Sustainable Sports Stadia:

Potential and Strategies for FC Barcelona's Camp Nou stadium

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Contents

0. Abstract.

The reduction of emissions from sports stadiums is achievable by concentrating our efforts on the reduction of transport related emissions, promoting day time events and applying natural lighting and ventilation strategies, together with investment on efficient electric appliances.

The findings from the literature review are applied to stablish which aspects are determinant when defining the environmental impact of sports stadiums. These are defined as: economic factors, lighting loads, water use, waste generation, impact of transport, and environmental policies and design guidelines.

FC Barcelona's Camp Nou stadium has been chosen as a good example of urban sports stadium, and its environmental impact is analysed in terms of these aspects: transport, water, waste and energy use.

Based on succesful examples and relevant data, a number of strategies are proposed and discussed in terms of their potential application and reduction of emissions of Camp Nou stadium.

Despite the limitations in measured data analysis for this report and following succesful examples and relevant data, some strategies are recommended as having more potential for a positive impact on emissions or for their feasible application at Camp Nou stadium.

It is aknowledged that the findings of this report would benefit from the availability of measured data relative to Camp Nou's energy consumption, and so it is the aim of this report to stablish a path of investigation for future research.

1.1. Purpose of this study.

The purpose of this study is to understand what is the potential for sustainable sports stadia in our current society, and for this purpose those factors involved are examined and a number of strategies are discussed to value their potential impact for reducing CO_2 emissions.

To achieve this, we need to understand the role that Sports Stadia play in our cities, our culture and our economy. Their environmental impact is described in terms of transport, waste, water management and energy use.

FC Barcelona's Camp Nou stadium is analysed using the methodology based on the findings of the literature review; strategies are developed and discussed in terms of their potential to improve the current environmental conditions of the stadium.

This study should be useful as a starting point for future research, which must be supported by specific measured data to observe the real impact of the strategies proposed.

1.2. Context and aims.

This study aims to understand the main aspects surrounding sports stadiums in terms of carbon emissions and energy use, considering their role in our society and their environmental impact.

It is the intention of this research to point out the extent to which our stadia can be sustainable, and elaborate a range of potential strategies to reduce their environmental impact.

Sports facilities are being redefined under sustainable principles; when London was granted the 2012 Olympics one of the main objectives of the Olympic bid was to host the Games 'combating climate change and reducing waste'.

This trend was already established at the 2000 Sydney Olympics, the 'Green Games', where its flagship Olympic stadium (now Telstra Stadium) set the benchmark for 'green stadia' and represented a new conception of the Games.

When FC Barcelona organised an international competition to renovate its sports facilities, one of the key aspects to consider was retrofitting renewable technologies, such as installing solar panels on the roof of the main venue, Camp Nou stadium, to reduce the club's carbon emissions.

It seems that we consider no longer acceptable to pollute carelessly while entertaining, and although this interest (if genuine) must be praised and supported, we must ask ourselves: how sustainable can our stadiums be?

2. Literature Review.

There are few published studies that explore energy use in sports stadiums and contribute to the critical discussion; few reports that provide actual data and a correlation between energy use, activity, fuel use and carbon emissions, that would be so useful to understand the environmental impact of sports stadia and assess the potential of future strategies.

Most of the data available consist of press articles listing the latest technological systems being implemented on newly built stadiums. This data offers limited criticism in terms of environmental impact, and although these articles have been useful to collect specific figures, they don't contribute to the critical study of sustainability issues regarding sports stadiums.

However, there is a number of articles that provide interesting data on strategies and solutions applied succesfully on existing stadiums, as these demonstrate the potential of some strategies and, in some cases, suggest further subjects for research.

The reason for this lack of extensive studies must lie in the fact that most of sports stadiums are privately-owned, and any studies carried on them are of a private nature; in terms of energy use and carbon emissions there is no relevant data

available that would contribute to the analysis and understanding of the environmental impact of sports stadiums.
It would probably facilitate the increase of studies a more active role of government and institutions, policing for sports stadiums being audited, allowing the creation of a database for analysis and support future research.
I have structured the revised literature according to the most relevant factors that contribute to the environmental impact of sports stadiums: economic factors, lighting loads, water and waste management, impact of transport, and policies and design guidelines, concluding with a review on sustainability and sports events

2.1. Economic factors.

Modern sports stadiums are conceived as multi-use facilities operating almost 24h offering a wide range of venues (restaurants, sports bars, concession outlets, offices, etc) as spectators are invited to 'arrive early and leave late', enjoying what in the sports events' business is known as 'the game experience' (Meyers 1995; Mendler and Odell 2004; Horwitz-Bennett 2006).
With the continuous expansion and improvement of their facilities, sports stadiums not only expect to attract more demanding sports fans, but also a variety of events (rock concerts, football and rugby finals, athletics, party rallies); when the Stade the France was built for the 1998 FIFA World Cup, it was expected that during its lifetime it would host approximately 40 sports and musical events, and it would play a key role as part of the city's bid to host the 2008 and 2012 Olympics (Sacks 1998).
Many cities are keen to invest in building sports stadiums as sport-related events are an opportunity for urban redevelopment, as well as an attraction for future business due to their potential to improve 'city branding' (Waitt 2000).
Construction of sports venues is an important economic tool for redevelpoment and revitalisation of city centres, sometimes concentrating the investment of suburban cities that wish to reflect their economic bonanza. Chapin (2002)

stablishes two kinds of positive impact of sports stadiums in their hosting communities; economic impact (revenue from visitors spending and stimulation of other developments) and non-economic impact (increased community visibility and enhanced community image – branding – related to the success of the venue).

As Chapin (2002) admits, there might be some controversy on the potential public benefits from hosting sports stadiums, as results may differ between academicc or consultancy research. However, there is agreement on the economic benefits that building a new sports venue (or a new extension) has on the finances of sports clubs or owners as a generator of short-term income (Depken 1999).

Whatever the outcome in economic terms is, continuous expansion of sports venues results in an increase of the amount of indoor space requiring heating, cooling and air conditioning; which added to the requirement for larger lighting installations increases significantly energy loads, giving evidence of the relation between the increase of energy consumption and revenue (Meyers 1995).

Conflict between economic profit and energy efficiency measures is exposed on the fact that many sports stadiums may consider spending extraordinary amounts of money in underground heating systems that are seldom used to prevent the pitch from freezing, as was the case at the Stade de France in Paris; although environmentalists argued that allowing the pitch to freeze would help killing worms in the turf and that heated pitches are of poor quality during the summer, it was preferred not to risk revenue (mainly from TV broadcasts) due to a frozen pitch (Sacks 1998).

Private entrepreneurialism has connected with the public interest for sports events as has turned economic profit and commercial targets as the main drivers behind every sports event (Waitt 2000).

We can't justify from a sustainable point of view the appearance of even larger venues with higher energy demands whilst despite their multi-use condition, the vast majority of sports venues go through short periods of maximum occupancy and long periods practically unoccupied (Horwitz-Bennett 2006).

The fact that many stadiums have been designed to adapt for future changes in their use or size, as Sydney's Olympic Stadium (Mendler and Odell 2000) could give us a clue on where a solution may lie; adaptability and flexibility have been stressed as key for some future developments as the 2012 London Olympics, where many Olympic venues are planned to be disassembled and built somewhere else after the Games.

2.2. Lighting loads.

Aiming to create entertainment venues attractive to spending customers, electrical systems are key to the success of sports stadiums; a state-of-the-art lighting installation, effective security systems (including surveillance and smoke control devices) and impressive advertisement, media and communication systems increase enormously power demand (Meyers 1995; Sacks 1998).

Lighting of sports venues has been identified as the most energy consumer, although it is seldom used when compared to other services (Corl et al 2003).

Whilst all these services contribute to improve the 'game experience' for attending spectators, there is need to provide also good entertainment for TV spectators; TV contracts provide a very appealing additional revenue to sports hosts that turn their stadiums into real-life broadcasting studios (Meyers 1995; Horwitz-Bennett 2006).

This 'stadium as stage' role puts the pressure on the lighting services, as TV broadcasting requires specific control of intensity, colour temperature close to sunlight and equally lit areas (Sacks 1998; Culley and Pascoe 2005; Horwitz-Bennett 2006).

A determinant factor for every major sports stadium is the requirement to provide continuous power supply; FIFA requires their hosting stadiums the capacity of generate at least 50% of their power on site (Sacks, 1998), a measure driven by the need to avoid game disruption and secure TV broadcasting and attendance revenue.

This self-sustaining requirement might just be the key for sports stadiums, as suggested by London Olympic bid plans for on-site power generation for all the Olympic venues (Kennett 2007).

With the future of sports stadiums turning them into real media centres, where spectators would have direct access from their seats to personalised entertainment and TV broadcasts would bring sports to the next level, it is reasonable to predict higher power loads (Meyers 1995) making more difficult for city grids to cope with so intense demands.

This fact would probably lead sports stadiums to supply their own energy demand in order to reduce costs. However, self-sustainability does not necessarily lead to reduced carbon emissions as the current mindset identifies increase of energy use with increase of revenue; only energy-efficiency measures and fuel-saving strategies (with the potential use of renewables) would reduce the impact of energy use in sports stadiums.

To reduce the impact of lighting on the overall energy consumption some stadiums have been upgraded with high efficiency lamps and lighting control sensors (Sacks 1998; Mendler and Odell 2000; Horwitz-Bennett 2005), although these measures mostly aim to reduce electricity costs rather than emissions.

In Sydney's Olympic Stadium on-site gas cogeneration was chosen to reduce electricity consumption from the grid; 2 gas-fired generators provide 57% of the electricity required (mostly for pitch lighting) and reduce electricity from grid consumption to just a 31% (mostly for cooling and air conditioning). These generators operate from 7am to 11pm, reducing on-peak electricity demand and therefore carbon emissions (Mendler and Odell 2000).

2.3. Water and waste management.

During the lifetime of a sports stadium there is going to be a severe demand of water resources, as they account for almost a 70% of the raw materials consumed during this period (Janssen 1999). Approximately 75% of the total water consumption will occur during operation (Janssen 1999), so there is great potential for water management to minimise the environmental impact due to water consumption.

Water conservation strategies deal mainly with rainwater collection and efficient water consumption (Kennett 2007; Mendler and Odell 2000).

At the 2006 Winter Games in Turin water consumption was reduced by a 30% by investing in efficient water services: low-flow appliances, low-flush toilets and spray taps (Kennett 2007).

In Sydney's Olympic Stadium there was installed a dual water supply that connected toilets and urinals to a non-potable water supply from the Olympic Coordination Authority (OCA) treatment plant, reducing potable water demand (Mendler and Odell 2000).

Another example is the 2000 Turin Winter Games; given the high rainfall rate of Turin (neighbouring Milan collects a double amount of water than London in less time) rainwater had to be considered as an issue and was incorporated instead as a solution; permeable hard surfaces, rainwater harvesting and attenuation helped in reducing surface water drainage by 30%, whilst storing collected water for irrigation (Kennett 2007).

For the 2000 Sydney Olympics, four underground water tanks collected a total of 3,200m^3 of rainwater that would be used for irrigation of the Stadium's pitch; storm water would be sent instead to OCA's collection system and treated to later return as non-potable water, contributing to a reduction of the Stadium's potable water demand by 56% to standards (Mendler and Odell 2000).

Waste management is another of the aspects to consider when sports events are concerned, most if we consider that a sports stadium generates approximately 671,000 tones of waste during its lifetime (Hes 2000); that equalls approximately two Empire State Buildings.

However important this figure might seem, solid waste only amounts to 5% of the total ecological footprint generated on a match day, and has the potential of reducing the total ecological footprint by just 1.3% (Collins 2004).

This figures must be considered in its relative value, as waste generated during use accounts only for 24% of the total during a stadium's lifetime (Hes 2000) and the impact of calculating the ecological footprint – forest and farm land required to manage waste – depends on the waste management strategy we consider, as waste incineration might have less impact on land resources than landfill.

Although with relatively less potential in terms of carbon emissions reduction, effective waste management strategies have a positive impact on cities, mainly by targeting waste generated during construction and demolition.

Janssen (1999) has calculated that waste generated by Sydney's Olympic Stadium during its procurement and construction stages accounts for 19% of the total, being demolition the highest contributor (predictably) with 57%; 24% of total waste is generated over 50 years of operation (less than 2% of the total per year).

London's Olympic bid plans for reducing waste from construction may well follow the example of Turin (Kennett 2007) where sustainable waste management guidelines stressed waste reduction during construction by recommending reuse of materials for construction where possible, reduction of supplier's packaging and use of existing buildings to minimise demolition waste.

At the 2000 Sydney Olympics, the impact of waste during operation stage was reduced by implementing separating waste for recyclables, compostables and landfill into 24 large collection rooms (Mendler and Odell 2000).

Another factor involving waste at the early stages of construction is illustrated with the strategies followed at the Stade de France in Paris and Sydney's Olympic Stadium; the use of abandoned or derelict sites.

Although this strategy makes sense from the urban planner's point of view (and it is certainly one of the main reasons for building sports stadiums as they are an opportunity to regenerate derelict urban areas) these sites mean dealing with landfill, industrial and toxic waste from the early stages of construction (Waitt 2000); the choice of a former gasworks site 7km from Paris was not free from controversy, as it required dealing with toxic and explosive gases (Sacks 1998); so it seems to be the case with London's Olympic site.

2.4. Impact of transport.

If we consider the extraordinary amount of people travelling to and from any major sports event (players, spectators, organising staff, media staff, working staff, etc) it is not difficult to realise the impact that this has on the environment.

As Collins (2004) points out when calculating the ecological footprint generated by the FA Cup Final at the Millennium Stadium in Cardiff, transport was responsible for 50% of the energy consumed; 73,000 users travelled collectively a total of 42 million km, and although less than 50% travelled by car, these generated 68% of the total transport footprint.

If we are to consider the emissions generated by any sports event in its full nature, transport emissions are indeed a main factor and have a lot of potential for reducing emissions; should those spectators have travelled by bus instead, emissions would have been reduced by 13% of the total (Collins 2004).

Making sure there are good connections to/from sports events is one of the key aspects for every host organisation, as facilitating the access of spectators to the venues makes perfect economic sense in terms of sales strategy.

However, this has been commonly acknowledged with the increase of parking space for private transport, adding the existence of parking facilities as part of the 'comfort treatment' for the spectator (Meyers 1995).

Some hosts have quite a different view; Arsenal FC set the target of 12% of spectators travelling by car (Culley and Pascoe 2005). This is an example of an urban stadium benefiting from a central location, well served by public transport and (most important) with space constraints for parking area.

This approach is matched by that of the organisers of the 2006 Winter Games in Turin, where main importance was giving to traffic-free access to the venues, placing the sports venues at walking distance and well connected by a landmark pedestrian bridge (Kennett 2007).

However reasonable it may seem to include transport emissions as an unavoidable issue when investigating the environmental impact of organising sports events, some studies have not considered it as a fundamental part of stadiums' design.

As Hes (2000) explains on his article, Janssen (1999) completed a Life Cycle Analysis (LCA) of Sydney's Olympic Stadium, as a fundamental part of the design process, to evaluate the impact of different measures on reducing energy consumption during the lifetime of the stadium. The assessment that structured the lifetime of the stadium in four stages: procurement, construction, operation and maintenance and, finally, demolition, included transport during construction as one of the factors contributing to the environmental assessment, although transport during operation was not considered.

Including transport during operation would have increased the overall embodied energy of the stadium, making these results less attractive than intended. Also, they would have probably misled the public of the good quality of the stadiums' design, which was essential to the assessment.

It is important however, not to miss the big picture and recognise that by nature sports events have a huge impact on the environment by means of associated transport.

2.5. Policies and design guidelines.

The application of sustainable principles to the development of sports stadia has in some cases been fundamental during the planning process; but correct policies must be followed by design guidelines supported by measured and compared data, based on successful examples; for this purpose extensive research and auditing must be done.

At the 2006 Turin Winter Games sustainability guidelines for design, construction and operation configured a handbook for future proposals and construction bids; this brought sustainability to the core of the process, avoiding the loss of effective measures through value engineering (Kennett 2007).

Similarly, plans for the 2012 London Olympics set the tone for controlling the impact of new structures by briefing the construction of a number of temporary venues, just to avoid the example of Athens, where Olympic venues remain underused only 7 years after the Games took place (Kennett 2007).

The elaboration of sustainable guidelines as part of the development process of a sports stadium can be an effective tool to ensure the adequacy of those measures proposed; for the 2000 Sydney Olympics, a 'green budget' was assigned to the design team with the objective to explore strategies for energy conservation, water and waste management and recycling (Mendler and Odell 2000).

As part of the design team investigation, a life cycle assessment (LCA) of the future stadium was integrated within the design development from early stages into planning, design and construction processes. This LCA compared the proposed strategies against standard measures in terms of energy consumption, emissions and natural resources; this assessment would facilitate future decision-making throughout the whole process (Hes 2000).

These measures encourage investigation and facilitate the creation of an active database that should be useful for future developments and form a base for further research.

However, there are examples where the application of green policies has been incoherent with those sustainable principles they were supposed to embrace, as priority was given to economic profit and budget (Waitt 2000).
As part of the 'green' promise of the 2000 Sydney Olympics, Environmentally Sustainable Design (ESD) was to be integrated throughout the whole process incorporating those lessons learned by specific research (including the above mentioned LCA study).
As Waitt (2000) points out, there were environmental concerns over the planning process right from the outset, as the Australian government exempted Olympic sites of presenting an Environmental Impact Assessment (EIA), which had been mandatory for all national projects, in order to speed the process of delivery of the Olympic venues.
These concerns were centred on the potential social impact of eliminating EIA as part of the process, as this was a planning tool that would alert decision-makers and the public about the consequences of the elements of the project; by avoiding it, effective citizens' participation on the process was reduced to information sessions and Olympic environmental consultation forms. These facts increased doubts on the environmental and social costs that would result from such a speed of process (Waitt 2000).

2.6. Sustainability and sports stadiums.

Sports stadiums are being reconsidered under sustainable principles, as there is an awareness of the huge impact they have in the environment in terms of energy use, transport, water and waste.
Revised data illustrates how sustainable measures have been applied to reduce the environmental impact of new sports stadiums, as well as how retrofitting new technologies is being considered for existing stadiums.

However, there are doubts on whether we should consider sports stadiums 'sustainable' given the fact that sports events, as they are currently conceived, are not sustainable at all.

Willis (2000) argues that the ambitions of the so called sustainable architecture are limited and have been constrained due to the fact that sustainability issues are not given enough importance and are incorporated as a symbol, an after-thought that is added to the aesthetic agenda.

According to Willis (2000), Environmentally Sustainable Design policies are incoherent and ineffective, as they expect to achieve sustainability by applying sustainable principles to economic and cultural processes that are not sustainable.

Design should focus on the sustainability of the processes involved, on creating connections to habits, lifestyles and cultural values, becoming 'architecture of sustainability' (Willis 2000).

However, a complete transformation of our current economic and cultural scenarios is not possible; most of our architecture supports unsustainable activities, for which an impact mitigation strategy is a reasonable and more sincere approach, as it would demonstrate the extent of the problem to be solve and trigger further research (Willis 2000).

For the purposes of this study we will consider strategies that deal with the 'unsustainable aspects' concerning sports stadiums, which are mainly: the problem of transport (more evident with international events), considerable energy loads with intensive and spread occupancy periods and inefficient energy use.

It is considered in this report that what makes sports stadiums unsustainable is the approach based on considering solely economic growth as the main drive for energy management.

This report proposes strategies that deal with those aspects where there is potential for reducing emissions without negative impact on economic profit.

3. Camp nou case study analysis.

FC Barcelona's Camp nou stadium is described in this section in terms of transport, water use, waste management and energy use, then analysed following the lessons from the literature review.
The methodology is based on the comparison of Camp nou with similar stadiums – in terms of size and location – that have applied succesfully strategies to reduce their environmental impact.
These strategies are analysed according to their potential application at Camp nou stadium and their limitations and particularities when doing so.
In the next section those available strategies are discussed and valued according to their potential to reduce Camp nou stadium's carbon emissions.
FC Barcelona recently organised an international design competition to regenerate its 22 hectares sports complex that includes: a 15,200 seats sports stadium, a 7,200 seats sports arena, a 1,200 seats ice-rink, a 1,200 seats indoors court and its flagship 98,700 seats Stadium Camp Nou.
It is ranked as the largest sports stadium in Europe – it has capacity for more spectators that the new Wembley Stadium (90,000 seats) and Sydney's Telstra Stadium (80,000 seats) – as it is certainly comparable in size to many Olympic stadiums, with its 55,000 m2 built footprint.

The design competition commemorates the 50th Anniversary of Camp Nou Stadium, built in 1957 to accommodate the fast-growing attendance at the original football pitch ground Les Corts, and aims to upgrade Camp Nou Stadium to 'a world class venue'.
The competition brief suggested that special consideration should be given to sustainable issues, specifically the use of renewable technologies to reduce energy demand; it was on the news that the retrofitting of PV panels on the stadiums roof would be considered as a potential solution.
Therefore the interest of this study for understanding the real potential of such appealing intentions, as sustainability issues seem to have attract the interest of public and private institutions.
Should we really talk about 'sustainable sports stadiums'? Or are sports events deemed to be unsustainable as long as their economic profit-driven approach to energy use is maintained?
Camp Nou Stadium is a good example of an urban sports stadium and its analysis should help us to understand a bit more the nature of such a characteristic urban element.

3.1. Transport.

Impact form transport must be considered in terms of carbon emissions and traffic disruption, as during match days the quality of air and lifestyle are affected considerably.

Occupancy rate is periodical, alternating during the season an average of two weeks between National League matches, including every fortnight a European League match. During the 2006 season an average of 30 matches per year were held at Camp Nou, resulting in one match every two weeks in average (less than 4% of the year).

If we consider that the average attendance during the 2006 football season was of 65,150 spectators (66% of full capacity) it is apparent the under use of such a venue. But the fact that it was considered to increase its total capacity to 150,000 spectators – as the number of registered members of the club was in 2006 – gives us an idea of the kind of mindset so common in the sports business.

Camp Nou Stadium, as many other stadiums in the world, attracts revenue by increasing its potential to hold larger venues and various facilities, and therefore holding larger events. During its 50 years of operation Camp Nou has hosted 47 football finals (including European League, World Cup and Olympics, 10 rock concerts, and a papal mass.

Several plans for extension of the sports complex have been recently rejected by the council, as the increase of commercial venues was not coherent with planning regulations granting use as 'green area' for the FCB sports grounds.

Nevertheless, recent plans for the regeneration of the complex include the demolition of the existing 15,200 seats stadium and contruction of offices and housing; profits from this planning operation would finance the regeneration of Camp Nou stadium and the construction of a new sports arena and new commercial venues such as: cinemas, fast-food restaurants and shops.

From the club's point of view, the upgrading of Camp Nou means an increase of competitiveness as a sports venue, as new and modern stadiums attract potential sponsors. As Chapin (2002) points out, there is a direct short-term profit resulting

from investment on the extension of sports venues, in terms of: increased attendance, higher ticket prices, higher concession sales and a marginal higher winning period for the team.
Neighbours associations have complained about the potential damage to the area of FCB plans for expansion in terms of increase of traffic congestion and decrease in value of the area, due to the extraordinary presence of such a multi-use venue.
The daily flow of visitors to FCB's History Museum (with 1.2 million annual visitors, it is the most visited museum in Catalonia and the sixth in Europe) represents a constant revenue and leads the way for converting Camp Nou in a 24-hours urban sports complex.
As mentioned above, increasing the use of existing facilities should make good practice as an efficient way of building use; however, plans to increase venues without considering energy use strategies mean an increase of the impact due to energy use and associated transport.

To understand the impact that spectators have when travelling to the stadium, we need to analyse how and when they travel and we will consider daily use and sporadic use (such as on a match day).
Camp Nou Stadium is well connected to public transport: 18 bus lines, 2 underground lines and 1 tram line operating 17 hours a day provide good connections to daily visitors; on a match day there is great traffic disruption, and the area requires traffic control and blockades to residential nearby areas.
There are only available 800 underground parking spaces, although the surrounds of the stadium offer enough parking space daily; on match days, parking is banned from 2 hours before the match and only public underground parking is available for visitors, as parking spaces inside the stadium are for special members' use.
It would seem that FCB encourages the use of public transport by offering limited parking space, but the reality is that these parking restrictions have been imposed by the council, as a measure to alleviate congestion and as part of the city policies to increase public transport.

According to council figures, when Barcelonans travel they use public transport a 30% of their journeys, while private transport is used a 20% of the times (56% car); an amazing 50% of the times they cycle or walk.

It is not difficult to give credit to these figures; Barcelona is one of the densest cities in Spain (see table 1) and has more pedestrian streets (0.92 m^2/ citizen); as there are wide avenues connecting the stadium with main transit areas, it is plausible that on a match day most of the visitors decide to get off the bus earlier and walk to the stadium 5 minutes in order to avoid being late due to traffic congestion.

	Population (million inh.)	Extension (km2)	Density (inh./ km2)
Barcelona	1.5	99	15,225
Madrid	3	607	4,720
London	9.5	2,263	4,172

Table 1. Barcelona density comparison

3.2. Water.

Barcelona has traditionally suffered problems of water supply due to the periodic droughts that affect water reserves from its main rivers Llobregat and Ter. Summer water restrictions have been common in the city since the late nineties.

At the same time, Barcelona has problems with flooding due to short but intense thunderstorms that affect the eastern Spanish coast during summer.

Water reservoirs in the Barcelona region are currently at 52% of full capacity, while last year this time they were at 40% of full capacity. Water supply has become a main issue in Spain during the last years, as the government approved in 2005 the National Hydrological Plan (Plan Hidrol6gico Nacional) that encourages water treatment and recycling.

The Catalan government (Generalitat) is expecting funding for the development of desalination, treatment and urban water reuse projects, and is campaigning for a more efficient water use by all sectors.

Camp Nou's water demand for its 7,140 m^2 pitch irrigation is a huge load on the city's water reservoirs. Requirements for pitch maintenance are increased by the fact that the pitch is shadowed by the stands during 5 months a year.

This issue appeared when the pitch level was lowered 3 metres to accommodate seating at the lowest stands. Instead of questioning the potential impact of such a measure in providing sunlight to the pitch, it was considered to follow the example of Vitesse FC and their Gelredome stadium in Arnhem that includes a retractable roof and a convertible pitch that would allow Camp Nou's grass to be taken outside and receive sunlight.

3.3. Waste.

Although waste generated during a match day accounts only for 5% of a stadium's environmental impact in terms of ecological footprint (Collins 2004), collection and processing of this waste can be a heavy burden on a city's rubbish collection system. In the case of urban sports stadiums, litter is a nuisance that can spoil the best sports event ever.

Barcelona Council has an urban plan for waste collection (Programa Metropolità de gestió de residus municipals, PMGRM 1997) that aims to minimise and prevent waste generation, minimise rejection and maximise materials circulation and recycling. It has set targets for treating 100% of generated waste (60% recycling and 40% treatment before landfill). There is prevision for an Eco-park in 2009 for the treatment of 300,000 tones of waste.

By applying such a policy, the council has forced FCB and other institutions to buy into waste management strategies.

In 2006, after a European League match against Chelsea FC, waste generated was collected for analysis by a waste management company (Applus+). The results would help FCB in creating a waste management model.

There is already an active model of waste management in Spain: Real Betis FC applies selective collection of waste generated during match days, and has spread

83 containers all over the stadium, close ot bars and access points, to collect plastic bottles, cans, cardboard and tetra brick. This measure, pioneering experience in Spain, has allowed recycling 44% of generated waste and boasts figures of 6.9 kg (plastic bottles, cans) per person annually and 12.1 kg (cardboard, paper) per person annually in the region.

The only incoherence of this campaign was the fact that it was launched on a match day by distributing 51,000 club calendars advertising the new 'green' attitude. Certainly not the best way to encourage waste reduction.

More importantly, this example shows how governmental action can encourage the application of waste strategies in sports stadiums; by setting policies and setting clear targets.

Another remarkable example is the waste management strategy followed at the 2000 Sydney Olympics (Mendler and Odell 2000); recycling and collection were paramount and for that purpose 24 large collection rooms were implemented, favouring selective waste.

For this purpose, it is useful to investigate the type of waste that is generated by Camp Nou's 55 sandwich trolleys, 9 hotdog trolleys and 80 bars, which consists mainly in plastic bottles and receptacles in general, paper and food.

Favouring the use of recyclable materials at those businesses operating inside the stadium would streamline the collection process and make it more effective, as it would ease identification and location of the correct collection point.

These recycling measures would facilitate enormously waste handling by the council, and encourage more waste-friendly attitudes to visitors, enhancing the educational aspects of sports related events.

It is also worth considering how new FCB plans for extension are going to increase waste generation, as its 15,200 seats stadium is to be demolished and substituted by a new sports arena.

Waste generated at demolition stage accounts for 57% of the waste generated during the lifetime of a stadium, whilst during construction it is generated a 19% (Janssen 1999); demolishing an existing building and constructing a new one would increase waste generation and energy use, as new modern facilities would increase energy demand.

Encouraging a more efficient use of the existing facilities and controlling growth are strategies that have proved to be effective in Turin (Kennett 2007) and have been dealt with foresight by the 2012 London Olympic plans, as some venues are required to be dismantled and rebuilt where required.

These are some potential ideas for future works at Camp Nou, as building venues that would prioritise flexibility and adaptability would reduce waste in the long term, as well as would accommodate an increasing number of facilities as commercial opportunities would require.

3.4. Energy.

For the energy use analysis at Camp Nou stadium we have considered energy for pitch lighting, only used for match days and pitch maintenance, and energy consumed at the indoor areas of the stadium. Therefore, we will consider energy use during a match day (pitch lighting and stadium facilities) and energy use during a regular day with no event held at the stadium (just stadium facilities).

The lack of measured data on Camp Nou's energy consumption limits this study to the elaboration of proposals based on hypothesis and estimations; nevertheless, literature findings from existing examples should provide enough data to assess the potential of some strategies.

Energy for pitch lighting is only consumed during match days; during 2006 there were played at Camp Nou 30 matches (Spanish football league and European league). Including friendly matches for charity and one non-football related event per year, we can estimate that Camp Nou helds events 35 days during the year; that is, approximately, that a 10% of the year the lighting of the stadium is in use.

If we estimate that, on an event day, lights are on from 6pm to 11pm that is 5 hours per event day, a total of 175 hours per year.

The stadium facilities operate practically on a daily basis, an estimation of 360 days per year (including event days) and an average of 8 hours a day, a total of 2,880 hours per year.

However, on a match day the stadium receives on average 65,150 visitors, a total of 1,954,500 visitors per year. If we compare this figures with the number of average daily visitors to the FCB museum and shops (3,300 daily visitors) the result is that on match days the stadium receives 62% of annual visitors, being in use only 10% of the year (calculations are sumarised in table 2).

	Visitors (Daily)	Visitors (Annual)		Operating hours/ day	Operating days/ year	Operating hours/ year
Camp Nou	65,150	1,954,500	62%	5	35	175
FCB Museum + Indoor venues	3,300	1,200,000	38%	8	360	2,880
Total	68,450	3,154,500	100%			

Table 2. Compared occupancy rate

The main characteristic of sports stadiums is their irregular utilisation rate: very intense and short periods of energy use and occupancy are followed by long periods almost unoccupied.

According to Corl et al (2003) pitch lighting accounts for 17% of the electricity consumption of a university campus sports grounds. As this is estimation for a sports ground with a reduced number of indoor facilities compared to an urban sports stadium, we can't be sure of how much energy goes into Camp Nou's pitch lighting.

However their study identifies pitch lighting as the function where most of electricity consumption goes, and if we consider that most of the lighting for a match is on peak demand that shows a great potential for reduction of emissions.

Indoor facilities of Camp Nou (see table 3) consume energy for air conditioning, lighting, power (lifts, emergency, security and media systems) and water for cooling and heating. Janssen (1999) made an estimation of energy use by function for Sydney's Olympic stadium (as shown on table 4) that helps us to understand the amount of energy that goes into air conditioning and cooling internal areas of the stadium (26% of the total energy consumed). This figure corresponds to electricity demand from the grid, as some of the demand is generated on site by cogeneration (two gas-fired generators).

As this electricity is on peak demand, there is some potential impact on emissions by reducing energy consumption during day time at the indoor facilities.

Facility		Area	Uses
Changing rooms	Changing room area		lockers, baths, showers, storeroom
	Water area		pool, 2 jacuzzis, sauna, steam bath, cold bath, relaxation
	Treatment area		
	Technical area		
Chapel			
Presidential box			147 people
VIPs lounge		800 m2	2,400 seats
Press rooms	Press conference room	225 m2	135 seats
	Mixed zone	200 m2	WIFI, radio, TV, mobile
	TV studios x 2No		
Press Gallery			192 seats
			28 radio cabins, WIFI, radio
Sports Medicine Centre			
Operative Contrrol Unit			
FCB Museum			
Nursery			
FCB Offices			
Private Boxes x 23No			256 seats
			Plasma tv, radio, office, catering

Table 3. Camp Nou facilities

4. Discussion of potential strategies.

For the above analysed aspects of Camp Nou stadium a number of strategies are discussed. These strategies are developed applying the findings from the literature review and discussed in terms of their potential application to reduce Camp Nou's environmental impact. Effective application of the proposed strategies has also been considered to assess future retrofitting.

The lack of actual measured data from Camp Nou unfortunately limits this study to the field of hypothesis making; however, the lessons from successful examples and previous studies is considered a useful tool to focus further research on potentially effective strategies.

This study aims to facilitate future research by demonstrating the potential of some strategies and discarding those which might not lead to effective results.

4.1. Transport

Barcelona has since the 1992 Olympics encouraged cycling – there is a total of 100 km of cycle lanes (1200 mm wide lanes each way) crossing the city – and in 2007 started a new cycle hire scheme to complement public transport. A total of 1,500 bikes are available from 100 stations for a membership of 24 Euros a year (1 Euro per week), to encourage cycling for short journeys; use is limited to 2 hours and penalised if exceed, as it is stressed by the council that it is not a tourist service, but a public transport service.

This strategy is similar to the ones in use in other European cities such as Copenhagen and Berlin, although more interesting for our study is the potential for its use to increase cycling visitors to the stadium.

In order to increase the number of match spectators, FCB offers its members the possibility of leasing their seats – for a match they won't attend to – for 50% of the ticket cost, that would be reduced from the next season's membership. It is a clever strategy to increase attendance and keep revenue, as new visitors pay more for their tickets and consume food and drinks.

Trying to accommodate a cycling scheme in such an agenda has to bring in extra profit for the club, otherwise it is deemed to fail. As Michael Pawlyn from Grimshaw Architects suggests for the Eden Project, a strategy to encourage cycling visitors with such a scheme could reward cycling by variable ticket pricing; visitors get reduced ticket prices depending on their chosen mean of transport, being the ones cycling, walking or using public transport the ones paying the less for their tickets. Visitors arriving by car with two or less passengers pay the highest price tickets, as this system takes in account carbon emissions per passenger for every transport mode.

As mentioned above, it is difficult to see such a measure applied at a sports stadium; despite helping to reduce traffic congestion and bringing visitors more quickly (Pawlyn 2001) on a match day, not even the perk of the potential use of the bikes for advertisement (Pawlyn 2001) could easily attract sports clubs.

The control of visitors' transport modes to the stadium seems to be under the exclusive public interest; councils have the power to encourage transport trends by the application of their policies, as is the case in Barcelona. Involving stadiums in the process should be achievable by these means, although for most urban stadiums the scope for change belongs to councils and government that provide public transport and services to stadiums.

However, if the application of policies evolves to more restringing control of the emissions generated by citizens and institutions, FCB would consider reducing its emissions due to transport.

Should this be the case, it should be more achievable by FCB to encourage more carbon friendly transport policies for its teams; given the international agenda of successful football clubs, transport by plane is the most frequent mode for both national and international destinations. Only teams that can't afford chartered flights or don't play international matches travel by bus.

Other potential strategies such as reducing the number of matches per year, or limiting the number of matches played abroad – maybe allowing the clubs to travel by train – is in conflict with the economic agenda of football clubs, that requires more matches in other countries to increase the club's merchandising in foreign countries. FCB spent a week during the 2007 pre-season on a tour in China and Japan playing a total of 3 matches and organising a number of other promotional events, much to its players' despair.

As Collins (2004) points out, emissions from visitors flying to the stadium to attend a final can be potentially be reduced by a 13% should they use another transport such as bus; FCB could encourage friendly ticket packages for visitors travelling by train or bus. Alternatively, better seat locations could be offered for public transport visitors as a reward.

Again, it seems only feasible that by council regulation clubs would buy into these policies, as there is no direct connection between economic profit and sustainable transport strategies.

4.2. Water

Some of these ideas may come back with the new upgrading of the stadium although they don't tackle the real problem of water supply. A more cost-effective strategy – from the sustainable point of view – would be to invest in more a effective irrigation system, as drip irrigation, that would reduce water demand.

Applying water harvesting strategies could prove to be useful, as it was the case at the 2000 Sydney Olympics (Medler and Odell 2000) however its effect may not be as positive, given the reduced average rainfall of Barcelona (590.1 mm) when compared to Sydney's (1222.7 mm).

Investing in more efficient water appliances would be useful given the amount of water used during a match day: low-flow appliances, low-flush toilets and spray taps reduced water consumption by a 30% during the 2006 Turin Winter Games (Kennett 2007).

Reducing water demand for irrigation and users (toilets and changing rooms) would allow Camp Nou to plug into the city's water reservoir and treatment plant with optimised loads.

In addition, a strategy for the treatment of hard surfaces over the complex would allow collecting runoff rain and storm water and contribute to the city water treatment plant, similarly to Sydney's Telstra Stadium (Mendler and Odell 2000).

4.3. Waste

Solid waste generated during a sports event may have little impact on reducing emissions (1.3% of total) however it has great periodical impact on the city waste collection system.

Selective waste collection applied at Sydney Olympic stadium (table 5) allowed to reduce landfill waste and increase the amount of compostible and recyclable waste generated (Mendler and Odell 2000), which certainly would help meeting the city targets for waste treatment.

Waste type	Mass proportion	Total tonnes (per year)
Compostible	40%	800
Paper and board to recycling	31%	600
Glass, aluminium, PET and steel to recycling	16%	300
Landfill	13%	300

Table 5. Annual spectator solid waste

Another interesting strategy for waste management is demonstrated by Nakazawa et al (2004) at their study about the benefits of the application of a returnable cup system for the Oita 'Big Eye' stadium.

The aim of the study was to confirm the reduction of generated waste by encouraging the use of a recyclable paper cup system that would also reduce the environmental loads of the whole waste management process (fig. 1)

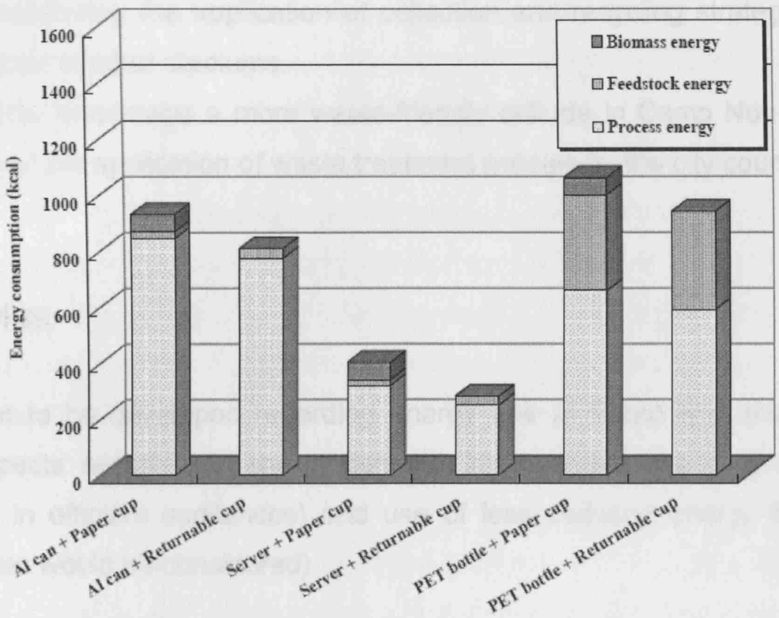


Fig.1 Comparison of energy consumption in 6 beverage services.

Various beverage distribution systems were compared in terms of embodied energy in: a) generation of the recipient; b) distribution of beverage; c) waste management of waste generated once the recipient is disposed.

Of all the beverage services compared, the paper cup recipient system had less embodied energy than aluminium cans or PET bottles (due to process energy required). Returning the recipient and recycling it (up to 20 times) reduced the amount of solid waste generated and energy involved in the whole process of generation, distribution and disposal.

Compared to the more traditional beverage distribution systems, which are currently applied at Camp Nou (not returnable aluminium cans and PET bottles), it represented a reduction between 60-80% of the environmental load of the waste disposal process.

Applying such a strategy would certainly improve waste management at the stadium, facilitating the application of collection and recycling strategies such as those applied at other stadiums.
It would also encourage a more waste-friendly attitude in Camp Nou visitors that could speed the application of waste treatment policies by the city council.

4.4. Energy

Strategies to be developed regarding energy use at Camp Nou must deal with these aspects: reduction of energy demand, improvement of energy efficiency (or investing in efficient appliances) and use of less polluting energy fuels (use of renewables would be considered).

The connection between energy demand and economic profit is at the core of the problem regarding sports events; continuous renovation and improvement of venues and services systems is identified as the way forward in terms of economic growth for sports stadiums owners.
The very conception of organising sports events, such as the Olympics – requiring extraordinary energy for construction and operation of a temporary event – is in contradiction with sustainable principles (Willis 2000). Emissions due to transport use by millions of spectators travelling abroad contribute by themselves to turn any international event held at a sports stadium into a heavy load for the environment (Collins 2004).
The fact is that most of the events that define our urban culture require huge loads of energy demand and their sustenance has a negative impact on the environment. Given their important economic role, any suggestions to give up this kind of events lacks sense of reality; also, an improvement of the situation would require changes far beyond the influence of architects or designers in general.
Although discussion of the use we give to energy might be considered by some authors as a moral imperative (Willis 2000), they also suggest that, for most of the

cases, we may need to tackle the problem of energy use by just mitigating the impact that our activities have on the environment, being this a first measure to achieve short-term results prior to more profound changes with long-term effects (if these are possible at all).

Decoupling increase of revenue and energy demand is the key for sustainable sports events. There are some strategies with the potential to reduce energy demand without limiting use of Camp Nou for economic profit.

Pitch lighting has great potential for reduction of energy demand and carbon emissions; the fact that it involves great amount of electricity on peak demand (between 6pm – 11pm) and that it accounts for 47% of the electricity consumption at Camp Nou, reducing the amount of pitch lighting required would have a great impact.

Football matches, rock concerts, any type of event held at Camp Nou occurs at night time; by helding all of the events (35 events per year) during day time would reduce electricity consumption by at least 40%, reducing emissions generated by peak demand electricity.

Although such an arrangement would not match current Spanish TV prime-time broadcasts, slotted at around 9pm, this should not pose an irresolute problem as football matches are played in other countries such as in the UK on midday weekends.

A compromise by clubs and the Football Association to reduce emissions by playing during day hours could be met by television companies at no greater loss.

Still focusing on pitch lighting, another strategy that would help to mitigate the impact of peak demand electricity would be to increase appliances efficiency.

Lighting efficiency measures have been identified as of great potential (Corl et al 2003) and could be retrofitted at no larger cost and relatively in short time.

This strategy could be combined with reduced night time operation hours, reducing even more electricity use (peak demand). The potential of retrofitting Camp Nou with high efficiency lamps and light control sensors has proven to be considerably cost-effective (Sacks 1998; Mendler and Odell 2000; Corl et al 2003; Horwitz-

Bennet 2005) and could potentially be implemented without interfering with normal operation of Camp Nou.

Harvey (2006) identifies investment on light efficiency and performance of as of great energy savings potential (75-80%); however this potential must be considered according to the existing lighting equipment performance and electricity that type demand that is saved; the potential is greater the less efficient appliances are and the more peak demand is saved. This may not be the case with Camp Nou, as it has sustained periodic renovation works and is likely to have fairly efficient lamps (halide).

Increasing light appliances efficiency would have a positive impact also at Camp Nou indoor facilities, given the amount of electrical equipment required for all-day operation (security, media, lighting, kitchens, etc).

However, given the fact that most of their operational time occurs during day time, it would be more cost-effective and straightforward to facilitate natural lighting for indoor areas as much as possible. It is understood that this measure would be more difficult to retrofit without involving major works at the stadium; since there is a regeneration plan ahead, this could be the opportunity to bring more natural light to the interior spaces (Mendler and Odell 2000).

Such an operation could be also helpful to facilitate natural ventilation for the interior facilities, and reduce electricity demand for air conditioning (Mendler and Odell 2000). Again, the application of this measure would be possible in case of major works at the stadium.

Following the example of Sydney Olympic stadium, we could apply more efficient energy generation strategies to reduce fuel use, which mainly is electricity on peak demand; two gas-fired generators reduce electricity demand on peak time by operating between 7am -11pm, therefore reducing emissions by reducing dependance from grid supply.

By switching to gas as fuel source, emissions would already decrease due to the better efficiency of the energy generation process. It would also reduce peak demand electricity by providing power to Camp Nou facilities – that operate mostly during daytime with a continuous demand rate – as well as hot water for the changing rooms. As pointed out by Harvey (2006), this process is even more effective as waste heat recovered at high temperature is used to provide hot water (which requires lower temperature).

As Harvey (2006) suggests, this sytem may not be so effective for individual buildings due to high costs and specialised maintenance required. However, if we consider Camp Nou stadium as an element within the FCB complex, the investment payback time would be reduced by the potential power and hot water supply for the rest of facilities, that include an ice rink and a sports arena.

The expected energy load increase after the regeneration of FCB complex and UEFA requirements for at least 50% power generation on-site (Sacks 1998) suggest there is great potential for upgrading the power plant at the stadium and generate power by cogeneration to optimise fuel use.

Sydney stadium's gas generators provide 57% of the total energy demand, reducing dependance of electricity from grid to a 0.5% of the total energy demand. Combined with a reduce use of Camp Nou during night time, would reduce extraordinarily lighting requirements and grid supply.

The use of renewables has some potential also at Camp Nou; given the amount of roof surface available (currently around 10,000 m^2) and the generous annual solar irradiation for Barcelona (an average of 1,635 kWh/m^2) it is worth considering the option of installing PV panels on the Camp Nou's main stand roof. A quick calculation would helps us grasp the potential of this strategy (solar data collected from International Sustainable Energy Organisation, ISEO):

a) Given the current available area of the main stand roof (10,000 m^2), and average annual solar irradiation for Barcelona (1,635 kWh/m^2) for a South-oriented surface inclined 40°,
b) We could assume – for a system efficiency of 16% (Scott 2005) – that there is potential to achieve:
   1,635 kWh/ m^2/ year x 10,000 m^2 x 0.16 = 2,616,000 kWh/ year, equivalent = 9,417 GJ/ year.

According to Janssen (1999) Sydney's Olympic stadium electricity demand from the grid was a total of 21,300 GJ/ year; electricity loads for cooling and air conditioning was 18,000 GJ/ year and the rest was for lighting, cooking, lifts and escalators, heating and hot water (3,300 GJ/ year). We must bear in mind that Sydney's cogeneration system produced a total of 47,700 GJ/ year for lighting and power during peak time.

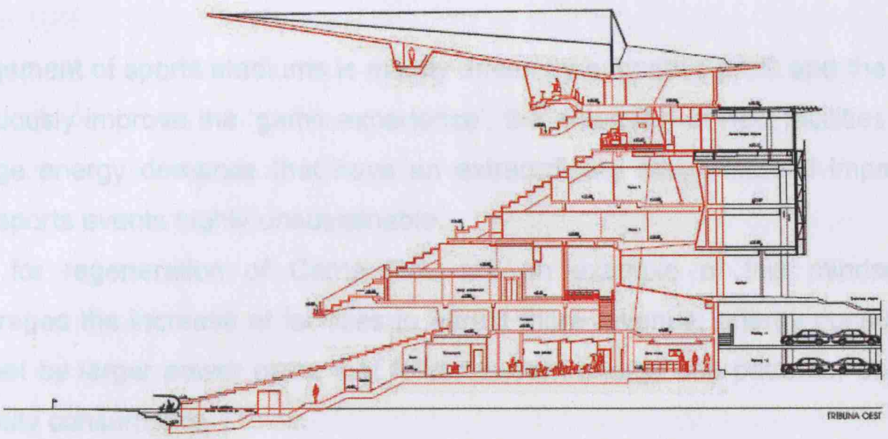
Function	Electricity (GJ/year)	Gas (GJ/year)	Total (GJ/year)
Heating + hot water	1,100	300	1,400
Cooling + air conditioning	18,000		18,100
Cogeneration		39,100	39,100
Power	400		400
Lighting	400		400
Kitchen	900	8,400	9,200
Lifts and escalators	800		800
Total	21,300	47,700	68,900

Table 4. Estimated annual energy use by function

Installing roof PV cells might not be enough to supply full electricity demand for Camp Nou; with the current roof area available, solar energy could be used for daytime power supply to reduce demand of peak time electricity. An extra benefit would be that peak supply coincides with peak demand for air conditioning in summer months.

Pitch lighting would require storage (by a generator placed at the lighting towers possibly) and extraordinary supply available in short period of time; installing solar PVs could prove to be more cost-effective for long-operation demands such as day time facilities, whilst reduction of electricity demand for pitch lighting would be achieved at no cost by just avoiding night time events.

Other benefits of installing solar PV cells is theis potential for retrofitting and being integrated within the roof structure (BIPVs), reducing use of materials and contributing to shading of the stands.



Data by Gutscher (2001, at Harvey 2006) investigated the potential of BIPVs in Spain and concluded that due to an elevated national electric consumption (one of the highests just below US) there was a potential of 48% energy saving. Reasons for this were mainly: solar energy availability and peak time electricity demand in summer months, together with the low PV installed power in Spain.

Further research should investigate what would be the payback time for installing BIPVs on Camp Nou's roof; accurate calculation using measured data and comparison against current electricity prices, PV installation costs (including potential government grants) would be useful to precise fuel and cost savings, essential to convince FC Barcelona of the potential of this strategy.

5. Conclusions.

Management of sports stadiums is mainly driven by economic profit and the aim to continuously improve the 'game experience'; the extension of new facilities reflect on huge energy demands that have an extraordinary environmental impact and make sports events highly unsustainable.

Plans for regeneration of Camp Nou are an example of this mindset that encourages the increase of facilities to attract more revenue; energy consumption is a met by larger power plans that follow current energy use patterns, based on electricity consumption.

Changing these energy use habits and applying new policies for waste and water management, together with new transport strategies, could have great impact in reducing emissions from sports stadiums.

As transport is main responsible for more than 50% of a stadium's footprint, tackling the problem of spectators movement towards Camp Nou has great potential. However it has been argued on this study that to do so, it is required active involvement from council and government to apply transport policies and encourage public transport. A bicycle use policy is already in practice in Barcelona, and given the easy access to Camp Nou in terms of public transport and walking or cycling routes, sorting out transport issues are probably the first issue on the agenda.

Waste and water management strategies may not have a huge impact in terms of air emissions, however they have huge impact in terms of pollution and associated energy use for waste processing. Water harvesting strategies and investing in more efficient water appliances would reduce Camp Nou's water consumption and plug into governmental policies for water use. Selective waste collection strategies would be applicable at no larger costs and would certainly ease the load on the city's waste treatment infrastructure; also, incorporating recycle-friendly beverage distribution systems would reduce waste generation even further.

Energy use is the other main target for reducing the environmental impact of Camp Nou, as 80% of energy consumption during its lifetime would be consumed during operation (Janssen 1999); reduction of energy demand and improvement of energy efficiency would be the main aspects to concentrate our strategies.

Energy use related strategies have great potential for reducing emissions, however some of them may be difficult to apply unless we reconsider the way we operate sports stadiums. This would be achievable by decoupling economic growth and energy consumption, as limiting the economic aspects of the business would certainly abort the application of any strategies.

Proposed strategies are concentrated in encouraging day time use of Camp Nou, investment in more efficient lighting and electrical appliances, and the application of effective energy generation.

The use of integrated photovoltaic cells (BIPVs) is considered to have potential, according to the literature revised. However, the lack of measured data from Camp Nou and relevant studies on solar energy applied to sports stadiums makes the recommendation of renewables a very attractive option that this report can only encourage to investigate further by future research.

Due to its relatively easy application and great impact on reducing peak time electricity demand it is recommended to increase use of daylight: by promoting the use of Camp Nou at longer day time hours and incorporating natural lighting into the internal facilities emissions would be reduced in terms of electricity for lighting and air conditioning. Increasing natural ventilation would contribute in reducing electricity demand even further.

The occasion of Camp Nou expecting major works is an exceptional opportunity to apply these strategies, as light wells and air extraction towers would be relatively straight forward to add and would work well with the high thermal mass of the Camp Nou (concrete floors and structure).

Investing in efficient energy generation, by implementing gas fired generators for cogeneration of power and hot water would be of great impact, but at larger cost than above mentioned strategies. Even with the occasion of having major works in the stadium the scale of the operation may not be as attractive to the club as less complex strategies.

However, this option is more applicable in the case of a new building, such as the new sports arena that is planned to be built in the FCB complex. Further research could explore the potential for complete energy supply of such a sports arena.

In terms of the application of renewables, this report lacks compared data to support any recommendation undoubtedly. From the findings of the literature review, retrofitting BIPVs is relatively easy – if compared to other strategies for energy generation on site – however its cost-effectiveness in terms of achievable emissions reduction in relation to the capital costs involved make this option not so attractive and straight forward as other previously mentioned strategies, such as encouraging more environment friendly transport habits and increased daytime use of Camp Nou.

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