GREENFOOT

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

Deliverable 4.4:

Guidelines for the Promotion of an Energy Performance Certificates for Sport Facilities

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Executive Summary

The ninth Sustainable Development Goal (SDG9) adopted by the United Nations in 2015 seeks to "Build resilient infrastructure, promote sustainable industrialisation and foster innovation". Economic growth, social development and climate actions are heavily dependent on investments in infrastructure, sustainable industrial development and technological progress. Inclusive and sustainable industrialisation, together with innovation and communities' participation, can unleash dynamic and competitive economic forces that promote energy efficiency and generate sustainable growth.

Sport and its facilities such as stadiums, gyms and arenas are intrinsic parts of the built environment and of the community's life. From mega-events to local stadiums and arenas, sports facilities are progressively making efforts to minimise their carbon footprints. The reasons for embracing sustainability all widely vary, from economics reasons (facilities that are environmentally sound are also economically efficient) to statute-oriented ones, but overall, these facilities understood the high-level importance of being good stewards of the environment. Unlike most standard buildings such as offices and residences, sports facilities get much more publicity in the media, both good and bad, and as a result they have a highly visible platform to encourage positive change.

Although sustainability at sport facilities is becoming more and more important at all sporting levels, currently there is no adequate energy performance certification (EPC) system capable of considering all the peculiarities of them.

Changing EPC credibility is one of the goals set by the EU for the decarbonization of the building sector with beneficial impact on energy policy development, energy planning, and for promoting energy conservation and sustainability.

In view of the general uncertainty of EPCs for football buildings, defining a new methodology for improving the data quality and readability is fundamental. The improvement in terms of reliability refers to the variance in results depending on the assessor's input data, calculation tools, and differences between predicted and actual energy performance, and it represents a crucial issue to unlock the generalized confidence in EPCs.

This deliverable proposes a few suggestions for the development of an Energy Performance Certificate for sport facilities with particular attention to football buildings, starting from the analysis of the state of the art of available energy rating systems (EPCs and internationally recognised sustainability protocols such as LEED and BREEAM), and from the critical evaluation of their strengths and weaknesses relating to the main peculiarities of sport facilities.

To overcome the lack of an adequate certification scheme for football buildings, in particular related their occasional and non-standard use, it appeared useful that the certification is based on an operational rating and a dynamic energy modelling, which allows to account for energy consumption in relation to the actual uses instead of using standardised input data and steady or semi-steady modelling, which can be unrepresentative for the specific building.

The input data for the energy evaluation can be drawn from a series of tools as Building Information Modelling (BIM), Building Management System (BMS) and digital twins, where available. In this way it will be possible to obtain a more accurate and not standardised certification and, at the same time, it will be cheaper and simpler than completely carrying out complex sustainability protocols (such as LEED, BREEAM etc.) based on dynamic energy modelling, so that this kind of certification is also accessible to small sports facilities with lower financial coverage.

List of acronyms and abbreviations

AFFA: Azerbaycan Futbol Federasiyalari Assosiyalari Ictimai Birlik
BEM: Building Energy Model
BIM: Building Information Modelling
BMS: Building Management System
BREEAM: Building Research Establishment Environmental Assessment Method
D: Deliverable
DoA: Description of Actions
DT: Digital Twin
ECM: Energy Conservation Measure
EE: Energy efficiency
EEB: Energy-efficient Building
EED: Energy Efficiency Directive
EPBD: Energy Performance Buildings Directive
EPB Energy Performance of Building
FAI: Football Association of Ireland
HVAC: Heating Ventilation Air Conditioning
IAQ: Indoor Air Quality
IEQ: Indoor Environment Quality
IoT: Internet of Thing
KPI: Key Performance Indicator
LED: Light Emitting Diode
LEED: Leaership in Energy and Environmental Design
MEP: Mechanical Electrical Plumbing
NCM: national Calculation Methodology
NPT: Net Present Value
PBT: Payback Time
PRM: Performance Rating Method
PV: Photovoltaic
RES: Renewable Energy Source
R&D: Research and Development
SHGC: Solar heat gain coefficient
SME: Small Medium Enterprise
SRI: Smart Readiness Indicator
U-value: Thermal transmittance
USGBC: U.S. Green Building Council
WP: Work Packaged

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1 Introduction

Deliverable 4.4 synthesises all the activities carried out within Task 4.4 and provides guidelines for the promotion of an Energy Performance Certificates for sport facilities with particular attention to football buildings. The following paragraphs provide a brief description of the deliverable's content, the target group, which the document is addressed to and the links with other project activities.

2 Description of the deliverable content and purpose

The analysis on the football building stock carried out in Deliverable 4.1 "Summary of best practices in EE and RES installations in sport buildings" revealed that there is a wide variety of buildings each with its own features, peculiarities, site conditions and needs, which all have great influence on the energy consumption.

In general, the main aim of an Energy Performance Certificate (EPC) is to serve as an information tool for building owners, occupants and real estate actors. EPCs can be a powerful market tool to create demand for energy efficiency in buildings by targeting energy improvements as a decision-making criterion in real-estate transactions, and by providing recommendations for the cost-effective or energy-optimal upgrading of buildings.

Currently, the standardised energy certification schemes are not adequate to well represent football building energy performances due to all the peculiarities of sport facilities and their occasional and non-standard uses.

The purpose of this deliverable is to discuss the direction for future improvements and provide useful guidelines for the promotion of a specific energy certification scheme for sport facilities that combines the Energy Performance Building Directive (EPBD) and the most recognised sustainability protocols (LEED and BREEAM) in order to give an accurate overview of the energy performance and provide a reliable and easy-to-understand classification scheme supporting sustainability and energy efficiency in football buildings.

The availability of a sport facilities-oriented EPC will allow to have a more accurate overview on the energy performance of football buildings, showing, for instance, to building owners, investors and fans the effect of the renovation they supported, improving in this way the marketing potential of sustainable sports buildings and related renovations.

As first step, the main features of sport facilities, as identified in D4.1 "Summary of best practices in EE and RES installations in sports buildings", were analysed in order to understand and identify the main peculiarities associated with this type of buildings and keep them in mind in the subsequent stages of elaboration of a specific energy certification scheme.

Then, a detailed analysis of the state of the art of available energy rating systems (EPCs and internationally recognised sustainability protocols such as LEED and BREEAM) was performed in order to identify strength and weak points. Specifically in EU, buildings' energy performances are assessed through:

1. Energy Performance Certificates (EPCs), regulated by the 2010/31/EC Energy Performance of Buildings Directive (EPBD), which are more appropriate for certifying 'standard' buildings such as residences and offices rather than buildings with a more complex functioning such as stadium and sports facilities;
2. complex and extensive sustainability certification schemes such as LEED and BRREAM protocols, which assess all sustainability aspects, but require considerable technical and economic commitment, often not economically sustainable for small sport centres.

In the last section of the deliverable, potential areas of improvements that should be included in a new EPC scheme for football buildings are suggested and investigated.

2.1 Target group and link with other activities

The main target group of this deliverable includes building owners, professionals (people who design, build and operate sport facilities), investors of the renovation scenarios, supporters of the crowdfunding campaigns and any other stakeholders who may be interested in viewing the results of the renovation process.
Task 4.4 is linked to the previously activities of WP4, which provide a framework and practical examples for the development of a specific energy certification scheme for the sport facilities and to Task 5.4 supporting the replication and exploitation of GREENFOOT concept in various EU countries.

3 Sport facilities main features

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]. 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 they 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.

As analysed within D4.1 "Summary of best practices in EE and RES installations in sports buildings" football buildings can be synthetised into 3 categories:

- Football stadiums, where official and competitive activities can take place;
- Sport and training centres, where regulated activities, not intended for competition, can take place as preparatory and training activities;
- Club headquarters, where all support and complementary activities can take place.

The above categories have different requirements, needs and priorities based on the activity carried out and on the number of practitioners or occupants in general.

Football stadiums

Football stadiums are very energy-intensive buildings often used with very low frequency (only one or two times a week) which involves in not-homogeneous energy consumption characterized by peaks reached during matches and periods with very low consumption. It has been estimated that a stadium, during the two hours of the match (including half-time and injury time) can consume up to 25,000 kWh[2] (power that could keep more than a dozen homes going for an entire year). The type of facilities and temporary arrangements available inside the football stadiums, and the related energy consumption, vary enormously inside the same category. On average, the main energy consumption is due to lighting, scoreboard and advertising screens as shown in the following diagram.

[1] SPORTE2 D7.1 Market Analysis. 2013.
2 https://selectra.co.uk/energy/news/world/world-cup-2018-stadium-energy-use

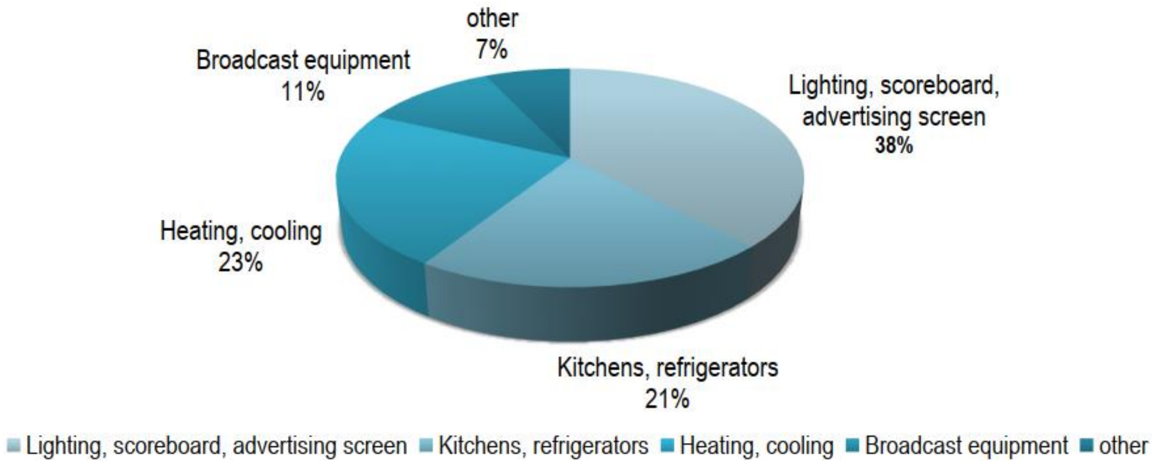

Figure 3-1: Estimated stadium energy consumption[1]

Sport and training centres

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. The HVAC systems for heating, cooling, ventilation and domestic hot water (DHW) production, generally account for a large proportion of energy use in sports centres as documented in the following diagram.

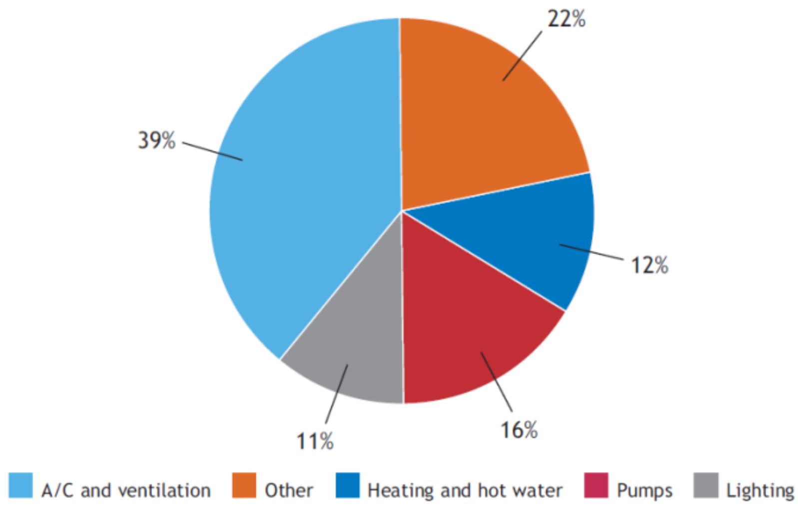

Figure 3-2: Energy cost of a typical sport centre with a pool[3]

Club headquarters

Club headquarters are typical office buildings housing the club's management and administrative staff, with usage patterns, energy demands and consumption similar to any other office building, with a stable use pattern throughout the week and the year.

Since this type of facilities is already well represented by available EPC, it has been excluded from the analysis for the development of tailored EPC for sport facilities.

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

In order to better understand the peculiarities of football buildings, it was deemed useful to make a comparison with other more standardised building (e.g. offices, residences, retail buildings). The following table summarizes the analysis carried out based on RINA Consulting's practical background.

Table 3-1: Comparison between football buildings and other standardised buildings

#	Means of comparison	Football stadiums	Sport and training centres	Other standardised buildings*
1	**Usage patterns**	Intermittent use with occupancy ranging between time intervals without use and time intervals with the maximum capacity. Generally used 1-2 times per week during the playing season	More constant usage throughout the week and the year depending on the type of activity and training planned.	Constant use through the week and the year with a standard occupancy (e.g. office buildings used from 9 a.m. to 6 p.m. form Monday to Friday).
2	**Main energy consumption**	- Lighting, scoreboard, advertising screen - heating, cooling - kitchens, refrigerators - broadcast equipment - other	- Air conditioning and ventilation - heating, hot water - pumps - lighting - other	- HVAC system - lighting - other electrical equipment
3	**Energy systems**	Often oversized: they run at appropriate levels only for periods of maximum use	Usually sized correctly	Usually sized correctly
4	**Specific services**	Specific services are likely to be present as: - Under-soil heating - pumps for the irrigation system - artificial lighting for grass growth	Specific services are likely to be present as: - pumps for the irrigation system - gym	Usually, no additional specific services are present
5	**Energy consumption**	Not easily predictable. Few benchmarks available. Very high energy peaks.	Not easily predictable. A few benchmarks available often not completely comparable (depending on the facilities included in the training centres)	Easily predictable with many benchmarks on average consumption available.
6	**Energy efficiency**	Tailor-made solutions are needed.	Tailor-made solutions are needed.	More standardized solutions are commonly available.

As result of the analysis, it appeared that in general, the energy consumption of football buildings and related sport facilities are difficult to predict and therefore to be standardised. Football stadiums and sport and training centres are unique by their physical nature (characteristics), their energy consumption profiles, the usage patterns, and the type of services and events they hold (e.g. special training events and tournaments, concerts...). Additionally, for football buildings there are just very few benchmarks available that can be used to establish reference points for assess and evaluate building performances.

In particular, as concern "usage patterns" football buildings have a middle-low frequency through the week and the year. Football stadiums are populated around twice a week, in occasion of matches and events, while for the rest of the time they are unused. Therefore, their use is very variable, differently to "standard buildings" (e.g. offices, residences, retail buildings...), which are occupied with a constant frequency through the week and the year, due to the fact that the activities that take place within them (as living, sleeping, working etc.) are constant through the time.

Regarding "main energy consumption", for football stadiums the main consumptions are related to lighting, scoreboard and advertising screen with secondary consumptions connected to heating, cooling, mechanical ventilation, kitchens, refrigerators, broadcast equipment, etc. The situation is completely reversed for sport and training centres and for "more standard buildings" where lighting is less impactful than in football stadiums and, naturally, scoreboard and advertising screen are not present. Here the main consumption is related to heating and cooling and secondly to lighting and other electrical equipment. For training centres, the hot water production is also relevant.

As concern "energy systems", since football stadiums do not have a constant use, most of the time the energy systems are oversized: they are necessary to satisfy energy peaks during matches, concerts etc. when the building is fully occupied, but they result excessive for the rest of the time and when the building is not fully occupied. Naturally this does not happen, or happen only for "wrong" design in more standard buildings where the energy demand is linear, predictable and energy peaks represent very rare cases.

Furthermore, in football stadiums there may be some "specific services", strictly connected to the performances that must be guaranteed for the playing field (with reference to the requirements that need to be included into certain UEFA's stadiums categories), such as underground heating, pumps for irrigation system, artificial lighting for grass growth, etc. All these types of services are highly energy intensive. In training centres, unless there are specific needs, there are usually only irrigation systems for the playing fields, while in the case of standard buildings this type of "special services" is not present.

It is important to keep in mind these features in the following analysis about the state of the art of the rating system, to better understand the weaknesses of the actual energy rating systems for football buildings.

4 State of the art of energy rating systems

Typically, buildings' energy performances are assessed through:

1. Energy Performance Certificates (EPCs), regulated by the 2010/31/EC Energy Performance of Buildings Directive (EPBD), which are more appropriate for certifying "standard buildings" such as residences and offices rather than buildings with a more complex functioning such as stadium and sports facilities;
2. Complex and extensive sustainability certification schemes such as LEED and BRREAM protocols, which assess all sustainability aspects, but require considerable technical and economic commitment, often not economically sustainable for small sport centres.

The following paragraphs provide a detailed analysis of the actual rating systems. The structures of energy certificates and sustainability protocols are analysed in depth in order to understand their purposes, strengths and weaknesses.

4.1 Energy Performance Certificates (EPCs)

Energy Performance Certificates (EPCs) are currently among the most important sources of information on the energy performance of the EU's building stock. They represent effective instruments to track buildings' energy performance (expressed in kWh/m^2) and support the implementation of minimum energy requirements within the regulatory process. The EPC may present additional indicators such as CO_2 emissions or the percentage of renewable energy sources.

EPCs are an instrument that contributes to the improvement of the overall buildings' performance in a transparent and comparable way across Europe. The purpose of an Energy Performance Certificate is to provide information on a building's energy performance rating and to make recommendations about cost-effective improvements.

As a matter of fact, EPCs provide information to consumers on buildings they plan to purchase or rent. They must be included in all advertisements in commercial media when a building is put up for sale or rent and must be shown to prospective tenants or buyers when a building is being constructed, sold, or rented and after a deal has been concluded, they are handed over to the buyer or new tenant.

4.1.1 Energy Performance of Buildings Directives (EPBD)

The EU Commission has set up a set of directives and policies that, in the last twenty years, contributed to the energy retrofit and decarbonisation of the whole EU building stock. The two main directives concerning built environment energy efficiency are the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive. The overarching aim of these instruments is to support the transformation of the EU's new and existing buildings into nearly-zero energy ones.

In particular, the EPBD can be considered the main EU legislative act for boosting buildings renovation, focusing on the increase of passive efficiency of buildings, as well as the integration of renewable energy systems and the attention to indoor air quality. Moreover, EPBD provides a strong support to investments in the energy efficiency of the building sector, currently causing about 36% of global Green House Gas emissions in EU member states, and accounting for about 40% of the total energy consumption, being the single largest energy consumer in Europe.

The following figure summarises the chronological evolution of related European Directives.

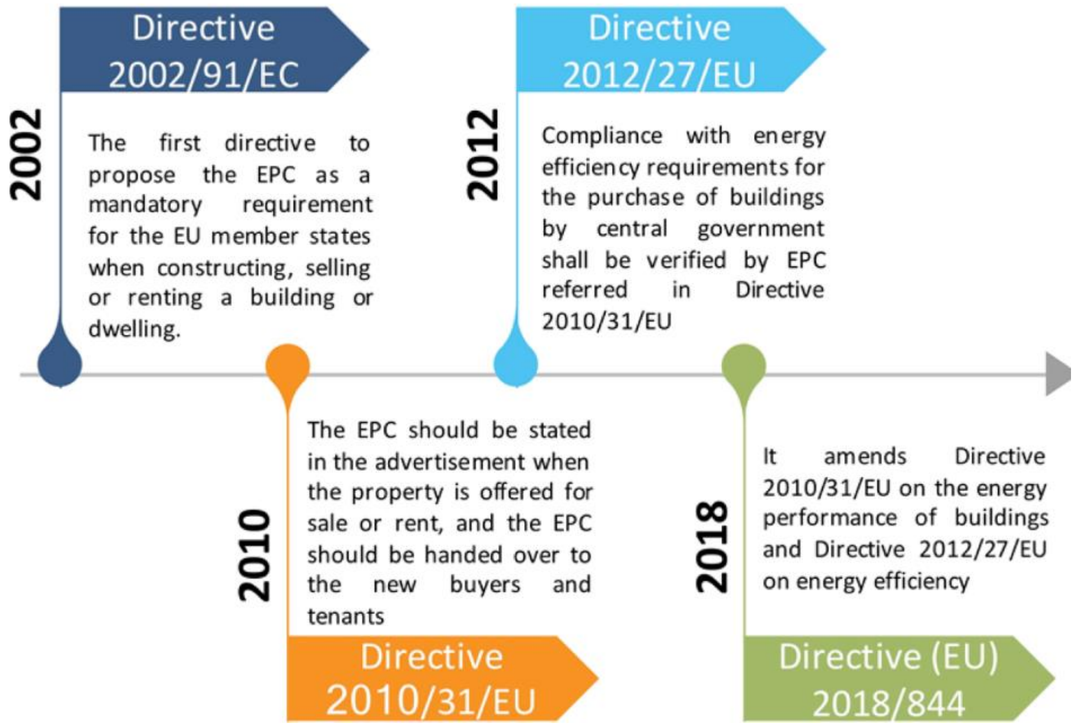

Figure 4-1: EU directives chronological evolution [4]

[4] Li, Y.; Kubicki S.; Guerriero, A.; Rezgui, Y.; Review of building energy performance certification schemes towards future improvement; Renewable and Sustainable Energy Reviews, volume 113, October 2019

The first version of EPBD (2002/91/EC) was released in 2002, requiring Member States to strengthen their national building regulations and introducing Energy Performance Certificates (EPCs).

A first revision of the directive was released in 2010 (EPBD Recast, 2010/31/EU). This Directive, together with the Energy Efficiency Directive (2012/27/EU) was the main policy document allowing to set virtuous standards to decarbonize the EU building stock accounting for 2050 established objectives, also creating a stimulating framework for financial investments in the sector by public authorities, privates and businesses.

A third amendment to the Directive was released in 2018 (2018/844/EU), which provided a greater focus on buildings smartness and buildings indoor environmental conditions. In particular, this directive introduces the Smart Readiness Indicator (SRI) of buildings, a strong political sign highlighting the Commission willingness to push the modernization of the building sector. Moreover, a significant improvement was provided by this directive by introducing a holistic approach for evaluating the energy performance of whole buildings (before, energy requirements were set only for single components).

Decarbonization constitutes a fundamental aspect of all EPBD directives, considering the reduction of environmental impact as key – such aspects were integrated also in the latest major policy framework, such as the EU Clean Energy package, which supports the energy transition from fossil fuels to cleaner energy and, more specifically, providing an operative instrument for translating Paris Agreement commitments into reality.

In December 2021, the Commission published a proposal for a revision of the directive and on the 7th December of 2023 the European Parliament and the Council reached a provisional agreement on the recast, that will go through the formal adoption process in early 2024 and it has the intent to reduce the emissions and energy use of buildings across the EU. The strengthened Energy Performance of Buildings Directive (EPBD) will support the EU's efforts to decarbonise buildings across the whole Union. This is an area in which the concrete impact of the European Green Deal will improve the quality of life for people, in their homes and workplaces, and lower their energy bills. This deal will also boost Europe's energy independence in line with the REPowerEU Plan and make a strong business case for a cleaner building sector in the EU.

The revised Directive will set out a range of measures that will help EU governments to structurally boost the energy performance of buildings, with a specific focus on the worst-performing buildings.

The following table provides a summary of the four main intentions of the provisional agreement.

Table 4-1: Intentions of the provisional agreement [5]

#	Intent	Description
1	**Better performing buildings to lower energy bills and cut emissions**	• Each Member State will adopt its own national trajectory to reduce the average primary energy use of residential buildings by 16% by 2030 and 20-22% by 2035, allowing for sufficient flexibility to take into account national circumstances. Member States are free to choose which buildings to target and which measures to take. • The national measures will have to ensure that at least 55% of the decrease of the average primary energy use is achieved through the renovation of the worst-performing buildings. • For the non-residential building stock, the revised rules require to gradually improve it via minimum energy performance standards. This will lead to renovating the 16% worst-performing buildings by 2030 and the 26% worst-performing buildings by 2033.

[5] https://ec.europa.eu/commission/presscorner/detail/%20en/ip_23_6423

		• Member States will have the possibility to exempt certain categories of residential and non-residential buildings from these obligations, including historical buildings or holiday homes. • Improved Energy Performance Certificates (EPCs) will be based on a common EU template with common criteria, to better inform citizens and make financing decisions across the EU easier. • To fight energy poverty and bring down energy bills, financing measures will have to incentivise and accompany renovations and be targeted in particular at vulnerable customers and worst-performing buildings, in which a higher share of energy-poor households live. • Member States will also have to ensure that there are safeguards for tenants, to help tackle the risk of eviction of vulnerable households caused by disproportionate rent increases following a renovation.
2	**Triggering a Renovation Wave**	The revised EPBD contains measures to improve both the strategic planning of renovations and the tools to ensure such renovations will happen. Under the agreed provisions, Member States will: • establish national Building Renovation Plans to set out the national strategy to decarbonise the building stock and how to address remaining barriers, such as financing, training and attracting more skilled workers. • set up national building renovation passport schemes to guide building owners in their staged renovations towards zero-emission buildings. • establish one-stop-shops for home-owners, SMEs, and all actors in the renovation value chain, to receive dedicated and independent support and guidance. In addition, the deal will help the EU to phase-out, in a gradual manner, boilers powered by fossil fuels. Subsidies for the installation of stand-alone boilers powered by fossil fuels will not be allowed as of 1 January 2025. The revised directive introduces a clear legal basis for Member States to set requirements for heat generators based on greenhouse gas emissions, the type of fuel used, or the minimum share of renewable energy used for heating. Member States will also have to set out specific measures on the phase-out of fossil fuels in heating and cooling with a view to a complete phase-out of boilers powered by fossil fuels by 2040.
3	**Boosting sustainable mobility**	The deal will also boost the take-up of sustainable mobility thanks to provisions on pre-cabling, recharging points for electric vehicles and bicycle parking spaces. Pre-cabling will become the norm for new and renovated buildings, thus facilitating access to recharging infrastructure and contributing to the EU's climate ambition. In addition, there will be strengthened requirements on the number of recharging points in both residential and non-residential buildings. Member States will also have to remove barriers to the installation of recharging points, to ensure that the 'right to plug' becomes a reality. Overall, recharging points will have to enable smart charging and, where appropriate, bi-directional charging. Finally, the provisions will ensure that there are sufficient parking spaces for bicycles, including cargo bikes.
4	**A zero emissions standard for new buildings**	The revised directive will make zero-emission buildings the new standard for new buildings. Under the agreement all new residential and non-residential buildings must have zero on-site emissions from fossil fuels, as of 1 January 2028 for publicly-owned buildings and as of 1 January 2030 for all other new buildings, with a possibility for specific exemptions.

		Member States will also have to ensure that new buildings are solar-ready, meaning that they have to be fit to host rooftop photovoltaic or solar thermal installations. Installing solar energy installations will become the norm for new buildings. For existing public and non-residential buildings solar will need to be gradually installed, starting from 2027, where this is technically, economically and functionally feasible. Such provisions will come into force at different points in time depending on the building type and size.

The provisional agreement requires formal adoption by the European Parliament and the Council. Once this process is completed, the new legislation will be published in the Official Journal of the Union and enter into force.

As anticipated, the EPBD underpins the majority of policies and regulations adopted by the single EU Member States to improve energy performance of buildings. It upgraded the existing regulatory framework to reflect higher ambitions and more pressing needs in climate and social action, while providing EU countries with the flexibility needed to take into account the differences in the building stock across Europe. In particular, the directive mandated the EU countries to introduce energy certification schemes for buildings and tighten their building energy regulations setting minimum energy performance requirements for new buildings, existing buildings undergoing major renovation and for the replacement or retrofit of building elements like heating and cooling systems, roofs and walls. To date, all 28 Member States have formally transposed the requirements of the Energy Performance of Buildings Directive into their national laws.

Article 3 of the EPBD required all EU Member States to adopt a methodology to calculate energy performance of buildings. This methodology underpins the energy performance certificate schemes implemented in the EU countries to indicate energy efficiency of the building stock. Such calculation includes, as a minimum, energy use related to heating, hot water, cooling, ventilation and lighting under standardised conditions - which, as already mentioned, are not suitable for sports buildings with discontinuous uses such as stadiums. Below the two main calculation methods are analysed.

4.1.2 Measured or calculated energy performance rating

To implement Article 3 of the EPBD, the EU Member States developed various calculation methodologies. To determine energy performance of the buildings, most countries opted for whole-building simulation, using thermal modelling software developed in accordance with specific standards. Thermal modelling is a useful method to calculate energy performance of a building through mathematical equations that relate physical properties of the building (external envelope's thermal conductivities, air permeability, type and efficiency of heating, ventilation and air conditioning systems, intensity of lighting, etc.) to the building's energy use under specific climatic conditions.

To define the energy performance of a building, there are two main methods:

- the calculated (asset) rating
- the measured (operational) rating

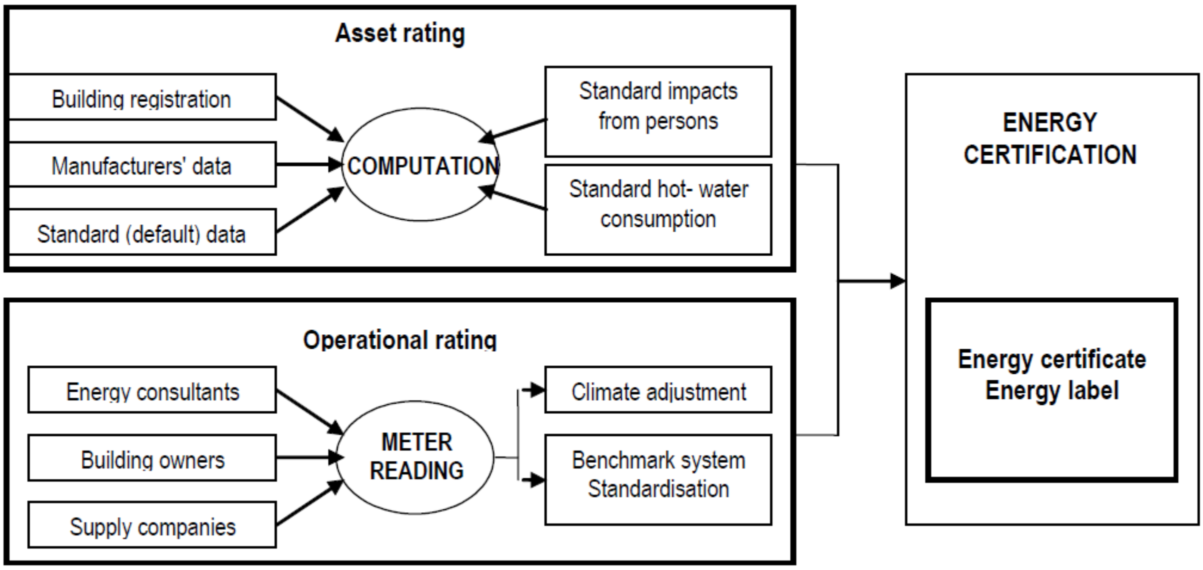

Figure 4-2: Data flows in calculated and measured building energy certification rating [6]

While the calculated (asset) rating method is based on standardised input data, the measured (operational) rating method is greatly influenced by the behaviour of the occupants. The aim of a building energy certification is to certify the building and not the users of the buildings, for this reason the calculated (asset) rating has been generally adopted by each EU Member State as the calculation method to generate the buildings' EPCs.

The current energy assessment framework prescribed by the EPBD is overwhelmingly based on the theoretical performance. Generally, the total energy performance of a building is compared with the total energy performance calculated for a notional building that possesses minimum acceptable specification (reference values coming from National Building Regulations for energy efficiency). The minimum specification is updated with every new version of Building Regulations to set out ever more stringent targets. The following figure summarises the compliance path.

[6] Jensen, O.M., Hansen, M.T. Thomsen, K.E. Wittchen, K.B. Development of a 2nd generation energy certificate scheme – Danish experience. ECEE summer study 2007, Nice, France

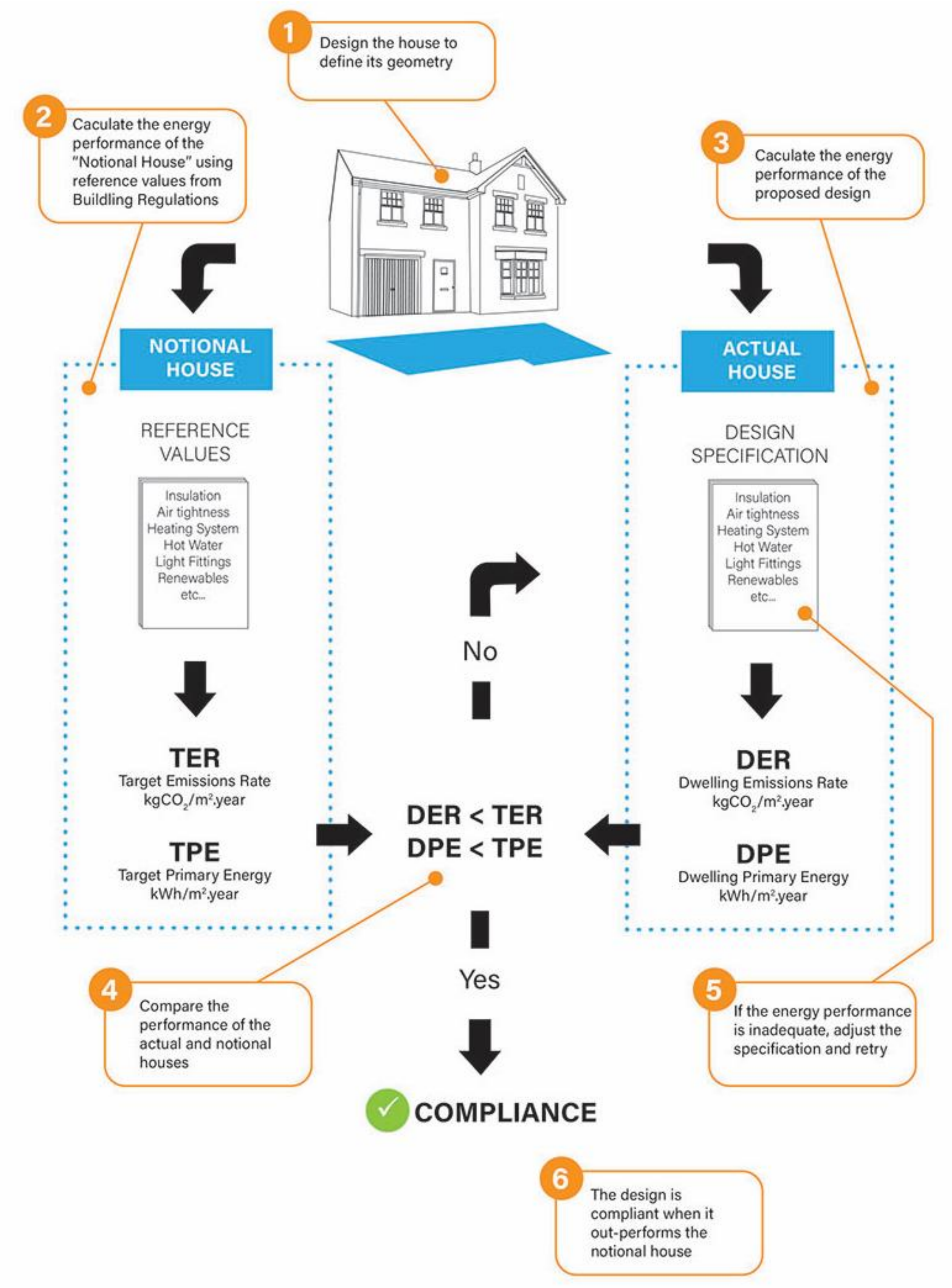

Figure 4-3: Energy performance evaluation and comparison with the notional building [7]

The **calculated (asset) rating** is determined by modelling the building under a defined set of standard conditions of occupancy, climate, environment and use. Asset rating includes energy use of heating, cooling, hot water, ventilation and lighting for non-domestic buildings. It applies to both new and existing buildings. In the case of existing buildings, the calculation methodology for asset rating will have to take into account that design data is

[7] http://www.solarblogger.net/2019/11/options-options-building-regulations.html

unlikely to be available in existing buildings and estimates and approximations will necessarily have to be performed.

An asset rating is evaluated at a *single point in time* and is a *long-term* metric since its drivers change very infrequently. Hence, an asset rating is often used for financial valuations, appraisals and sale or lease transactions since they are more dependent on long term performance of a building than on the current or historical usage of its most recent occupant.

To deduce an asset rating, one often needs to construct an energy model that runs a computer simulation on a 3D building information model after taking into consideration the building's construction, structure, geo-location, building physics and weather conditions. One can then assess a building's potential performance by comparing the asset rating to a baseline model or to the notional building and normalizing it to occupancy schedules, equipment loads, construction materials and systems. In addition, an energy model identifies potential energy savings that could be obtained through design changes such as adding insulation, changing windows, or improving daylight controls. Because, an asset rating is determined by long-term assumptions, the energy conservation measures (ECMs) recommended by such an evaluation often require capital investment but lead to deeper, long-term energy savings.

The **measured (operational) rating**, on the other hand, is normally used to perform detailed Energy Audits in order to define more precisely the behaviour of the building in relation to the actual uses.

A building's operational rating is based on day-to-day operations of the building and measures the operational performance of a building that are affected by a number of operating conditions that need to be considered. Examples include building occupants' density, temperature set points, occupancy profiles and operation schedules of building services and small power loads. Since these operating conditions are often unknown (e.g. for new buildings) or subject to a lot of uncertainty (e.g. in existing buildings), standardized conditions or tailored assumptions can be used to overcome the lack of data and the uncertainties.

Operational rating compares actual operational energy use of a building with its peer group, across a baseline period. Operational rating is often measured and analysed by data from sensors, smart meters and building management systems. It is best used for assessing the impact of operational improvements such as adjusting the economizer controls, changing the set points or the building's operating schedule.

In some cases, the rating selected is a combined rating: Asset and Operational ratings are combined to create one, more holistic unit. How this is done, diverge between Member States.

The map displayed in following figure illustrates the methodology types in use in each Member State.

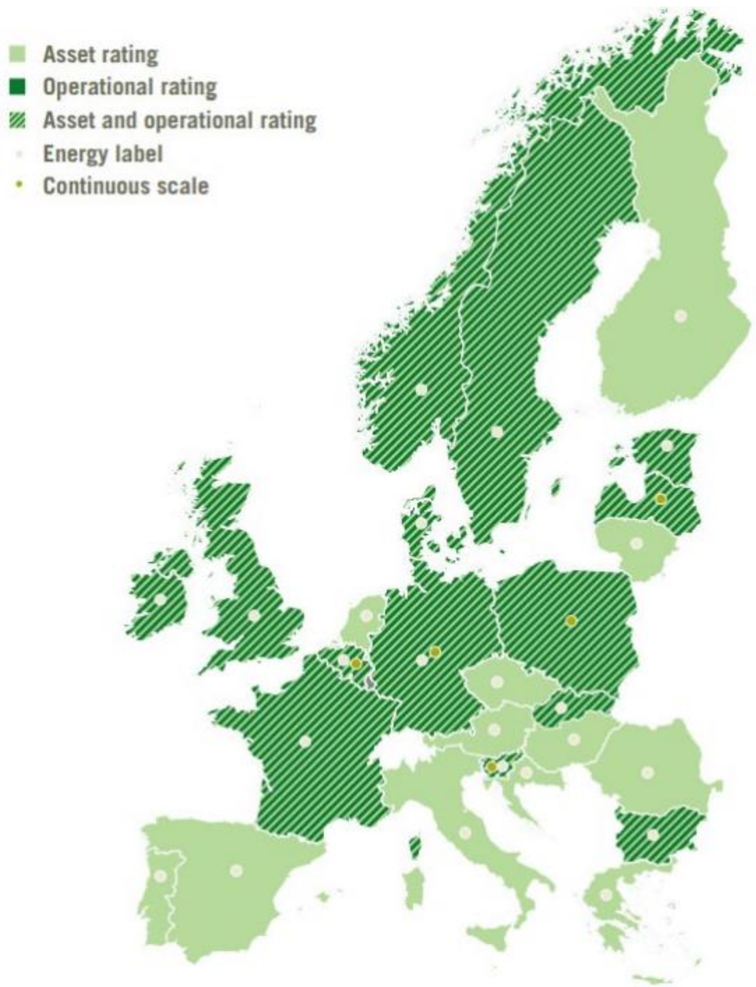

Figure 4-4: Overview of methodologies used in European countries [8]

The following table summarises the main differences between measured and calculated energy performance rating.

Table 4-2: Measured and calculated energy performance rating comparison

	Asset rating	**Operational rating**
Assumptions	Long term	Short/Med-term
Performance Criteria	As designed	As operated
Benefit	Increase in Asset Value	Decrease in Operational Expenses
Performance calculation	Modeled performance at a given snapshot in time	Actual energy use over a given period of time
Evaluation Method	Energy Modeling	Sensors, Meters and Data Analytics
Investment needed	Medium-to-large capital investments	Low-cost
Usage profile	Standardised	Tailored

[8] Stromback, J.; Hobson, D.; Streng, E.; Serrenho, T.; Bertoldi, P.; Advanced quality and use of energy performance certificates (EPCs) by investors and financial institutions, JRC Technical report, European Union, 2021

4.1.3 EPC information and energy indicators

The EPCs include an energy performance rating (e.g. with energy labels from A to G, where A is the most energy-efficient grade and G is the least energy-efficient grade) useful to evaluate the energy efficiency of buildings. They include information on the energy performance of the building's envelope, use of technical installations and primary energy consumption that can be used for various purposes by a wide range of stakeholders. The energy performance indicators are measured in kWh/m^{2}year.

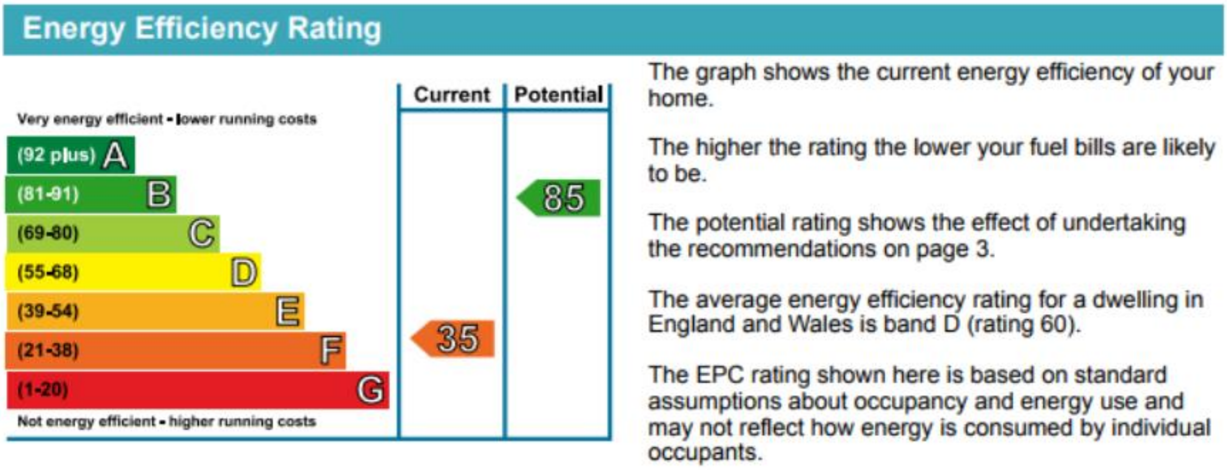

Figure 4-5: Energy Performance Rating example

In order to increase the usability of the EPCs information (for building owners and tenants), additional requirements and recommendations regarding the scope of the certificates were introduced in the EPBD recast (Art. 11):

- EPCs shall include recommendations for the cost-effective or cost-optimal improvement of the energy performance of a building or building unit unless there is no reasonable potential for such improvement compared to the energy performance requirements in force (obligation).
- Recommendations included in the EPC shall be technically feasible for the specific building (obligation).
- EPCs shall provide an indication as to where the owner or tenant can receive more detailed information (obligation).
- EPCs may include additional information, such as the annual energy consumption for non-residential buildings and the percentage of energy from renewable sources in the total energy consumption (recommendation).
- EPCs may include additional information, such as the actual impact of heating and cooling on the energy needs of the building, on its primary consumption and the carbon dioxide emissions (recommendation).
- EPCs may provide an estimate for the range of payback periods or cost-benefits over its economic lifecycle, as well as incentives of a financial or other nature, as well as financing possibilities (recommendation).

4.1.4 EPC databases across Europe

Building a central EPC register to collect EPC data is not compulsory under EU legislation. Member States have freedom in the development of EPC registers. The first Member States to have set up a database for EPCs were Austria and Bulgaria (2005), afterwards the registers spread throughout Europe. In a few countries there are separate databases by building type, such as for new and existing buildings and for residential and non-residential buildings.

The main information gathered consists of key indicators presented in the EPC, including reference information, building geometry, type of EPC, energy performance information, recommendations, energy assessor details, energy losses, etc. The register format varies between Member States from a simple folder structure with an electronic copy of the EPCs to advanced SQL databases. Some countries use an Excel spreadsheet format to gather EPC data. Usually, uploading the EPC information in the database is exclusively the responsibility of the certifier, while the responsibility to manage the databases in most Member States lies with the central and/or regional government bodies.

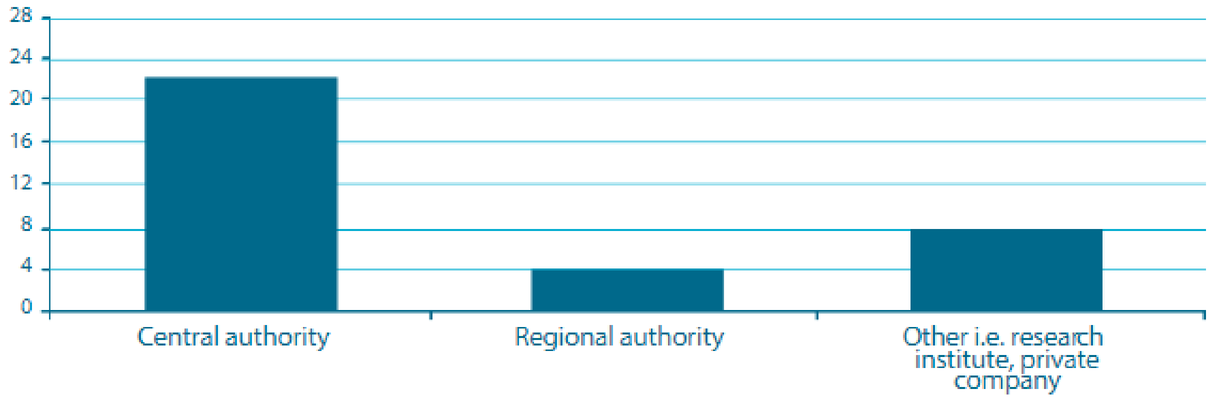

Figure 4-6: Management of EPC registers across Europe [9]

If EPC ratings are public information, financiers can access them for multiple purposes and they can make comparisons between their own holdings and the national average. Another potential use mentioned would be their ability to make pro-active enquiries into potential investments using the ratings as one criterion.

Energy data must be also available in public advertisements. In fact, EPBD requires that when a building is offered for sale or rent, the energy performance indicator has to be shared in commercial media.

4.1.5 Quality assurance of the EPC

A reliable and trustworthy EPC enhances the confidence of the potential investors to purchase a higher energy performance level building and the building owner to retrofit his/her property into a higher energy level. The quality of EPCs depends on a broad range of aspects, including qualifications of the certifiers, the methodological framework and software tools, the approach to the collection of input data and the penalty systems.

The EPBD recast introduced new requirements to increase the quality assurance of the EPCs, as summarised in the following figure.

[9] Arcipowska A.; Anagnostopoulos F.; Mariottini F.; Kunkel S.; Energy Performance certificates across the EU. A mapping of national approaches, BPIE, 2014

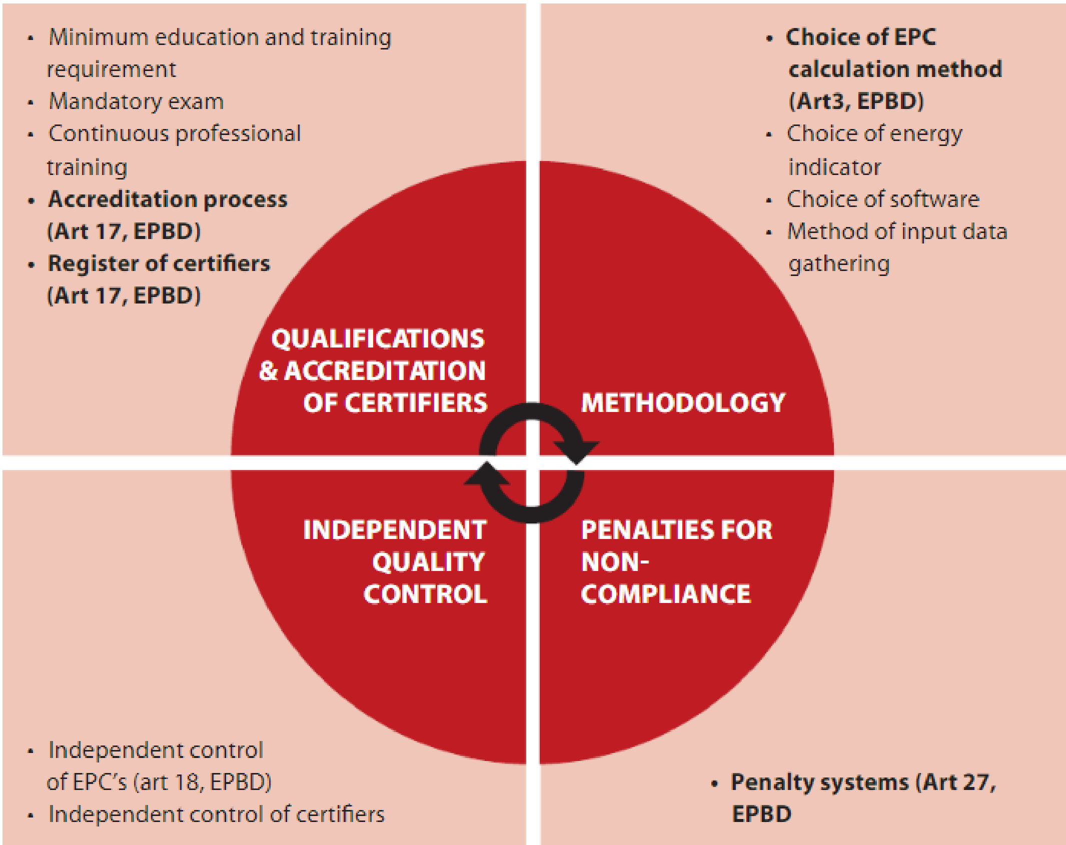

Figure 4-7: Elements of the quality assurance of EPC systems [10]

The competence of the certifier is considered among the most influential factors affecting the quality and cost of the EPCs. Member States have flexibility in designing the system of training and/or accreditation of qualified experts. To guarantee an appropriate level of qualification and to take into account the expert's competence in the accreditation process, there are a variety of requirements applied at the national (or regional) level, such as: minimum requirements regarding a certain level of education and professional experience, a mandatory training programme and mandatory exam, an accreditation procedure and others.

In most Member States, the expert skills are differentiated according to the type of building evaluated; the more complicated the energy audit is (e.g. for non-residential buildings and/or buildings with advanced technical systems), the more expertise is required.

In most countries a technical university degree is required to be a certifier (i.e. mechanical, civil and electrical engineering, architecture) or a training followed by an exam. Therefore, in some countries professional experience might be required. The duration and cost of training vary across Member States, but also at the national level.

In 20 out of 28 Member States, a compulsory exam to check the certifiers' skills is recognised as a best practice. Mandatory training is required in only 14 out of 28 Member States and, in some countries, only when there is a lack of education and professional experience[10].

In an increasing number of countries, relatively new measures were implemented such as programmes for a continuous professional development of the certifiers and obligation for a periodic renewal of the licence.

[10] Arcipowska A.; Anagnostopoulos F.; Mariottini F.; Kunkel S.; Energy Performance certificates across the EU. A mapping of national approaches, BPIE, 2014

Most Member States made publicly available the list of qualified and/or accredited experts and organisations for the assessment of the energy performance of buildings[11].

As concerns the methodological framework, as previously analysed, EPCs can be made choosing between asset rating and operational rating. Some European countries have adopted the methodology exclusively based on asset rating. In other countries, both the methodologies are foreseen, depending mainly on the building type or building age. In others, however, the operational rating applies only for non-residential or other specific type of buildings; in others the operational rating is extended to all the existing buildings while, for new builds, the rating selected is the asset one. The choice of methodology to be presented on the energy performance certificate determines to a large extent the credibility, reproducibility and the cost of the EPC.

Other aspect that contributes to the quality of EPCs is the use of software. In some of the European countries qualified expert can use commercial ones, in others both public software and commercial software and just in few countries there are only public software products. The commercial ones usually have to be approved by the government, unless there is no public software in the country. The choice of the software depends on many factors: purpose, preferences, availability (i.e. price) and quality.

Furthermore, to guarantee the quality of EPCs it is necessary the quality of input data. To obtain sufficient information to calculate energy performance levels (i.e. asset rating methodology), a qualified expert needs to have access to at least the full project documentation and/or conduct an on-site inspection of the buildings, that is mandatory in most of the European countries.

To ensure success and truthful certificates, are provided control systems to verify a random selection of at least a statistically significant percentage of all the energy performance certificates issued annually. In this way, input data, results and recommendations are verified. Control systems are generally conducted in two phases: a simple audit of the input data and the results and a detailed audit that, in addition to the veracity of the input data and results, takes into account the recommendations, the project documentation and includes an on-site visit. Member states can delegate the responsibility for the implementation of a quality control system.

Each Member State lay down the rules on penalties applicable to infringements of the regulation[12].

4.1.6 Weak points of the current rating system for football buildings

In general, although financial institutions today may make use of EPCs as a general marker of a building's condition, EPCs are not usually used:

- To accurately quantify a building's carbon footprint;
- To quantify the impact of a particular measure on a building's carbon footprint or energy consumption;
- To quantify a potential return on investment against certain measures;
- To replace a building audit;
- To make a final investment decision concerning a building renovation or upgrade;
- To manage investment risk concerning a return on investment;
- To ascertain if a particular building renovation plan or set of specific measures will bring a building from one EPC grading to another.

This is often due to a lack of accuracy of the input data and general reliability of the results. Furthermore, the main issues of EPCs have been summarised within the following table.

[11] Olasolo-Alonso, P.; Lòpez-Ochoa, L. M.; Las-Heras-Casas, J.; Lòpez-Gonzalez; L. M.; Energy Performance of Building Directive implementation in Southern European countries: a review, Energy and Buildings, volume 281, February 2023
[12] Arcipowska A.; Anagnostopoulos F.; Mariottini F.; Kunkel S.; Energy Performance certificates across the EU. A mapping of national approaches, BPIE, 2014

Table 4-3: Main issues of EPCs

#	Main issue	Description	Hypothetical solutions
1	**Mandatory use policies**	Absence of mandatory use policies for financial institutions and funds	Institution of mandatory use policies for financial institutions and funds, that would support an increase in awareness among investors and increase in their use
2	**Timeframes**	Lack of set timeframes for improvements or buildings to reach certain rating, to encourage definite refurbishments and increase finance	Creation of consistent and reliable regulatory timeframes to encourage definite refurbishments and increase funding in a substantial manner
3	**Standardisation**	Lack of standardisation across European Union Member States, making comparability of results impossible	Ensuring that quality and reporting standards for EPC ratings are consistent and robust across Member States would improve the image of EPCs in those markets and encourage their uptake
4	**Quality of EPC rating methodologies**	Lack of assurance of qualified personnel performing the EPC audit. Unequal, low or inconstant requirements and thresholds for becoming a licensed EPC issuer/inspector. E.g. self-reporting is allowed in certain Member States, without any visit from an inspector to the property	Training and qualification requirements concerning personnel performing the EPC audit would need to be reviewed and improved in some Member States
5	**Degree of detail**	Lack of details. EPCs are considered overly simplistic for use in financial analysis	In order to form the basis for the quantification of the value of any form of investment, the accuracy in EPCs ratings must improve substantially. This must include a significant increase in reporting granularity and also in measurement and verification

As regards football buildings it is necessary to make further considerations.

For football buildings individual user behaviours and the operational conditions of the building and systems have an important influence on the overall energy performance of the building. While calculating energy performance using standard conditions is a good compromise to calculate the energy performance of buildings such as residences and offices, it does not allow to represent consistently the energy performance of sport facilities such as stadiums and training centres characterized by a large variety of activities, 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. Consequently, the adoption of simplified and a standardised energy uses can be not representative for all the football building types and cannot give an accurate estimate of potential energy savings.

For existing football buildings, as actual energy use is not directly comparable with the calculated energy use with standardized conditions, it is often very difficult to identify what proportion of this discrepancy is due to deviations from standardised operating conditions and what proportion is due to specific issues associated with the virtual energy model. The result is that the virtual energy model cannot be validated compromising the reliability of the outcomes of the calculations.

Additionally, as seen previously, football buildings and specifically stadiums have significant energy consumption linked to the equipment which includes broadcast equipment, scoreboards advertising, consumption of commercial areas (e.g. kitchen, refrigerators etc.); under-soil heating, pumps for the irrigation system and artificial lighting for grass growth and others (e.g. maintaining & cleaning service, etc.); etc. Nowadays, EPCs assessment considers only air conditioning (heating, cooling and ventilation), domestic hot water production and lighting, but not the previous aspects, because in “standardised” buildings such as offices and residential ones, additional consumption from equipment does not impact significantly the whole energy consumption and does not affect the certification.

For a football building, this represents one of the major weak points of the current rating system although EPCs are cheaper and easier to implement than sustainability protocols, such as LEED and BREEAM.

4.2 LEED rating system

Developed by the US Green Building Council, the LEED (Leadership in Energy and Environmental Design) green building rating system is a framework for identifying, implementing and measuring green building and neighbourhood design, construction, operations and maintenance[13].

Figure 4-8: LEED Leadership in Energy and Environmental Design logo

LEED is a voluntary, consensus-based tool which serves as a guideline and assessment mechanism for the design, construction and operation of high-performance green buildings and neighbourhoods.

Based on existing and proven technology, it evaluates environmental performance from a whole building perspective over a building’s or neighbourhood’s life cycle, providing a definitive standard for what constitutes a green building in design, construction and operation. The LEED rating systems is designed for rating new and existing commercial, institutional and residential buildings as well as neighbourhood development.

The LEED rating systems aim to promote a transformation of the construction industry through strategies designed to achieve seven goals, which are the basis for LEED’s prerequisites and credits:

- To reverse contribution to global climate change;
- To enhance individual human health and well-being;
- To protect and restore water resources;
- To protect, enhance, and restore biodiversity and ecosystem services;
- To promote sustainable and regenerative material resources cycles;
- To build a greener economy;

[13] https://www.usgbc.org/leed

- To enhance social equity, environmental justice, community health, and quality of life.

LEED is designed to address environmental challenges while responding to the needs of a competitive market. Certification demonstrates leadership, innovation, environmental stewardship, and social responsibility. LEED gives building owners and operators the tools they need to immediately improve both building performance and the bottom line while providing healthful indoor spaces for a building's occupants.

LEED-certified buildings are designed to deliver the following benefits:

- Lower operating costs and increased asset value;
- Reduced waste sent to landfills;
- Energy and water conservation;
- More healthful and productive environments for occupants;
- Reductions in greenhouse gas emissions;
- Qualification for tax rebates, zoning allowances, and other incentives in many cities.

By participating in LEED, owners, operators, designers, and builders make a meaningful contribution to the green building industry. By documenting and tracking buildings' resource use, they contribute to a growing body of knowledge that will advance research in this rapidly evolving field. This will allow future projects to build on the successes of today's designs and bring innovations to the market.

LEED certification consist of 5 different rating systems. Projects are required to use the rating system that is most appropriate. However, when the decision is not clear, it is the responsibility of the project team to make a reasonable decision in selecting a rating system before registering their project. The project teams should first identify an appropriate rating system, and then determine the best adaptation.

Figure 4-9: LEED Rating systems

The description of the rating systems is summarised in the following table.

Table 4-4: LEED rating system

#	Rating system	Description
1	**LEED BD+C: LEED for Building Design and Construction**	Buildings that are new construction or major renovation. At least 60% of the project's gross floor area must be complete by the time of certification (except for LEED BD+C: Core and Shell). The criterion changes slightly according to the type of intervention: new construction and major renovation; core and shell development; schools; retail; data centres; warehouses and distribution centres; hospitality; healthcare; homes and multifamily low-rise; multifamily midrise. **Sport facilities are not explicitly mentioned.**

2	**LEED ID+C: LEED for Interior Design and Construction**	Interior spaces that are a complete interior fit-out. In addition, at least 60% of the project's gross floor area must be complete by the time of certification. The criterion changes according to the type of intervention: commercial interiors; retail; hospitality. **Sport facilities are not explicitly mentioned.**
3	**LEED O+M: LEED for building Operations and Maintenance**	Buildings that are fully operational and occupied for at least one year. The project may be undergoing improvement work or little to no construction. Must include the entire building's gross floor area in the project. The criterion changes according to the type of intervention: existing building; retail; schools; hospitality; data centres; warehouses and distribution centres. **Sport facilities are not explicitly mentioned.**
4	**LEED ND: LEED for Neighbourhood Development**	New land development projects or redevelopment projects containing residential uses, non-residential uses, or a mix. Projects may be at any stage of the development process, from conceptual planning through construction. It is recommended that at least 50% of total building floor area be new construction or major renovation. Buildings within the project and features in the public realm are evaluated. The criterion changes according to the type of intervention: plan; built project
5	**LEED for Homes**	Residential buildings that are new construction or major renovation. It encourages the design and construction of high-performance green homes, including affordable housing, mass-production homes, custom designs, stand-alone single-family homes, duplexes and townhouses.

Sports facilities do not have their own category but are included generally in "new constructions" or "core and shell" types.

When several rating systems appear to be appropriate for a project, it is necessary to evaluate:

- If a rating system is appropriate for less than 40% of the gross floor area of a LEED project building or space, then that rating system should not be used.
- If a rating system is appropriate for more than 60% of the gross floor area of a LEED project building or space, then that rating system should be used.
- If an appropriate rating system falls between 40% and 60% of the gross floor area, project teams must independently assess their situation and decide which rating system is most applicable.

All LEED rating systems contain four principal types of requirements as summarised below.

Table 4-5: LEED requirements

#	Requirements	Description
1	**Prerequisites**	Required elements, all of which must be met before a project can be considered for LEED certification
2	**Core Credits**	Specific actions a project may take in the categories described above. All Core Credits are voluntary, but each level of LEED certification requires that certain thresholds of credits used must be met
3	**Innovation credits**	Bonus credits given for exemplary performance beyond Core Credit performance levels or implementation of innovative actions that confer significant environmental benefits not covered in the rating system

4	**Regional priority credits**	Bonus credits that acknowledge the importance of local conditions in determining best environmental design, construction, and operations practices

4.2.1 LEED BD+C Rating system structure

For the purposes of GREENFOOT, only LEED BD+C (LEED for Building Design and Construction) rating system is taken into consideration. The following categories are used in the LEED BD+C rating system.

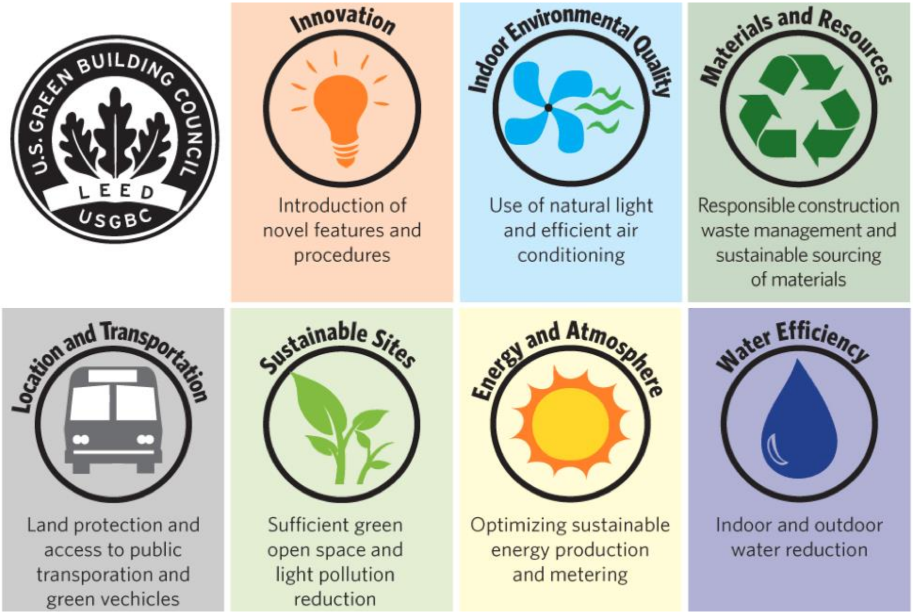

Figure 4-10: LEED BD+C Categories [14]

Table 4-6: LEED BD+C categories

#	Category	Max achievable points	Description / Intent
1	**Integrative Process (IP)**	**1**	Support high-performance, cost-effective project outcomes through an early analysis of the interrelationships among systems.
2	**Location and Transportation (LT)**	**16**	Selection of sites in previously developed high-density areas that are not sensitive and are brownfield or high-priority designations, as well as methods of alternative transportation
3	**Sustainable Sites (SS)**	**10**	Reduce the impact that building sites have on the environment
4	**Water Efficiency (WE)**	**11**	Reduce the use of potable water for purposes other than drinking and reduce overall water usage
5	**Energy and Atmosphere (EA)**	**33**	The Energy and Atmosphere (EA) category is about designing a building that uses as little energy as possible through conservation, efficiency, and the use of alternative renewable energy sources.

[14] https://ronnisch.com/construction-services/leed/

6	**Materials and Resources (MR)**	**13**	This category focuses on minimizing the embodied energy and other impacts associated with the extraction, processing, transport, maintenance, and disposal of building materials.
7	**Indoor Environmental Quality (EQ)**	**16**	The category addresses design strategies and environmental factor such as air quality, lighting quality, acoustic design and control over one's surroundings
8	**Innovation (IN)**	**6**	Achieve significant, measurable environmental performance using a strategy not addressed in the LEED green building rating system.
9	**Regional Priority (RP)**	**4**	Section's aim is to promote strong relationship between the local context achieving specific environmental, social equity, and public health priorities.

The LEED rating system is based on a 100 points scale with 10 bonus points available for innovation in design, exemplary performance, or achievement of credits identified as having regional importance in a project's location. LEED project certification is awarded according to the following scale: 40-49 points LEED Certified; 50–59 points LEED Silver; 60–79 points LEED Gold and 80+ points LEED Platinum.

Figure 4-11: LEED Certification levels

The allocation of points in each category is based on the potential effect of each credit with respect to a set of impact categories (global warming, greenhouse gas emissions, fossil fuel use, toxins and carcinogens, air and water pollutants, and indoor quality). Credits that most directly address the prioritized impacts are given the greatest weight.

4.2.2 Energy performance assessment

For the purposes of obtaining LEED certification two approaches to assess building energy performance are available. The first is the Prescriptive Compliance Path which allows certain projects (small-medium offices, retail, school, and hospital) to achieve up to 6 points when they meet the prescriptive measures of the ASHRAE Advanced Energy Design Guide. The other approach is the Whole Building Energy Simulation, which allows up to 18 points when the building demonstrates improvement on energy cost against a normalised building.

The main credits that interest the energy performance assessment are:

- Minimum Energy Performance (prerequisite)
- Optimize Energy Performance (credit)
- Renewable Energy Production (credit)

LEED rewards with many points those projects which demonstrate a substantial reduction in consumption encouraging the use of dynamic energy modelling. In this regard, the impact of the credits in the Energy and Atmosphere (EA) category, which concerns the energy consumption of the building, is notable.

The mandatory prerequisite "Minimum Energy Performance" requires to reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the building and its systems.

The Whole Building Energy Simulation requires the use of a simulation program that can perform a dynamic thermal analysis to the specifications that are laid down by ASHRAE Standard 90.1-2010 appendix G that is known as Performance Rating Method (PRM). The method specifies that two types of building models are created. The first is the proposed building model and the second is the baseline building model.

Note that the baseline building needs to be set up with orientations of 0, 90, 180 and 270 degrees respectively in order to normalise the self-shading effect.

Following table shows the main requirements for setting up these two building models.

Table 4-7: Summary of guidelines of setting up the proposed and baseline building models

	Proposed building	Baseline building
Weather file	Hourly weather data that best represents the climate at the construction site. The selected weather data shall be approved by the rating authority.	
Geometry	Same as design	Same as design except: - Vertical fenestration: Max. 40% window-to-wall ratio distributed in each facade - Skylight area: max. 5% skylight-to-roof ratio - Orientation: Creating 4 baseline building models by rotating the entire proposed building model to 0, 90, 180 and 270 degrees and then averaging the results
Solar shading	- External shading devices and site obstructions are modelled; - Manuel fenestration shading devices such as blinds or shades shall not be modelled, but automatically controlled shades and blinds may be modelled	No consideration for any shading devices and site obstructions.
Zoning requirements	Both proposed and baseline building models need to follow certain thermal zoning rules depending on whether HVAC zones are designed or not.	
Material & Construction	Same as design	External constructions need to conform to specified U-values based on the building type, space type, fenestration area and climate zone
Room data	Lighting power is determined based on whether the lighting system exists, designed or specified	Lighting power shall be determined using the same categorization procedure and categories as the proposed design
	- Miscellaneous equipment and occupancy gains shall be estimated based on the building type or space type and are identical in proposed and baseline building designs. - Schedules of occupancy, lighting power, equipment power and HVAC operation system are the same as design for both the proposed and baseline models. - Temperature and humidity control set-points shall be the same for proposed and baseline building models.	
HVAC system	HVAC system is determined based on whether the system exists, designed or specified.	HVAC system has to use a specified system type mainly based on building type, fuel type, floor area and building height.

Hot water system	- Same as the actual/design system when the water service system exists/is specified - Matching the system used in the baseline model when the system hasn't been specified	- Same as the actual system when the water service system exists - It shall match the min. efficiency requirements when the system is specified - It shall use electrical-resistance system and match min. efficiency requirements when the system has not been specified.
Infiltration & Ventilation	Infiltration rate is the same as design and minimum outdoor air ventilation rates are the same for the proposed and baseline building designs.	
Renewable	Modelled	Not modelled

The energy rating is then calculated based on the annual energy cost of running the proposed building against the average annual cost of running the baseline building by using actual rates for purchased energy or State average energy prices, as displayed in the following table.

Table 4-8: Points for percentage improvement in energy performance

New Construction	Major Renovation	Core and Shell	Points	Points (Healthcare)	Points (Schools)
6%	4%	3%	1	3	1
8%	6%	5%	2	4	2
10%	8%	7%	3	5	3
12%	10%	9%	4	6	4
14%	12%	11%	5	7	5
16%	14%	13%	6	8	6
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
32%	30%	29%	13	15	13
35%	33%	32%	14	16	14
38%	36%	35%	15	17	15
42%	40%	39%	16	18	16
46%	44%	43%	17	19	-
50%	48%	47%	18	20	-

4.2.3 LEED Certified stadiums in the United States and Europe

There are at least 30 LEED-certified sports venues up and running or in the works[15]. Below some of the most famous stadiums in the United States:

Figure 4-12: Stadiums which received a LEED certification in the USA
(5 of them have been awarded Platinum, 14 Gold, 10 Silver, 5 Certified) [16]

The first professional sports building to receive a LEED platinum certification in the world was, in 2017, Mercedes-Benz Stadium in Atlanta, United States. The goal to obtain the highest certificate was achieved by spending almost 1.6 billion dollars. Sustainability measures range from LED lighting, which saves up to 60%, to the installation of 4,000 photovoltaic solar panels, which reduced energy consumption by 29% compared to a traditional stadium. As regards water consumption, it was possible to achieve a saving of 47% of water compared to the reference standards. In addition, the stadium has a rainwater management system with a large storage capacity. Sustainable mobility has been strongly encouraged. The stadium offers bicycles on event days and numerous charging stations for electric vehicles[17].

In Europe, in 2015 San Mamés stadium (where the Athletic de Bilbao football club plays) was the first sport building to receive a LEED certification. Some of the most important features of the building and that were taken into account for the LEED Certification are the integration of the stadium in the urban fabric, the promotion of the use of public transport and a lower water consumption that allows to achieve a saving of 47% of drinking water compared to a reference building with standard equipment.

In general, in Europe the percentage of LEED certified stadiums and sports buildings is decidedly low, considering that many buildings were built several years ago and should therefore be redeveloped. At the moment, in fact, not only they do not meet the LEED certification criteria, but they also represent great energy guzzlers.

[15] https://www.sportsbusinessjournal.com/Journal/Issues/2022/04/04/In-Depth/LEED-certification.aspx
[16] https://www.rts.com/resources/guides/leed-certified-stadiums-list/
[17] https://www.mercedesbenzstadium.com/

4.3 BREEAM rating system

BREEAM stands for "Building Research Establishment Environmental Assessment Method" and is the most widely used building environmental rating scheme in the U.K. The method was founded in 1990 in the United Kingdom by the Building Research Establishment (BRE). It sets the standard for best practice in sustainable design and has become a measure used to describe a building's environmental performance. It is used voluntarily in more than 70 countries, with several in Europe having gone a stage further to develop country specific BREEAM scheme, for example: The Netherlands (BREEAM NL), Spain (BREEAM ES), Norway (BREEAM NOR), Sweden (BREEAM SE) and Germany (BREEAM DE).

Figure 4-13: BREEAM logo [18]

The aims of BREEAM are:

- to mitigate the life cycle impacts of buildings on the environment;
- to enable buildings to be recognised according to their environmental benefits;
- to provide a credible, environmental label for buildings;
- to stimulate demand and create value for sustainable buildings, building products and supply chains.

The rating system offers 6 different certification schemes as described in the following table. Each standard uses a common framework that adapts to the location of the asset and supports international consistency and comparability.

Table 4-9: BREEAM rating systems

#	Rating system	Description
1	**BREEAM New Construction**	For new-build buildings. It provides a framework to deliver high performing and sustainable newly built assets, that support commercial success whilst also creating positive environmental and social impact.
2	**BREEAM In-Use**	For existing non-domestic buildings in-use. Can be used to assess and benchmark the operational sustainability of all operational asset types.
3	**BREEAM Refurbishment & Fit-Out**	For domestic (UK only) and non-domestic building fit-outs and refurbishments. Can be used to assess refurbishment of the external envelope, structure, core services, local services, and interior design of existing.

[18] https://bregroup.com/products/breeam/

4	**BREEAM Communities**	For developments at the neighbourhood scale or larger. It provides a framework to support planners, local authorities, developers and investors to integrate and assess sustainable design in the master planning of new communities and regeneration projects.
5	**BREEAM Infrastructure**	For new infrastructure projects. It is the world's first sustainability rating scheme to improve design, construction and maintenance of infrastructure assets.
6	**BREEAM Home Quality Mark**	For new-build domestic buildings (UK only). It is a trusted standard for new homes in the UK.

4.3.1 BREEAM Rating system structure

For the purposes of GREENFOOT, BREEAM New Construction and BREEAM Refurbishment & Fit-Out are taken into consideration. These protocols encourage all energy efficient building solutions, to reduce energy inefficiency, carbon emissions and support active management throughout the operational phase of the building's life.
The following 10 categories are used in both BREEAM rating systems.

Figure 4-14: LEED BD+C Categories

Table 4-10 BREEAM New Construction and BREEAM Refurbishment & Fit-Out categories

#	Section	Description/Intent
1	**Management**	This category encourages the adoption of sustainable management practices in connection with design, construction, commissioning, handover and aftercare activities to ensure that robust sustainability objectives are set and followed through into the operation of the building. Issues in this section focus on embedding sustainability actions through the key stages of design, procurement and initial occupation from the initial project brief stage to the appropriate provision of aftercare.

2	**Health and wellbeing**	This category encourages the increased comfort, health and safety of building occupants, visitors and others within the vicinity. Issues in this section aim to enhance the quality of life in buildings by recognising those that encourage a healthy and safe internal and external environment for occupants.
3	**Energy**	This category encourages the specification and design of energy efficient building solutions, systems and equipment that support the sustainable use of energy in the building and sustainable management in the building's operation. Issues in this section assess measures to improve the inherent energy efficiency of the building, encourage the reduction of carbon emissions and support efficient management throughout the operational phase of the building's life.
4	**Transport**	This category encourages better access to sustainable means of transport for building users. Issues in this section focus on the accessibility of public transport and other alternative transport solutions (cyclist facilities, provision of amenities local to a building) that support reductions in car journeys and, therefore, congestion and CO_2 emissions over the life of the building.
5	**Water**	This category encourages sustainable water use in the operation of the building and its site. Issues in this section focus on identifying means of reducing potable water consumption (internal and external) over the lifetime of the building and minimising losses through leakage.
6	**Materials**	This category encourages steps taken to reduce the impact of construction materials through design, refurbishment, maintenance and repair. Issues in this section focus on the procurement of materials that are sourced in a responsible way and have a low embodied impact over their life including extraction, processing and manufacture and recycling.
7	**Waste**	This category encourages the sustainable management (and reuse where feasible) of construction and operational waste and waste through future maintenance and repairs associated with the building structure. By encouraging good design and construction practices, issues in this section aim to reduce the waste arising from the construction and operation of the building, encouraging its diversion from landfill. It includes recognition of measures to reduce future waste as a result of the need to alter the building in the light of future changes to climate.
8	**Land use and ecology**	This category encourages sustainable land use, habitat protection and creation, and improvement of long-term biodiversity for the building's site and surrounding land. Issues in this section relate to the reuse of brownfield sites or those of low ecological value, mitigation and enhancement of ecology and long-term biodiversity management.
9	**Pollution**	This category addresses the prevention and control of pollution and surface water run-off associated with the building's location and use. Issues in this section aim to reduce the building's impact on surrounding communities and environments arising from light pollution, noise, flooding and emissions to air, land and water.
10	**Innovation**	The innovation category provides opportunities for exemplary performance and innovation to be recognised that are not included within or go beyond the requirements of the credit criteria. This includes exemplary performance credits, for where the building meets the exemplary performance levels of a particular issue. It also includes innovative products and processes for which an innovation credit can be claimed, where they have been approved by BRE Global. The cost-saving benefits of innovation are fostered and facilitated by helping encourage, drive and publicise accelerated uptake of innovative measures.

Independent licensed assessors carry out an assessment of a scheme and each of the criteria is scored and then multiplied by a weighting. For new constructions, two assessment stages are carried out: a design stage assessment which results in an initial certificate, and a post-construction assessment resulting in a final certificate being issued and a rating awarded.

There are currently six different BREEAM certification levels as shown in the following table.

Table 4-11 BREEAM certification levels

BREEAM rating		% score
Outstanding	★★★★★	≥85
Excellent	☆★★★★	≥70
Very good	☆☆★★★	≥55
Good	☆☆☆★★	≥45
Pass	☆☆☆☆★	≥30
Unclassified	☆☆☆☆☆	<30

An unclassified BREEAM rating represents performance that is non-compliant with BREEAM, in terms of failing to meet either the BREEAM minimum standards of performance for key environmental issues or the overall threshold score required to achieve at least a Pass rating.

The BREEAM rating benchmarks enable a client and all other stakeholders to compare the performance of a building with other BREEAM rated buildings of the same type, and the typical sustainability performance of a stock of buildings.

In this respect each BREEAM rating broadly represents performance equivalent to:

1. Outstanding: Less than the top 1% of buildings (innovator)
2. Excellent: Top 10% of buildings (best practice)
3. Very Good: Top 25% of buildings (advanced good practice)
4. Good: Top 50% of buildings (intermediate good practice)
5. Pass: Top 75% of buildings (standard good practice)

4.3.2 Energy Performance Assessment

The energy assessment in BREEAM is referred to as Credit Ene 1 “Reduction of CO_2 emissions”. It allows up to 15 credits to be achieved when the assessed building demonstrates an improvement in the energy efficiency of the building fabric and building services. The energy performance of the building is shown as a CO_2 based index.

The number of credits achieved is determined by comparing the building’s CO_2 index taken from the Energy Performance Certificate (EPC). The EPC is generated based on the U.K. National Calculation Methodology (NCM). It provides an energy rating for the building ranging from A to G where A is very efficient and G is the least efficient. To be able to set up the asset rating, two building models need to be created, using any of the approved simulation tools, which are the actual building and the reference building (known as the ‘Notional building’). The asset rating is then calculated as the ratio of the CO_2 emissions from the actual building to the Standard Emission Rate which is determined by applying a fixed improvement factor to the CO_2 emissions from the reference building. The following table shows the main requirements for setting up these two building models.

Table 4-12: Summary of guidelines of setting up the actual and reference building models

	Actual building	Reference building
Weather file	CIBSE Test Reference Year weather data covering 14 locations in the U.K. are used for compliance simulations. The chosen weather data shall be taken as the one from the 14 locations, which is closest in distance to the building site and used for both actual and reference building models.	
Geometry	Same as design	Same as design except areas of windows, doors and roof lights that must conform to rules set out in the NCM modelling guide
Solar shading	- External shading including site obstructions and shading devices are to be modelled - Internal shading is to be modelled.	It must be subject to the same site shading from adjacent buildings and other topographical features as are applied to the actual building model.
Zoning requirements	Both the actual and reference buildings follow the same ruling arrangement that is defined based on HVAC and lighting.	
Material & Construction	Same as design	- Construction U-values must conform to these U-values that are identified in the NCM modelling guide. - Special considerations apply to ground floors where the U-value is a function of the perimeter/area ratio
	U-values of display windows must be taken as 5.7 W/m2K in both the actual and reference building models. -Smoke vents and other ventilation openings must be disregarded in both building models.	
Room data	- Lighting power density is allowed to use proposed design figures if known.	- Lighting power density is a fixed value dependent on the assigned room activity.
	- Each space must contain the same activity and therefore the same activity parameter values in both the actual and reference buildings. These activity parameters include occupancy times, density, sensible and latent gains, equipment gains and schedule profile, lighting lux level and schedule, heating set-point temperature, HVAC operation profile, hot water demand and outside air requirement. - The activity in each space must be selected from the NCM Activity Database	
HVAC system	System efficiency, fuel type and auxiliary energy figures are the same as design.	- Heating fuel type must be gas. - Heating SCoP must be 0.73 and auxiliary energy must be taken as 0.61 W/m^2 - Cooling set point is fixed at 27 °C and the cooling SSEER must be taken as 2.25
Hot water system	- Hot water demand is defined by the selected room activity. - System efficiency and fuel type must be taken from the proposed design.	- Hot water demand is specified by the same room activity shared with the actual building. - System overall efficiency must be taken as 45% and it must be a gas-fired system.
Infiltration & Ventilation	- The calculation method used to predict the infiltration rate must use the air permeability. The air permeability of the actual building is modelled as design and the air permeability of the reference building must be 15 $m^3/(h{\cdot}m^2)$ at 50 Pa. - Ventilation rates and profiles are defined by the selected room activity based on the NCM Activity database.	

Renewable	Yes	No

4.3.3 BREEAM Certified stadiums in the United States and Europe

There are 30 BREEAM-certified stadiums, 19 of which located in U.K [19]. One of the first professional sports building to receive a BREEAM certification with Very Good Level was, in 2013, the Salford City Reds Community Stadium in Barton, U.K. The Salford Community Stadium provides an arena for sports, events and conferences for businesses and communities throughout the North West.

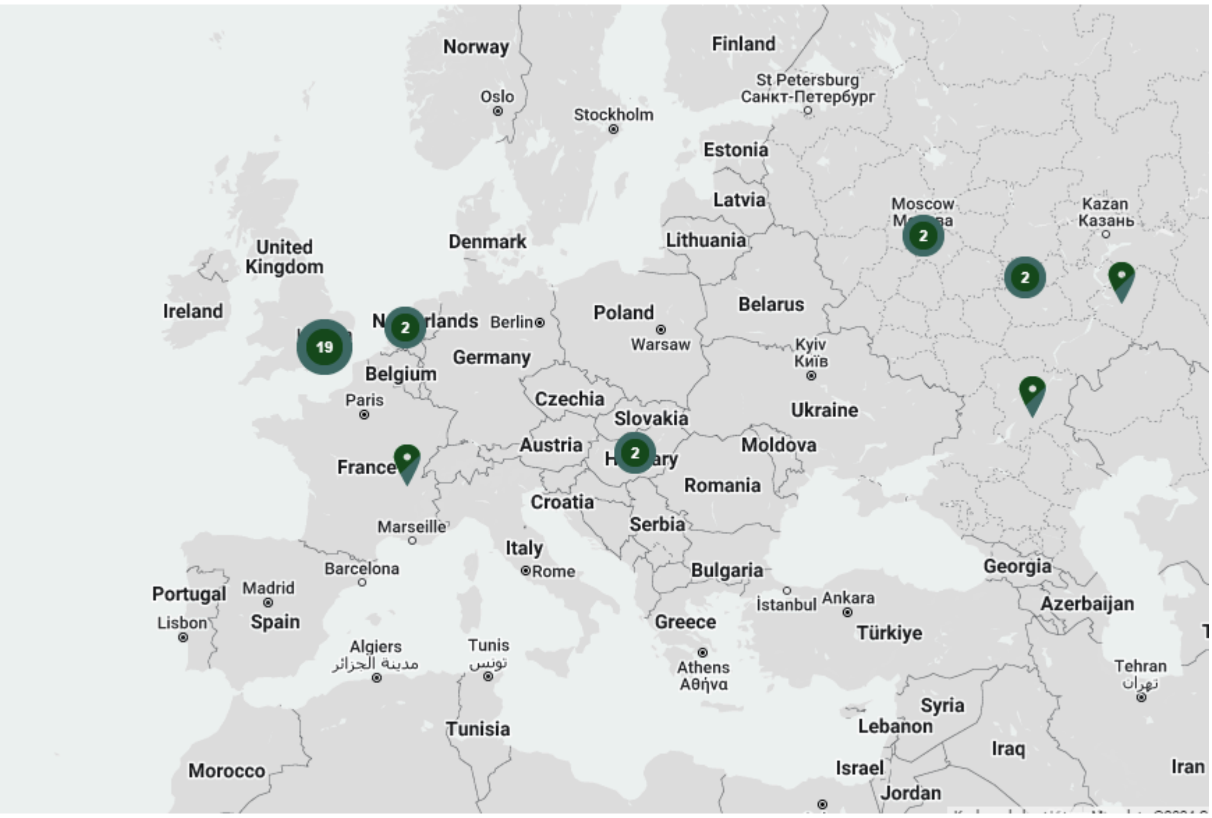

Figure 4-15: Stadiums which received a BREEAM certification in Europe [19]

Due to the recent 2018 FIFA World Cup, also in Russia 6 new stadiums were certified with the BREEAM protocol. Certifying stadiums in accordance with sustainable standards was an important aim for the tournament organisers: building sporting arenas in line with 'green standards' not only reduces their impact on the environment but also largely determines usage in the future, including a decrease in the use of water and energy.

Generally, as for the LEED certification scheme, the percentage of BREEAM certified stadiums and sports buildings is decidedly low.

4.4 Weak points of LEED and BREEAM rating system

LEED and BREEAM rating system are the most used and recognised certification schemes. Although they manage to provide a detailed picture regarding the sustainability of buildings, they present some critical aspects that limit their large-scale adoption.

[19] https://tools.breeam.com/projects/explore/index.jsp

The main limit is represented by the prohibitive costs which on a practical level make this type of certification used only by large clubs for large investments such as the construction or redevelopment of large stadiums. The high costs include the fees for the certification (which depend on a number of factors, including chosen rating system, type of project, size of the building, etc.), professional costs for specialised certifies and technicians and increased capital costs for constructions. Realistically, small sports facilities, which are very numerous throughout Europe and in many cases are those most in need of renovation to improve their energy performance and reduce consumption, and which could therefore benefit greatly from certification, cannot afford the registration fees and fares and therefore often forgo this type of certification.

Additionally, the level of detail required by both schemes could result in a design complexity with the need for experts and longer design times. Since up-to-date sports facilities do not have their own category but are included generally in "new constructions" generic types, the requirements of specific credits could be too strict and not easily usable in all situations.

For major renovations, there may be also difficulties in finding the data useful for compiling the assessments, resulting in a significant waste of time and costs higher than those normally required for standard building design.

5 Proposed guidelines for the certification of sport facilities

As already mentioned, previous considerations in EPC have observed a lack of data quality for energy performance evaluation and currently there is no adequate energy certification system capable of considering all the peculiarities of sport facilities. More specifically, the calculated energy use in EPC does not reflect actual energy consumption. Energy Performance Certificates (EPCs), regulated by the 2010/31/EC Energy Performance of Buildings Directive (EPBD), can be easily drawn up, but they are more appropriate for certifying 'standard' buildings such as residences and offices rather than buildings with a more complex functioning and relevant consumption beyond those related to HVAC systems and lighting (those are the only consumption included in EPCs) such as stadium and sports facilities. On the other hand, sustainability certification schemes such as LEED and BREEAM protocols, which assess all the sustainability aspects (land use, water management, transport, materials etc.) are very expensive.

The key aim of this report is to provide guidelines and recommendations to implement a certification scheme for football buildings, which meets the criteria of accuracy, speed, and economy, to strengthen and improve the quality and use of certificates, introducing new and cost-effective methods and harmonizing new methods. The intent of these guidelines is to transcend current barriers and overcome:

- the gap between standard outcomes of EPC schemes and real consumption patterns;
- the lack of accuracy of the building's energy assessment results;
- the lack of convergence across the European Union;
- the inclusion of smart and novel technologies;
- the lack of important attributes such as equipment consumptions, indoor air quality and thermal comfort.

A holistic framework is needed to strengthen and improve the quality and use of certificates, introducing new and cost-effective methods and harmonizing systems. The improvement in terms of reliability refers to the variance in results depending on the assessor's input data, calculation tools, and differences between predicted and actual energy performance, and it represents a crucial issue to unlock the generalized confidence in EPCs.

The following paragraphs provide specific suggestions for the improvement of EPCs for sport facilities. The following basic methodologies have been analysed:

- energy assessment carried out with dynamic energy modelling;
- integration with BIM models;

- use of data monitoring and BMS;
- integration with Digital Twin models;
- inclusion of Smart Readiness Indicators (SRI).

Essentially, all this would allow to have a certification that is no longer permanent, but short-lived, i.e., referring to data relating to energy consumption collected in a specific period or event. In this way it would be made visible how the outcome of the certification changes depending on the moment to which the data collected refers: a certification obtained during a match or training could be compared with one whose energy consumption was detected during the absence of people inside the building.

Additionally, it is essential that the new certifications and the related energy consumption are used to present results to the owner, but also to the public and those who have participated in the funding. This could be possible thanks to graphical interfaces / dashboards that show the data collected by the sensors through intuitive graphics: they should be a convenient, reliable, and cost-effective and informative tool for the public (building occupants, owners) and professionals (designers, engineers, building managers). The Facility Managers could manage them, but they could be viewable by everyone, to disseminate the results obtained.

5.1 Energy assessment through dynamic energy modelling

An energy model is the perfect route to predicting building performance. The calculation method with a steady-state or quasi steady-state approach adopts a number of simplified hypotheses (ventilation rates, external thermal loads, etc.) that are often remarkably precautionary compared to the real conditions and denotes calculations of heat balance over a sufficiently long time (typically a month or a whole year), ignoring the stored and released heat. Dynamic effects are considered only by using some empirically determined gains and loss utilization factors.

Football buildings are characterized by a large variety of activities, 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. For these reasons, individual user behaviours and the operational conditions of the building and systems have a great influence on the overall energy performance of the building.

The adoption of simplified and standardised energy uses can not be representative for all the football building types and cannot give an accurate estimate of potential energy savings of energy retrofitting interventions. For this reason, the **first suggestion** for the development of reliable EPCs for football buildings is to **adopt dynamic energy simulation models**, capable of simulating the actual pattern of consumption, determine the needs and performance of the building and its system on an hourly or sub–hourly basis.

Specifically, dynamic building energy simulation is a way of calculating the energy performance of buildings based on detailed simulation models, which are able to reproduce the behaviour of the real building, in every hour of any day of the year. Furthermore, the dynamic simulations are based on tools capable of providing customized models as desired by the certifier, who, therefore, can build ad hoc occupancy plans capable of taking into consideration the peculiarities of football buildings. In recent years, the spread of dynamic energy modelling is experiencing growth exponential, also driven by dissemination of voluntary environmental certifications such as LEED and by the European Community Directives recent developments, which are increasingly guiding European states in this direction.

In fact, Directive 2010/31/EU recommends obtaining reliable results from energy models, to carry out calculations using a dynamic method, which has already been foreseen for years among the methods illustrated by European technical standards such as EN 13790 and 15603.

There are several simulation tools in the current market, which offer different levels of accuracy and compatibility with other type of software, such as 3D visualisation tools or BIM authoring tools. Those tools are based on multivariable calculation methods that conduct detailed building simulations under actual operational conditions (operational rating methods) taking into account users' preferences of internal comfort conditions as well as real weather data.

The dynamic energy model assessment should include:

- Assessing energy consumption and providing a breakdown of key drivers;
- Analysing peak building loads and condensation;
- Assessing passive design strategies including solar shading, thermal mass and natural ventilation;
- Determining the impact of overheating and the knock-on effect to occupant thermal comfort;
- Whole building ventilation strategies including natural, mechanical and hybrid solutions;
- Simulating the impact of time schedules as each building has its own particular needs, whether this be a daily or seasonal variation, it is crucial to include the impacts of when occupants, lights and equipment operate within the building;
- Building control strategies using formula-based controls responding to parameters active throughout the simulation;
- Renewable energy potential to offset building energy demands.

The goal is to obtain a model of simulation of the energy behaviour of the building as close to real behaviour as possible, to evaluate the energy performances, the alternative design solutions or to plan retrofit interventions on existing buildings.

The outputs obtainable from a dynamic simulation software are usually a valuable source of data on the behaviour of the building, both from a quantitative and numerical point of view and in terms of future trends. In fact, the results allow to control how the energy needs of a building vary from day to day, or even hour to hour, depending on the change in external temperature, the presence or absence of occupants, etc.

Concerning the energy renovation of football buildings, using dynamic model simulations has the potential of lowering the performance gap between the promised and real savings when compared to steady tabulated approaches.

5.2 Integration with Building Information Models (BIM)

Energy analysis is a complex and expensive process which in traditional design is usually postponed to the final phase of a project. At present, data acquisition and data processing for producing EPCs can be different depending on the adopted tools.

Generally, although the EPC calculation relies heavily on default values, the energy assessor has to collect sufficient building information (surfaces, volumes, product and system data, etc.) and enter them into the software tool. This can be very time consuming. Naturally the situation is more complex when it comes to existing buildings, which moreover make up the majority of the football building stock.

In order to increase the accuracy of the energy performance assessment of sport facilities, in particular for complex cases such as stadiums or medium-large training centres, it would be good to include in the assessment the information, coming from a Building Information Modelling (BIM) of the building, if already available.

The adoption of a BIM-to-BEM approach would allow to optimise assessments regarding the energy performance of a building, manage the entire energy simulation process and have overall control over energy consumption during operation and maintenance.

Building Information Modelling (BIM) refers to a highly collaborative real-time process for the generation and intelligent management of a building's data that is gathered during its entire life cycle. It consists in a holistic process of creating and managing information for a built asset.

Based on an intelligent model and enabled by a cloud platform (real time collaborating), BIM integrates structured, multi-disciplinary data (geometry, materials' thermal features of the building envelopes, etc.) to produce a digital representation of an asset across its lifecycle.

The BIM methodology allows the various supply chain operators of the different sectors (architecture, structures, mechanical, electrical and hydraulic systems etc.) to collaborate in a new multidisciplinary dimension during the different phases of the life cycle of the structure to extract, insert or develop process information with rapid results and immediate feedback. This is also favoured by standards such as open BIM which promotes interoperability between different actors equipped with different modelling software. The use of BIM is becoming more and more common in all building life stages:

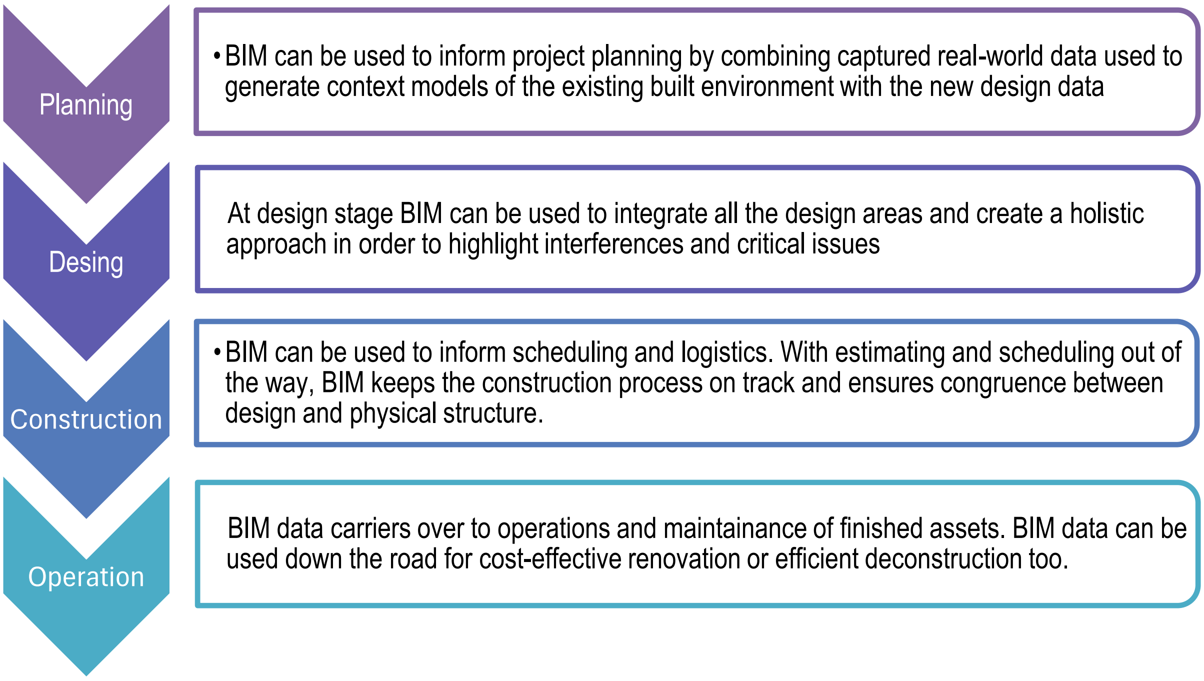

Figure 5-1: BIM benefits for different stages throughout the construction process

Furthermore, current research is analysing new ideas and new procedures to make the process of developing and completing a BIM model increasingly rapid and automatic. For example, for existing buildings, the development process of a BIM model can potentially start from the point cloud scanned with special laser scanners and automatically arrive at a model in which the various objects that compose it contain information within them and preserve the meaning of what they represent.

Although the construction sector is increasingly adopting BIM technologies, with or without incentives from public authorities, most EU countries do not yet use BIM or other digital documents to issue EPCs, as it is not mandatory. An exception is given by Belgium and the Netherlands, which are planning to develop methodologies for BIM use for EPCs calculations in the coming years.

The interoperability between the BIM model and the energy modelling software is essential for the success of the operation ensuring a correct exchange of data. Geometric data and different architectural, mechanical, energetic and acoustic components of the building can be imported more or less immediately into energy simulation software.

Additionally, the models can be populated with precise information about scheduled building use and occupancy. The subsequent processing should be able to generate a real energy model on which all the necessary checks can be carried out to evaluate in detail the performance achieved by the model in terms of primary energy and estimate the different energy performances of the building.

An interesting impact on the calculation procedure is represented by the thermal bridges: with a detailed description of the building envelope through BIM, it becomes possible to have a 3D transmission analysis of the building shell, meaning that there is no need any more to have a dedicated analysis of thermal bridges.

In conclusion, it is clear how the **adoption of the digital methodology represented by Building Information Modelling** can be extremely helpful for those designers and certifiers who work on large and medium-sized works, but who want to achieve high performance levels, optimizing the choices made in the design phase and avoiding possible errors and excessive variations during the construction phase of the work and achieving the expected energy performance rating.

5.3 Use of data monitoring

Energy data monitoring is a process of collecting, recording and analysing data relating to the different energy consumption in a given building. This process can concern and be applied to a single system and building's zone or to the entire HVAC and building.

Given the general uncertainty of EPCs for football buildings, where often the theoretical consumption declared in the certificates does not reflect the actual consumption of the buildings, a further suggestion to improve the accuracy of EPCs is to **determine the actual energy performance** of a building and its potential savings due to energy renovations **by including data coming from a direct monitoring in the energy assessment**.

To improve the accuracy of the energy assessment, it is important to conduct long-term monitoring with an adequate toolkit of sensors and meters according to the existing building typology. There is a large number of energy meters and data collection techniques available on the market for monitoring electricity and other utilities. At present, most of the European countries should have implemented smart meters for gas and electricity at building level or are in the process of rolling them out. There have been several policies in Europe aiming at smart metering roll-outs. The first-of-his-kind legislative provisions dealing with smart meters were part of the so-called "Third Energy Package", in force for all countries in Europe, which was approved by the Council and the European Parliament in 2009 (Annex I.2 to the Electricity Directive (2009/72/EC)). These provisions had to make sure that by the year 2020, a minimum of 80% of the consumers would have been served by smart meters.[20]

The goal of the monitoring campaigns is to focus on the collection of real operational data with minimal impact on the existing building services and taking advantage of the utility meters already in use. The collected data should then be used to calibrate and validate the calculation methods used for the development of EPCs, improving their credibility and minimizing the energy performance gap between the theoretical (calculated) and the actual energy consumption.

Different levels of building energy monitoring can normally be considered, based in the specific monitoring goals. The minimum requirement involves the data needed for balance verification, including those needed for climate adjustment. Depending on the monitoring duration, three main categories of measurements can be defined to evaluate the time resolution:

- Spot measurement (one day) to instantaneously detect the value of a metric or to quickly check the functioning of a subsystem;

[20] Vitiello, S.; Andreadou, N.; Ardelean, M.; Fulli, G.; Smart Metering Roll-Out in Europe: Where Do We Stand? Cost Benefit Analyses in the Clean Energy Package and Research Trends in the Green Deal; Energies, 2022

- Short-time measurement (usually week or month-based) to check the profile of metrics that vary with time;
- Long-time measurement (more than one year) to assess metrics that are influenced by variations in weather, occupants' behaviour, or other operating conditions.

In general, the selected time resolution can be associated with the three main following categories:

- Measurement of energy consumption using building meters, sub-metering, and plug load measurements;
- Measurement of occupants' comfort and activity, using temperature, occupancy, humidity, CO_2, and air quality;
- Measurement of the main parameter for the local climate characterization.

The more accurate the data, the more accurate the predictions on the energy performance of the interventions and the related economic evaluations will be. For the development of adequate EPCs, the monitoring approach selected should falls into the long-time measurement typology (for collecting data during the heating and cooling season) and include the measurement of the energy needs and the indoor/outdoor temperature levels.

To guarantee a constant level of accuracy, it is essential to facilitate monitoring data integration into the energy assessment and allow a continuous energy monitoring. A practical solution is to include monitoring data coming from a Building Management System (BMS) and/or a Digital Twin (DT).

5.3.1 Building Management Systems (BMS)

A Building Management System (BMS) is an overarching control system able to monitor the energy performance of a building as well as manage, control and supervise the different building services and establish smooth interaction between various building components and units.

Collecting data for the development of accurate EPCs means being able not only to understand energy consumptions but also to get knowledge of other consistent parameters as occupancy levels and patterns, types of users' activity, types of systems and equipment present and types of spaces encompassed in the building.

To achieve this level of detail, one of the solutions that can lead to enhance the EPC accuracy for football buildings is the use of data coming for a **Building Management System** (BMS). Additionally, a BMS allows to collect information and energy data on operational performance before and after the interventions and control data during operation and maintenance, providing to be a very useful tool available to facilities managers and building owners.

Going into some details, a Building Management System (BMS) is an intricate network made of 3 distinct parts: hardware, software and user interface components, each playing a vital role in the overall functionality and effectiveness of the system.

The **hardware** part consists of:

- sensors and actuators: these are the fundamental hardware components of a BMS. Sensors collect data on various environmental parameters such as temperature, humidity, light levels, motion, smoke presence, and more. Actuators, on the other hand, are devices that take action based on the sensor inputs, such as adjusting the heating, ventilation, air conditioning (HVAC) systems, lighting, or triggering alarms.
- controllers: these are the brains of the BMS hardware. Controllers receive data from sensors and send commands to actuators. They are programmed to make decisions based on the sensor data, following predefined criteria to maintain the desired environmental conditions.
- networking hardware: this includes routers, switches, and other networking devices that enable communication between sensors, controllers, actuators, and the central BMS server. These components ensure that data flows seamlessly across the system.

The **software** part is responsible for processing the data collected by sensors. It analyses these data to identify trends, detect anomalies, and make decisions. Advanced BMS software uses algorithms and machine learning techniques for more sophisticated data analysis.

The **user interface** part is typically a dashboard accessible via computer or mobile devices. These dashboards present real-time data, alerts, and system statuses in a user-friendly format. They allow operators to monitor the entire building's systems at a glance and make adjustments as needed. Modern BMS interfaces are designed for ease of use, offering customisable views to suit different user preferences and roles. They often feature intuitive controls for adjusting system settings, scheduling tasks, and accessing reports.

A BMS allows for totally integrated plants supervision and remote management of all the systems and units connected to the system, from the air conditioning system to the broadcasting equipment. This means that all services and equipment included in a football building, with all the data relating operability and consumption, may be supervised through the use of a single platform.

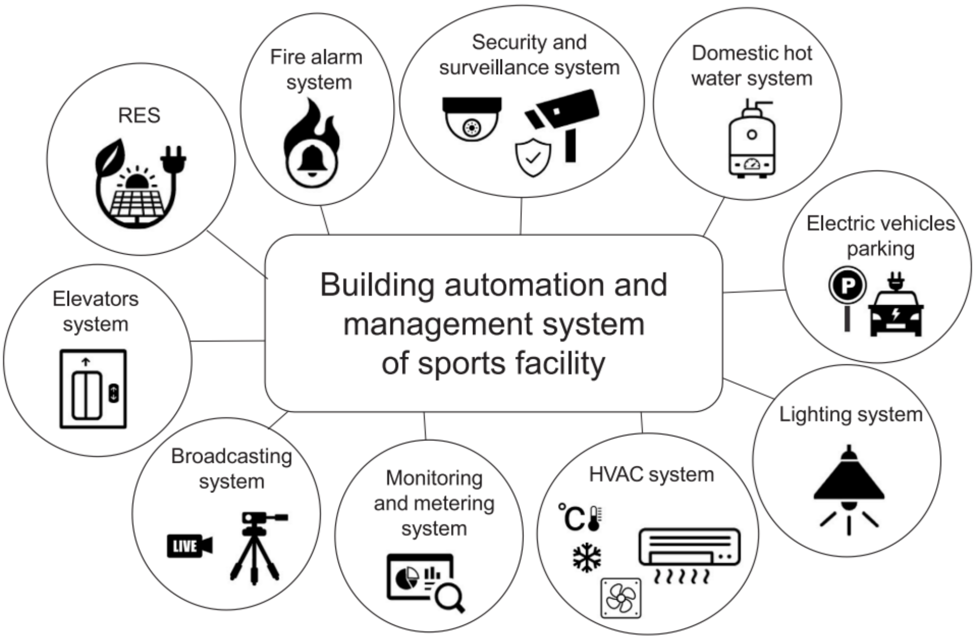

Figure 5-2: Overview of a typical BMS of sport facilities [21]

The availability of a BMS allows to guarantee a continuous monitoring, a constant level of accuracy for the monitoring data and will facilitate the integration of data in the energy assessment.

5.3.2 Integration with Digital Twin models

Digitalization has played a major role in the building sector in the last few decades. Something similar to BIM, but more advanced, is depicted by the concept of Digital Twin (DT). They both represent the digital version of physical objects but differing in purpose: BIM models are mainly used for planning and design, while digital twins are used also at a later stage for monitoring and management, therefore after the building's construction.

[21] Renewable and Sustainable Energy Reviews, Volume 162, July 2022, 112401

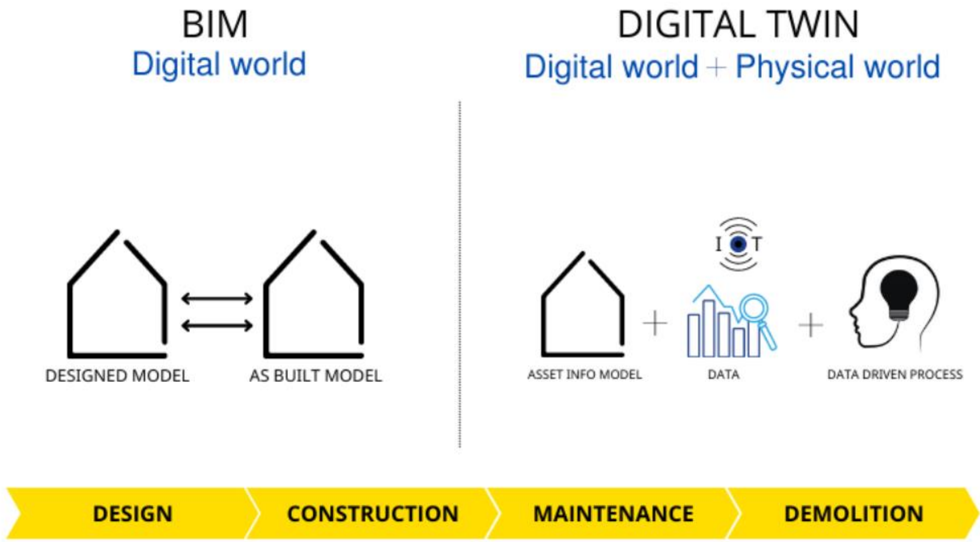

Figure 5-3: Digital Twin as a union of the BIM model and smart building [22]

A Digital Twin should reflect a physical asset in the most thorough way possible, encompassing all available technical, operational, and organisational information at all phases. The interaction between physical and digital worlds must be automatic and bidirectional. In this way, the data obtained from the physical asset is sent to the Digital Twin, and the physical product reacts to information received from the digital one.

A Digital Twin is used to model, simulate, predict, and optimise the behaviour and design of various components and systems representing in real time. It is characterised by the incorporation of real-time (or near real-time) measurements to reflect the building asset's behaviour and functional characteristics.

Since a Digital Twin is typically composed of data which receives from sensors and other sources installed in buildings, IoT devices play a very important role in creating the Digital Twin for a building. Through sensors and internet-connected devices, the IoT can help ensure that all aspects of the building are closely monitored and controlled. The application of an IoT infrastructure on a building, together with internet protocols, communication networks and analytical data flows, allows the creation of the so-called "smart building".

IoT devices provide energy consumption data and the state of the state of the equipment. Concerning the indoor environment of a building, installed sensors can deliver data flows relating to a large variety of human-comfort parameters like internal temperature, humidity, or carbon dioxide concentration. The correlation of all the above measurements and the link with the BIM model can generate insights and guide the development of accurate EPCs particularly for complex buildings such as football stadiums and medium-large training sport facilities.

The following diagram shows the approach followed in the D^2EPC project for the initial conceptualization of the building of the Digital Twin oriented towards the processes of energy performance certification[23].

[22] https://bim.acca.it/digital-twin-cosa-e-come-funziona/
[23] https://www.d2epc.eu/en

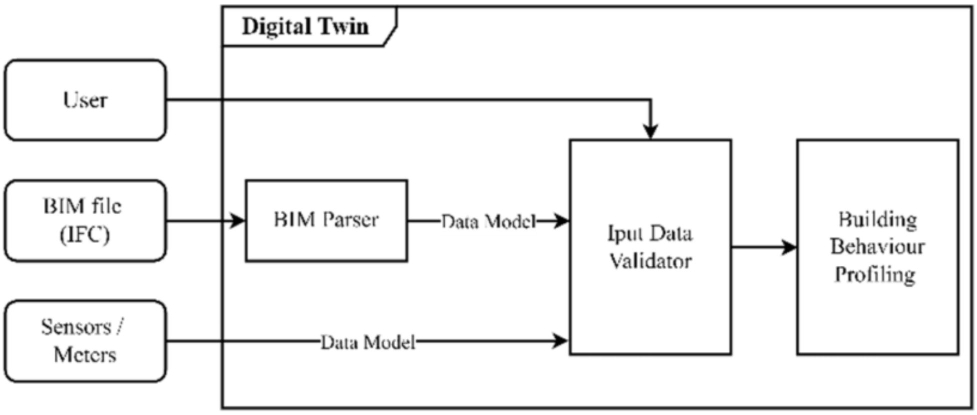

Figure 5-4: Digital Twin as a union of the BIM model and smart building [24]

The DT is comprised of three main sub-modules:

- the BIM Parser: to retrieve all the information included in the BIM file;
- the Input Data Validator: to ensures the logical integrity of input and stored data, including both the set of information retrieved from the BIM files and the data streams from the installed sensors/meters on the examined building;
- the Building Behaviour Profiling: to correlate the building's sets of steady and dynamic data, in order to construct a copied instance of the original building entity.

In conclusion, for the release of a new energy certification scheme for football buildings it would be advisable to provide for the presence of a **digital model and real-time monitoring data**, both in new buildings and in existing ones subject to renovation. This would allow to have a reliable digital replica of the building, making an accurate energy performance assessment represented in real time available to managers.

5.4 Inclusion of Smart Readiness Indicators (SRI)

The Smart Readiness Indicator (SRI) is an assessment scheme for the intelligence of buildings, which was introduced by the European Commission in the directive for the Energy Performance of Buildings in 2018. It is a common EU scheme that encourages the integration of smart innovative technologies in buildings creating healthy, energy-efficient and comfortable buildings, including through building automation and electronic monitoring of heating, hot water, ventilation and lighting.

Refurbishing an existing building does not necessarily mean making it smart. For example, the intervention could be aimed only at improving the performance of the envelope, isolating the dispersing surfaces. This type of intervention actually reduces the building's energy needs, but incorrect management by users can still cause energy waste and excessively high consumption. In a smart building, on the other hand, all systems and devices are part of a single integrated system, functioning in relation to each other, in an automated and optimised way. It is the building itself that detects its own needs and regulates the functioning of the systems accordingly. Furthermore, collecting data on the building itself, on the systems and on internal comfort has the advantage of preventing breakdowns, and always ensures the best possible conditions for the users.

[24] Koltsios, S.; Katsaros, N.; Mpouzianas, N.; Klonis, P.; Giannopoulos, G.; Pastaltzidis, I.; Chatzipanagiotidou, P.; Klumbytė, E.; Jurelionis, A.; Šeduikytė, L.; Georgali, P.; Fokaides, P.; Ioannidis, D.; Tzovaras, D.; Digital Twin application on next-generation Building Energy Performance Certification scheme, IEEE International Smart Cities Conference (ISC2), 2022

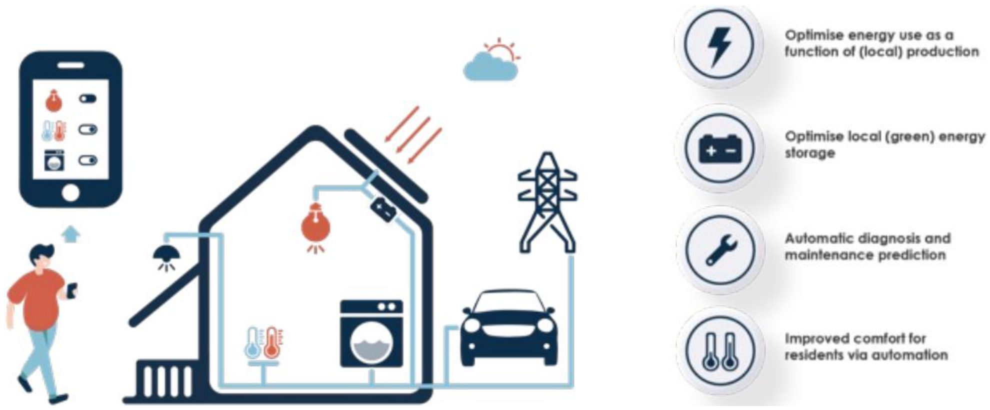

Figure 5-5: SRI objectives [25]

There is no doubt that the smarter a building is, the lower its consumption will be. For this reason, to evaluate the overall energy efficiency of football buildings it would be good for the new certification to **include the assessment of SRIs (Smart Readiness Indicators)**.

The inclusion of SRIs into the new dynamic EPCs for football buildings would open up the possibility of making the added value of smart technologies and digital services more tangible (in terms of energy and comfort) as well as increasing awareness of the benefits for users and owners.

An SRI assessment evaluates buildings (or building units) based on their capacity to satisfy the following three key functionalities:

- Optimise energy efficiency and overall in-use performance;
- Adapt the operation to the needs of the occupant;
- Adapt to signals from the grid (energy flexibility).

According to the proposed SRI methodology, a building's "intelligent readiness" score is represented by a percentage value that expresses how close (or far) the building is from the maximum ideal level of intelligence. The higher the percentage, the smarter the building.

The three key functionalities can be further detailed into seven impact criteria as shown below.

Figure 5-6: SRI impact criteria

The methodology for calculating the SRI is based on the assessment of smart-ready services that the building has or could use ("service catalogue"). These services are grouped into 9 technical domains summarised below.

[25] https://energy.ec.europa.eu/index_en

Figure 5-7: SRI technical domains [26]

Technical domains, impacts and functionalities are aggregated into an overall score that highlights a building's intelligence. The result can be presented either as a single overall score, or as a relative score or as a label classification.

	%		%				%	
	Optimise energy efficiency and overall in-use performance		Adapt its operation to the needs of the occupant				Adapt to signals from the grid (energy flexibility)	
	%	%	%	%	%	%	%	
	Energy efficiency	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage	
Heating	%	%	%	%	%	%	%	%
Cooling	%	%	%	%	%	%	%	%
Domestic hot water	%	%	%	%	%	%	%	%
Ventilation	%	%	%	%	%	%	%	%
Lighting	%	%	%	%	%	%	%	%
Dynamic building envelope	%	%	%	%	%	%	%	%
Electricity	%	%				%	%	%
Electric vehicle charging		%		%		%	%	%
Monitoring and control	%	%	%	%	%	%	%	%

Figure 5-8 scores calculated at different levels [27]

Entering into details, there are different methods to calculate the SRI (the assessment process is the same but the service catalogue is different, which means the level of expertise required to conduct the assessment is different):

- **Simplified method**: it provides a simplified service catalogue and it is typically used for existing residential buildings or small non-residential buildings (low complexity). It follows a check-list approach and the assessment time is less than 1 hour (also self-assessment is possible);

[26] Smart Readiness Indicator (SRI), Training slide deck, versione 2.0 (January 2022), https://ec.europa.eu/smart-readiness-indicator
[27] https://energy.ec.europa.eu/index_en

- **Detailed method**: it provides a detailed service catalogue and it is typically used for new buildings and non-residential buildings (higher complexity). It is necessary a on-site inspection and the assessment time is less than 1 day, but the involvement of an expert with support from a facility manager is necessary.
- **Customised method**: possible if the applicable services are chosen one by one in the existing service catalogue and if additional services can be defined within each technical domain

The choice between regular methods (A or B) or a customised one can depend on country specificities and or implementation phase.

6 Conclusions and future works

Although sustainability at sport facilities is becoming more and more important, currently there is no adequate energy certification system capable of considering all the peculiarities of them, in particular related to their occasional and non-standard use. For football buildings in fact, individual user behaviours and the operational conditions are extremely important and difficult to standardise among a large variety of buildings.

Previous analysis revealed that under the "football buildings" category there is a wide variety of buildings each with its own features, peculiarities, frequency of occupation, site conditions and needs, which all have great influence on the energy consumption.

Since the main aim of an EPC is to serve as an information tool for building owners, investors and real estate actors to identify the energy performance of a building and the related opportunities for energy renovations, it is extremely important to have an accurate overview of the energy performance and provide a reliable and easy-to-understand classification scheme also for football buildings. The current EPC schemes for football buildings have problems, such as not being fully representative of the actual energy performance and consumptions of the facilities and provide low quality and insufficient information to stimulate renovation.

To overcome the lack of an adequate certification scheme for football buildings, this report proposed a few suggestions which, for various reasons, would be useful to include in the development of a new certification scheme for sport facilities that combines the EPBD, best practices from LEED and BREEAM and new technologies such as BIM and Digital Twin models.

As analysed, in fact, the current EPC schemes regulated by the 2010/31/EC Energy Performance of Buildings Directive (EPBD) showed that the adopted method (simplified and with standardised energy uses) is suitable to represent consistently the energy performance of standard buildings such as offices and residences, while it is not reliable to represent the non-standard conditions of football buildings which are characterised 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. Moreover, football buildings and specifically stadiums have significant energy consumption linked to the equipment such as broadcast equipment, scoreboards advertising, under-soil heating etc that are not covered by current EPC schemes.

On the other hand, complex and extensive sustainability certification schemes such as LEED and BREEAM protocols, allow for more accurate rating and assess all sustainability aspects, but require considerable technical and economic commitment, often not economically sustainable for small sport centres. Additionally, the level of detail required by both schemes could lead to significant design complexity and time expenditure.

To improve the quality of EPCs for sport facilities the following suggestions have been proposed:

- energy assessment carried out with dynamic energy modelling;
- integration with BIM models;
- use of data monitoring and BMS;

- integration with Digital Twin models;
- inclusion of Smart Readiness Indicators (SRI).

As the first suggestion, it appears useful that the EPCs for football buildings are based on an operational energy rating and a dynamic energy modelling which allows to account for energy consumption in relation to the actual uses instead of using standardised input data and steady or semi-steady modelling which are not well-representative for sport buildings and their peculiarities.

In order to create an energy certification based on dynamic modelling and increase the accuracy of the energy performance of sport facilities, in particular for complex cases such as stadiums or medium-large training centres, it would be also useful to adopt a BIM-to-BEM approach able to integrate within the energy model all the useful information coming from a BIM model, saving time for data collection and for modelling. Integrating BIM models means also creating a replicable and robust approach for EPC generation by speeding up the data acquisition process while keeping costs low.

Currently there is not a complete interoperability between BIM and energy modelling software and within data exchange process some issues may occur. However, current research is rapidly developing procedures and tools to overcome these bottlenecks and BIM-to-BEM interoperability is continually improving and there is no doubt that its importance will substantially grow in the coming decade.

Another improvement that can offer major opportunities in relation to the energy performance assessment of football buildings consists of the integration of monitored data. Data monitoring, in fact, allows to draw up an ad hoc certification on the building in question, overcoming the limitation of using standardized data or hypotheses. The suggestion is to include long-term monitoring data derived from an adequate toolkit of sensors and meters to calibrate the energy assessments. Carrying out accurate energy monitoring is a fundamental step with a view to the evaluation of the actual energy performance of a football building and of the potential saving due to energy renovations.

The current technological advances in digitalization are also offering new opportunities to integrate real-time monitoring data from IoT devices into the building's Digital Twin in order to reflect the real behaviour and functional characteristics of the building asset. The use of new technologies such as BMS and Digital Twin allows to guarantee a continuous monitoring, a constant level of accuracy and the integration of real-time data in the energy assessment.

Finally, the new EPCs of football buildings should include the Smart Readiness Indicators (SRI), which ensures the evaluation of the smartness of the buildings relating to the level of automation. They can at the same time contribute to better quality of the construction and of the installed energy systems, as well as to the market uptake of smart building systems.

All these aspects should not be seen as alternatives, but rather as something that can coexist. **The next generation EPC for football buildings should rely on dynamic energy modelling and on BIM model, benefit from monitoring data, Digital Twin technologies and use building smart-readiness indicators to create a more reliable, affordable, comprehensive and customer-tailored instrument, which could better represent energy efficiency, together with occupants' perceived comfort and air quality.**

Finally, to better adapt to the different ways in which football buildings are used, certification could take on a new temporal dimension and therefore have temporary validity (e.g. seasonal, per event, etc.). Having analysed this, it is worth noting that this would be possible to have a certification that is no longer permanent, but short-lived, i.e., referring to data relating to energy consumption collected in a specific period or event. In this way it would be made visible how the outcome of the certification changes depending on the moment to which the data collected refers:

a certification obtained during a match or intensive training session could be compared with one whose energy consumption was detected during the absence of people inside the building.

To conclude, it appeared that the definition of a new methodology to improve the data quality is fundamental for the development of EPC for football buildings. The next generation EPC will be a comprehensive information source, that can play an important role in promoting energy performance improvements of football buildings and play an active role in the real estate market, strongly influencing real-estate and building owners to invest more in energy renovations.

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