMART EYE for irrigation and draining.

C.6	Electrical equipment and special technologies

C.6.1 Artificial lights for grass growth



https://www.stadia-magazine.com/news/field-lighting/allianz-arena-first-to-use-led-lights-to-grow-turf.html#prettyPhoto

i. General description	
Main function	Improve the growth of natural and mixed-synthetic grass in football stadiums and playgrounds in general. The system also provides a turf heating that favors the melting of snow (up to 5 cm) and ice during the coldest periods.
Applicable to	⚽ Stadiums. ⚽ Training centres.
ii. Technical features and design parameters	
Technical features	High Photosynthetic light modules are structures equipped with particular lamps capable of emitting a homogeneous light with spectrum between 400 and 700nm, which is useful to improve the natural photosynthesis process of the turf and maintain constant vital values, in particular for periods of low sunlight irradiance (late winter, autumn, early spring). The benefits of adopting an LED-based system allows groundskeepers to adjust the color of light to encourage photosynthesis (typically grass uses red and blue light for photosynthesis). Generally, multiple mobile rows of luminaries are placed on closeable supports to be used when needed. The lighting fixtures add both light and heat to facilitate grass growth when natural sunlight and temperature are not sufficient.
Design parameters	A general rule of thumb is that 1% more light will produce a similar percentage increase in growth, resulting in a 1% higher yield [32].
iii. Conditions for implementation	
Site conditions	No particular site conditions are required. The lamps are fixes on recloseable supports which made the system very flexible.
Recommended applications	Recommended for those climates and building configurations where natural sunlight and temperature are not sufficient to guarantee an adequate grass growth.
Maintenance best practices	The system requires very low maintenance.

iv. Strengths	v. Barriers
⚽ Improvement and maintenance of turf ⚽ Easy positioning, use and storage ⚽ Speed up germination and recovery of the grass	⚽ High operating cost that can reduced using a PV system to provide free electricity

[32] https://recreationalsystemsint.com/products/rsi-sports-leds/stadium-grass-grow-lighting

vi. Performance and potential impacts

Energy performance	Adopting LED technology, it is possible to reduce energy consumption compared to conventional sodium vapor luminaires used in outdated technology. Additionally, a PV system with storage can provide free electricity to power the lamps.
Cost savings/ Payback time	Cost savings and payback time must be carefully evaluated based on the maintenance costs needed to guarantee and adequate turf.
Adaptability with crowdfunding schemes	Level of adaptability: **Medium** (total score between 4 and 5)

Return of investment	Visibility and image return for club and fans			Carbon footprint reduction			Experience improvements for fans and users		
	high	medium	low	high	medium	low	high	medium	low
< 3 years	**4**	3	2	**4**	3	2	4	3	**2**
3 to 10 years	3	3	1	3	3	1	3	3	1
> 10 years	2	1	0	2	1	0	2	1	0

*return of investment to be evaluated on the specific case, it can vary.

vii. Relevant examples

Allianz Arena (Munich)

Allianz Arena is a football stadium in Munich with a 70.000 seating capacity for international matches and 75.000 for domestic matches.

https://www.stadia-magazine.com/news/field-lighting/allianz-arena-first-to-use-led-lights-to-grow-turf.html#prettyPhoto

The Allianz Arena implemented 4 LED systems with integrated and fully automatic infrared and irrigation to cover the entire width of the pitch along with Infrared Technology. The 4 LED units together cover the entire width of the pitch.

The LED200 IR grow lighting system promotes photosynthesis which enables and reinforces grass growth on sports playing surfaces under all circumstances. The remote-controlled system is designed to quickly and strongly recover grass after games and events and ensures full grass coverage throughout the entire year.

The right amount of Infrared Radiation is added automatically according to climate circumstances.

- Amount of LED fixtures: 104
- Amount of Infrared fixtures: 26
- kW consumption: LED only 16kW. Including Infrared 64kW

8 APPENDIX 2 – Stakeholders questionnaire

This survey aims at gathering feedback on the solutions proposed within the Technical Catalogue in order to both communicate the results of the task 4.1 activities and to collect preliminary impressions of the main GREENFOOT stakeholders. The results are used to improve the Technical Catalogue and will guide next steps in the WP4 activities on Candidate Building.

8.1 Questionnaire template

Name of the company/organisation: _____

Technical Catalogue

1. Which are the most promising areas of improvement for enhance energy efficiency in football buildings? (please insert an X for the selected option in the following table)

	Technologies to exploit RES (renewable energy sources)
	Improvement of the lighting system
	Modernisation of HVAC systems, plant and equipment
	Implementation of BMS (Building Management Systems).
	Renovation of the building envelope
	Upgrade of electrical equipment and specific technologies

2. General evaluation of the Technical Catalog, choose between:

   (please insert an X for the selected option in the following table)

	Exhaustive: solutions proposed are to be detailed within further WP4 activities on the Candidate Building
	To be adjusted: limited adjustment are needed for the solution proposed
	To be implemented: a few solutions are missing and need to be implemented within additional sheets

3. Which solutions will you promote the most? (low, medium, high levels)

			Low	Medium	High
C.1	Renewable Energy Sources	C.1.1 – Photovoltaic systems (PV)			
		C.1.2 – Solar thermal panels			
		C.1.3 – Biomass heating systems			
		C.1.4 – Geothermal systems			
		C.1.5 – Small wind turbines			
C.2	Lighting	C.2.1 – LED technology for floodlighting			
		C.2.2 – LED technology for internal lighting			
		C.2.3 – Lighting controls			
C.3	HVAC systems, plants and equipment	C.3.1 – High efficiency Heat Pumps			
		C.3.2 – High efficiency Condensing Boiler			

		C.3.3 – High efficiency Air Handling Units (AHU)			
		C.3.4 – Cogeneration systems			
		C.3.5 – Trigeneration systems			
C.4	Building Automation	C.4.1 – Building Management Systems			
C.5	Building envelope	C.5.1 – Thermal insulation			
		C.5.2 – High-performance windows			
		C.5.3 – Cool roofs			
		C.5.4 – Green roofs			
C.6	Electrical equipment and specific technologies	C.6.1 – Under soil heating			
		C.6.2 – Artificial light for grass growth			

4. Please specify type of improvements needed.

5. From you experience, do you suggest additional solutions to be included in the Technical Catalogue or to be developed in details in the further WP4 steps?

			Additrional solutions
C.1	Renewable Energy Sources	C.1.1 – Photovoltaic systems (PV)	
		C.1.2 – Solar thermal panels	
		C.1.3 – Biomass heating systems	
		C.1.4 – Geothermal systems	
		C.1.5 – Small wind turbines	
C.2	Lighting	C.2.1 – LED technology for floodlighting	
		C.2.2 – LED technology for internal lighting	
		C.2.3 – Lighting controls	
C.3	HVAC systems, plants and equipment	C.3.1 – High efficiency Heat Pumps	
		C.3.2 – High efficiency Condensing Boiler	
		C.3.3 – High efficiency Air Handling Units (AHU)	
		C.3.4 – Cogeneration systems	
		C.3.5 – Trigeneration systems	
C.4	Building Automation	C.4.1 – Building Management Systems	
C.5	Building envelope	C.5.1 – Thermal insulation	
		C.5.2 – High-performance windows	
		C.5.3 – Cool roofs	
		C.5.4 – Green roofs	
C.6	Electrical equipment and specific technologies	C.6.1 – Under soil heating	
		C.6.2 – Artificial light for grass growth	

8.2 Questionnaire collection

Name of the company/organisation: Football Association of Ireland

Technical Catalogue

6. Which are the most promising areas of improvement for enhance energy efficiency in football buildings? (please insert an X for the selected option in the following table)

	Technologies to exploit RES (renewable energy sources)
	Improvement of the lighting system
	Modernisation of HVAC systems, plant and equipment
	Implementation of BMS (Building Management Systems).
X	Renovation of the building envelope
X	Upgrade of electrical equipment and specific technologies

7. General evaluation of the Technical Catalog, choose between:

(please insert an X for the selected option in the following table)

	Exhaustive: solutions proposed are to be detailed within further WP4 activities on the Candidate Building
	To be adjusted: limited adjustment are needed for the solution proposed
	To be implemented: a few solutions are missing and need to be implemented within additional sheets

8. Which solutions will you promote the most? (low, medium, high levels)

			Low	Medium	High
C.1	Renewable Energy Sources	C.1.1 – Photovoltaic systems (PV)	X		
		C.1.2 – Solar thermal panels			X
		C.1.3 – Biomass heating systems	X		
		C.1.4 – Geothermal systems	X		
		C.1.5 – Small wind turbines	X		
C.2	Lighting	C.2.1 – LED technology for floodlighting			X
		C.2.2 – LED technology for internal lighting			X
		C.2.3 – Lighting controls			X
C.3	HVAC systems, plants and equipment	C.3.1 – High efficiency Heat Pumps	X		
		C.3.2 – High efficiency Condensing Boiler		X	
		C.3.3 – High efficiency Air Handling Units (AHU)	X		
		C.3.4 – Cogeneration systems	X		
		C.3.5 – Trigeneration systems	X		
C.4	Building Automation	C.4.1 – Building Management Systems		X	
C.5	Building envelope	C.5.1 – Thermal insulation			X
		C.5.2 – High-performance windows			X

		C.5.3 – Cool roofs	X		
		C.5.4 – Green roofs		X	
C.6	Electrical equipment and specific technologies	C.6.1 – Under soil heating	X		
		C.6.2 – Artificial light for grass growth	X		

9. Please specify type of improvements needed.

    1. Upgrading of floodlights to LED models.
    2. Upgrade of all windows & doors to higher effiencey models.
    3. Installation of solar panelling where applicable.

10. From you experience, do you suggest additional solutions to be included in the Technical Catalogue or to be developed in details in the further WP4 steps?

			Additrional solutions
C.1	Renewable Energy Sources	C.1.1 – Photovoltaic systems (PV)	
		C.1.2 – Solar thermal panels	
		C.1.3 – Biomass heating systems	
		C.1.4 – Geothermal systems	
		C.1.5 – Small wind turbines	
C.2	Lighting	C.2.1 – LED technology for floodlighting	
		C.2.2 – LED technology for internal lighting	
		C.2.3 – Lighting controls	
C.3	HVAC systems, plants and equipment	C.3.1 – High efficiency Heat Pumps	
		C.3.2 – High efficiency Condensing Boiler	
		C.3.3 – High efficiency Air Handling Units (AHU)	
		C.3.4 – Cogeneration systems	
		C.3.5 – Trigeneration systems	
C.4	Building Automation	C.4.1 – Building Management Systems	
C.5	Building envelope	C.5.1 – Thermal insulation	
		C.5.2 – High-performance windows	
		C.5.3 – Cool roofs	
		C.5.4 – Green roofs	
C.6	Electrical equipment and specific technologies	C.6.1 – Under soil heating	
		C.6.2 – Artificial light for grass growth	