RUGBY FOOTBALL UNION

Energy Statement

Twickenham Stadium – East Stand Extension

July 2016

Twickenham East Stand Redevelopment

Energy Statement

Issue and Revision Record

Rev / Issue	Date	Description	Revision Details	Prepared	Checked
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1 EXECUTIVE SUMMARY

ME Engineers have been engaged to develop an energy strategy in support of the extension of the east stand at Twickenham Stadium.

This energy assessment for the proposed redevelopment of the East Stand is written in response to the London Borough of Richmond upon Thames planning policy, and the more recent framework of the Greater London Authority (GLA) London Plan (March 2015), policy 5.2.

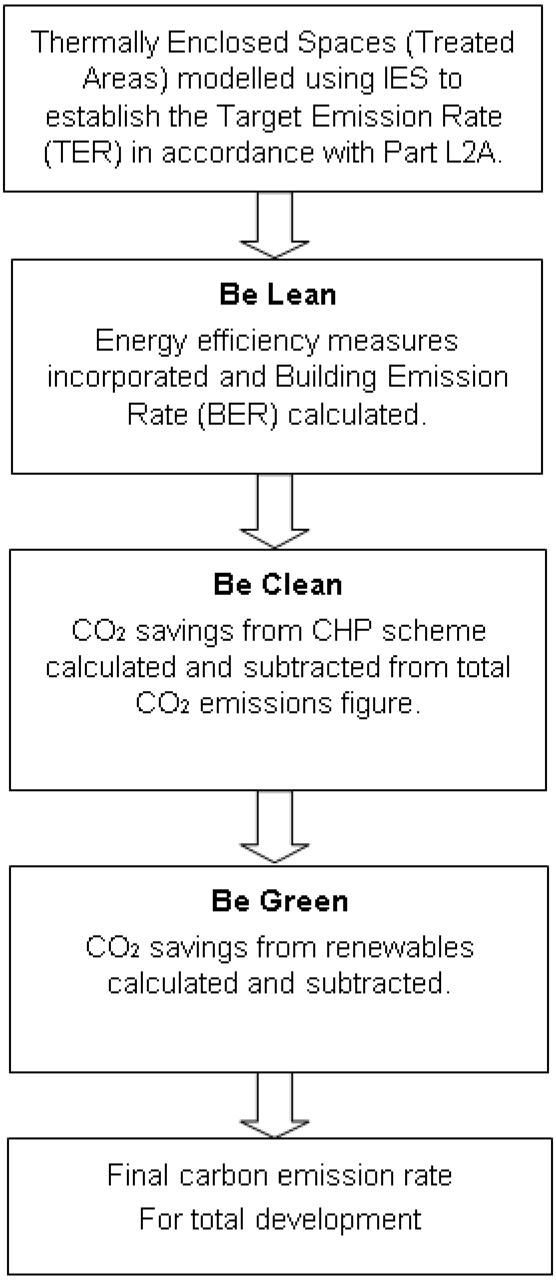
In addition to energy efficiency measures, this document demonstrates that the additional provision of a Combined Heat and Power (CHP) system and a proposed PV array, provide an increased carbon emissions reduction compared to energy efficiency and passive measures alone.

Energy Efficiency and renewable energy technologies have been evaluated for this scheme, and their feasibility for incorporation into the scheme has been assessed.

A dynamic energy simulation has been undertaken to establish the energy consumption and carbon emissions of the proposed building. The building was broken down into Thermally Enclosed Spaces, and Non-Thermally Enclosed Spaces, where only the thermally enclosed spaces have been assessed.

- Thermally Enclosed Spaces. These are spaces within the building that are inside the thermal line, and which will be conditioned. These spaces will have a regulated energy consumption for Heating, Cooling, Hot Water, Lighting and Auxiliary Energy.

1.1 Calculation Methodology



1.2 Be Lean

1.2.1 Passive & Active Energy Solutions

The following summarises the various energy efficiency measures used to reduce the buildings inherent energy consumption and associated CO2 emissions.

- The building envelope U Values have been where possible, improved upon the Part L limiting values when an area weighting is considered. The following U-Values are an average calculated across all the Thermally Enclosed spaces.

Element	Part L2A U-value Limiting Standards (Area Weighted Average)	Average U-values Proposed for Thermally Enclosed Spaces Only
Roof	0.25W/m^{2}K	0.18 W/m^{2}K
Walls	0.35W/m^{2}K	0.26 W/m^{2}K
Floor	0.25W/m^{2}K	0.22 W/m^{2}K
Glazing	2.2W/m^{2}K	1.6 W/m^{2}K

- Improved building air tightness of 4m^3/hr is proposed for thermally enclosed spaces.
- Low energy lighting.
- Automated lighting control systems.
- High efficiency boilers.
- Heat recovery on mechanical ventilation systems.
- High efficiency motors with variable speed drives for pumps and fans.
- Power factor correction on incoming electrical supplies.
- Building energy management system with monitoring and energy targeting software

1.3 Be Clean

1.3.1 District Heating

Currently, there is no local district heating system which can be utilised by the proposed development.

In order to allow for future inclusion into a community-heating network should one become available, the on-site central heating systems will be provided with future connection points.

1.3.2 Combined Heat and Power

A feasibility study has been carried out to determine the Buildings suitability for a Combined Heat and Power (CHP).

To ensure that all the energy generated will be utilized the base heating load of the development has been taken as the criteria for sizing a CHP system. It is no believed that a sufficient base load exists within the east stand alone, and therefore a CHP system exporting to the hotel and gym facility in the adjacent south stand is proposed.

1.4 Be Green

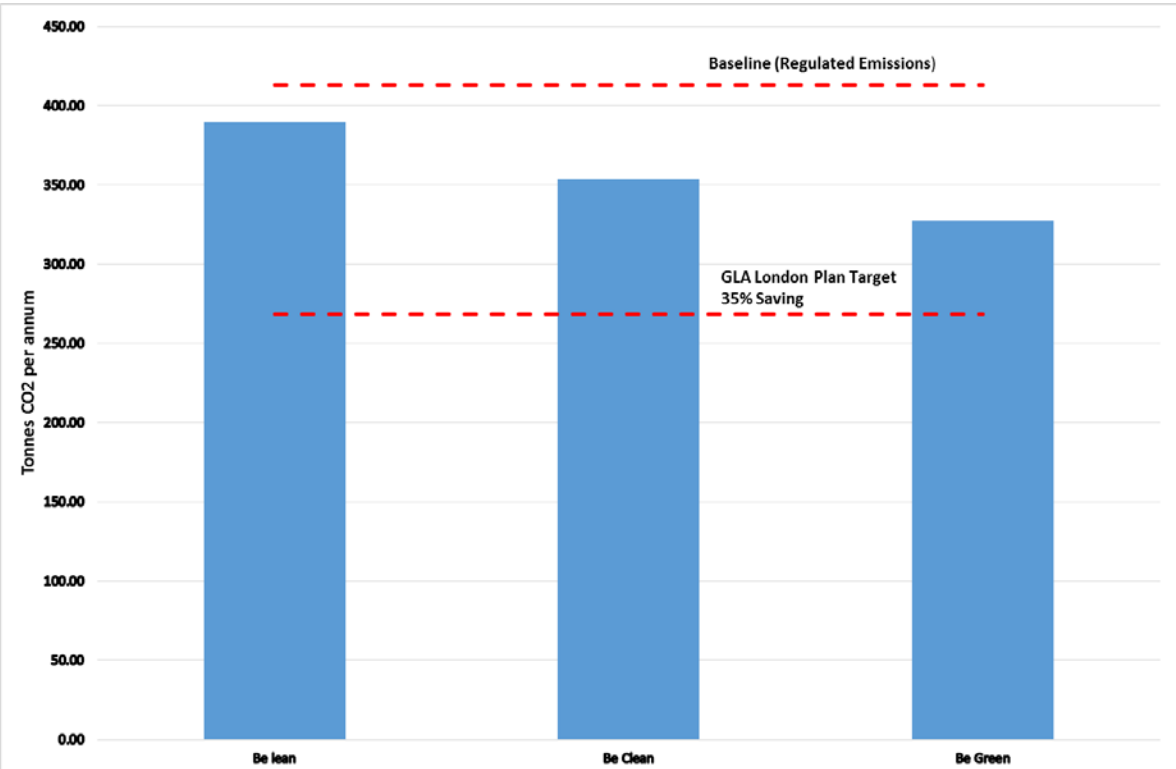
The following table describes the various renewable technologies which have been assessed for inclusion into the development to further reduce CO_2 emissions.

Technology	Comments	Conclusion	Calculated CO_2 Saving ($kgCO_2$/year)
Photovoltaic Panels	Although there is no suitable unshaded south facing roof space on the east stand, a PV system has been considered to be installed on the roof of the south stand, also within the site.	40kW peak system included.	25,785.04
Ground Source Heating and Cooling	Potential Solution (subject to detailed site survey) but conflicts with proposed CHP for heating load. Installation of CHP calculated to achieve the greater CO_2 saving.	Not suitable	N/A
Biomass Heating	Cannot achieve a high renewable target due to installation of CHP. Concerns over future fuel supplies, exhaust flus are problematic, requires additional plant area and has the burden of a high maintenance cost, not considered suitable.	Not suitable	N/A
Solar Hot Water	Solar thermal is not a feasible option for the development due to shading of roof space and would compete for the same hot water/heating load as the CHP.	Not suitable.	N/A
Wind	Wind turbines are not thought to be a feasible option. The issues surrounding the use of wind turbines range from noise, to unsuitable (turbulent) wind conditions, and the scale of wind turbine required to get to a high enough point at which they would be favourable	Not suitable.	N/A
Hydrogen Fuel Cell	Only a renewable if run on hydrogen which is as yet not considered commercially viable. Many current installations are running on natural gas.	Not suitable.	N/A

1.5 Summary of Carbon Emissions

	Carbon Dioxide Emissions (Tonnes CO2 per annum)	
	Regulated	Unregulated
Baseline: Part L 2013 of the Building Regulations Compliant Development	413.08	272.21
After energy demand reduction – Be Lean	389.55	272.21
After CHP – Be Clean	353.80	272.21
After Renewables – Be Green	327.45	272.21

The total reductions in regulated carbon emissions for the stadium amount to 20.72%% over baseline emissions rates.



2 INTRODUCTION

2.1 General Information

This energy assessment document has been written to satisfy the requirement of the Greater London Authority's London Plan (March 2015), Policy 5.2 – C which states:

'***Major development proposals should include a detailed energy assessment to demonstrate how the minimum targets for carbon dioxide emissions reduction outlined… are to be met within the framework of the energy hierarchy***'.

As required by Policy 5.2 the following sections are included within this energy assessment:

a) Calculation of the energy demand and carbon dioxide emissions covered by the Building Regulations and, separately, the energy demand and carbon dioxide emissions from any other part of the development, including plant or equipment, that are not covered by the Building Regulations (see paragraph 5.22) at each stage of the energy hierarchy.

b) Proposals to reduce carbon dioxide emissions through the energy efficient design of the site, buildings and services.

c) Proposals to further reduce carbon dioxide emissions through the use of decentralised energy where feasible, such as district heating and cooling and combined heat and power (CHP).

d) Proposals to further reduce carbon dioxide emissions through the use of on-site renewable energy technologies.

2.2 Development Description

The development comprises an extension and refurbishment of the existing East Stand which will be used as additional hospitality space comprising dining and bar areas together with associated kitchen and WC's.

The East Stand will be refurbished, and will include upgrades to its infrastructure, that will improve the overall performance of the building and reduce associated energy consumption relating to the running of the building.

3 POLICY CONTEXT

3.1 National Planning Policy Framework

The energy statement has been structured with the relevant policies of the National Planning Policy Framework (NPPF) in mind. This policy outlines how developments should be planned to reduce carbon emissions and protect the environment.

3.2 GLA London Plan (March 2015)

The GLA (Greater London Authority) sets out in the London plan the various policies relating to sustainable development. The design team acknowledges the requirements which are set out within the various policies within the GLA document, and through exploring the various sustainable design options as set out in this section, will aim to meet those targets wherever viable, and technically possible.

In addition to all other relevant policies, the design team will pay particular attention to the following:

3.2.1 Policy 5.2 Minimising Carbon Dioxide Emissions

Policy 5.2 requires that for both residential and non-domestic buildings a 40% reduction in CO2 emissions is demonstrated, benchmarked against the 2010 Building Regulations target emissions rate. Since the publication of the London Plan 2011 the GLA Guidance on Preparing Energy Assessments (April 2015) has revised the target for both residential and non-domestic buildings to 35% below the Building Regulations 2013 target emission rate.

This energy assessment demonstrates how the GLA 2015 targets for carbon emissions reductions will potentially be achieved. This will be within the framework of the energy hierarchy:

1. Be Lean – Use less energy
2. Be Clean – Supply energy efficiently
3. Be Green – Use renewable energy

3.2.2 Renewable Energy

In line with policy 5.2, the development will, subject to feasibility provide a reduction in expected carbon dioxide emissions through the use of on-site renewables energy generation.

3.3 London Borough of Richmond upon Thames Core Strategy

The design team acknowledges the requirements of London Borough of Richmond upon Thames core strategy, and the development proposals will reflect the following sustainability policies where relevant to the building services design.

3.3.1 CP1 Sustainable Development

This policy seeks to 'maximise the effective use of resources' including energy, and reduce the associated environmental impacts. This includes achieving standards under the BREEAM scheme. The MEP design will take these requirements into account, and therefore support achieving the required environmental standards.

3.3.2 CP2 Reducing Carbon Emissions

This policy seeks to minimise carbon emissions through requiring developments to utilise means of energy reduction, and therefore reduce carbon emissions. In addition to the London Plan, the policy stipulates that the development:

1. Evaluate, develop and use decentralised energy, where appropriate, and
2. Achieve a reduction in CO2 emissions of 20% through on-site renewable energy generation.

3.4 London Borough of Richmond upon Thames Development Management Plan

In addition to the core strategy and London plan, the design team proposals will employ sustainable design, and energy efficiency practices to ensure compliance with the following policies:

3.4.1 DM SD1 Sustainable Construction

This policy requires that the development will include measures designed to mitigate the effects of, and enable the adaptation to climate change. The policy also stipulates that developments should meet 'Zero Carbon' Standards.

3.4.2 DM SD2 Renewable Energy and Decentralised Energy Networks

The development will look to comply with this policy through implementing, subject to a feasibility assessment, on site renewables and decentralised energy systems where possible. In line with this policy, the design will incorporate provision for connection to decentralised energy networks should an existing one not yet be feasible to connect to.

3.4.3 DM SD3 Retrofitting

This policy requires that all retrofitting and refurbishment elements of the development ensure that high standards of energy efficiency are maintained throughout. The development refurbishment elements will be designed in line with this policy.

4 DYNAMIC ENERGY MODELLING

4.1 Model

The east stand was modelled to establish baseline regulated emissions using the IES VE software suite.

Thermally Enclosed Spaces are spaces within the building that are inside the thermal line, and which will be conditioned. These spaces will have an associated regulated energy consumption in regards to:

- Heating
- Cooling
- Auxiliary Power
- Lighting
- Hot Water

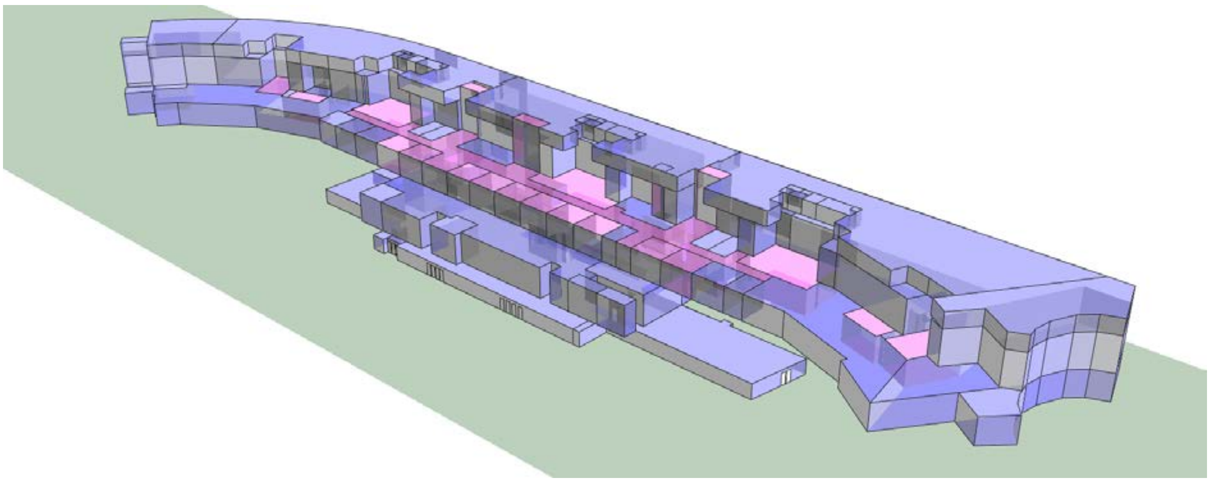


Figure 1 IES Model of Thermally enclosed Spaces

4.2 National Calculation Methodology

National Calculation Methodology (NCM) profiles have been applied to the appropriate zones of the model as required.

5 SUSTAINABLE DESIGN PROPOSALS TO USE LESS ENERGY 'BE LEAN'

5.1 General

The east stand will look to adopt good sustainable building services solutions, which provide reduced energy input while maintaining appropriate conditions for the staff and occupants in the stadium. The building will be initially designed to achieve the following 'good practice' objectives.

- The adoption of passive measures, such as external shading have been incorporated in the shape and form of the buildings, wherever possible to limit the base CO_2 emissions in line with the 'Be Lean' principle.
- It is proposed to install mechanical and electrical engineering systems that will assist in achieving the lowest possible annual energy input thereby reducing the level of CO_2 emissions.

5.2 Good Practice Measures

The key focus of the detailed designs will be to minimise energy usage first, and then to find the most efficient and economical systems to serve the required purpose. Spaces shall be evaluated to anticipate seasonal internal temperatures based on the load profile of the room prior to making decisions on conditioning level.

5.3 Sustainable Objectives

5.3.1 General

During the detailed design development, close attention will be paid to coordinating and integrating the structure and the occupied areas to:

a) Minimise direct solar gain.

b) Optimising daylight factors in where possible and appropriate.

c) Optimise utilisation of plant and systems.

d) Optimise control and flexibility of the installations.

e) Incorporate appropriate energy recovery systems.

f) Incorporation of CHP plant

In addition, the environmental services proposals will be designed using the latest techniques for 'active and passive' energy recovery and conservation, to enable the most advantageous, cost effective 'energy targets' possible to be achieved.

The following sections describe the good practice elements to be reviewed and incorporated where suitable with the renewable elements identified and covered in detail in a later section of this report.

5.3.2 Passive Energy Solutions

Among the passive design aspects of the east stand, the thermal performance will be improved beyond the limitation of the building regulations, to minimise heat losses in winter and heat gains in summer.

The table below indicates the U-Values that are being proposed for the east stand.

Element	Part L2A U-value Limiting Standards (Area Weighted Average)	Average U-values Proposed for Thermally Enclosed Spaces Only
Roof	0.25W/m^{2}K	0.18 W/m^{2}K
Walls	0.35W/m^{2}K	0.25 W/m^{2}K
Floor	0.25W/m^{2}K	0.18 W/m^{2}K
Glazing	2.2W/m^{2}K	1.60 W/m^{2}K

The limit for the design air permeability is 10m3/hr/m2 at 50 Pa in accordance with current Building Regulations, however, for this development, improved air tightness is to be achieved as follows for the thermally enclosed spaces.

3m3/hr/m2 at 50Pa for the Thermally Enclosed Spaces

5.3.3 Zoning

It is anticipated that the engineering services installation will be suitably zoned, both at a macro level for the whole site and micro level for the individual areas.

Heating, ventilation, water services and electrical zoning shall be configured to promote the maximum flexibility in order to enable remodelling and re-planning to be undertaken at a future date.

To control and monitor energy consumption it is envisaged that provision for sub-metering of all major services to each zone will be required and that this shall be interfaced with the site building management systems.

5.3.4 Variable Speed Drives

The use of frequency inverter variable speed drives is proposed for all major pump sets and ventilation fans. For primary heating and chilled water distribution systems the variable speed circulation pumps are to be used in association with two-port control valves.

The use of variable speed drives will also remove the use of belt drive pumps.

5.3.5 Plant Sizing

All the central plant including air handling units, boilers and chiller units will be selected so that they correctly reflect the required loadings for the building. Over sizing of fans will be avoided, unless they are provided with inverter drives for variable duty operation or to assist in the testing and commissioning process of the plant and system.

5.3.6 Heating Systems

The heating for the development is provided by CHP generation paralleled with natural gas boilers for peak load and standby. The CO2 emission savings through implementation of the proposed CHP scheme is considered elsewhere within this report.

The heating system will incorporate zonal pumping arrangements with run and standby facilities as appropriate, with compensated variable temperature heating circuits to supply the terminal heaters.

5.3.7 Day lighting

The design of the buildings will seek to maximise daylight where possible and appropriate, while limiting direct solar gains and mitigating the risk of overheating through specification of solar control glazing and provision of shading where feasible and appropriate. Although daylight in some areas may be slightly affected by any potential solar shading, the reduction in cooling demand for internal spaces outweighs the requirement for supplementary artificial lighting. Daylight dimming will be utilised to further reduce the amount of associated energy consumption for the lighting installation.

5.3.8 Lighting Installation

The lighting installation throughout the stadium shall maximise the use of low energy lamps and high efficiency electronic ballast technology wherever possible, and linked to daylight and PIR sensors for dimming and switching.

In addition long life lamps will be incorporated into all aspects of the installation, utilising LED technology whenever the task permits.

The complete lighting installation shall be controlled via separate automatic PLC based control systems. The system generally operates on a pre-set time based programme to minimise the operating hours of all luminaires. The systems provide fully interactive control terminals, which enable the operator to override or amend the programme should the required operational needs the separate areas change.

The lighting throughout the stadium will form a mixture of functional and decorative luminaires.

5.3.9 Ventilation Systems

The mechanical ventilation systems will include where appropriate recirculation system with a free cooling capacity, and heat recovery components such as plate exchangers, thermal wheels, or run around coils.

These facilities will be designed to recover both heating and cooling energy in the winter and summer seasons. The choice of clean or dirty extract systems shall be selected to achieve the most efficient energy recovery option, back into their respective supply air systems.

The use of variable speed drives will be considered on ventilation plant where there is likely to be variations in occupancy levels and the air volume can be controlled by the use of CO_2 or occupancy sensors.

5.3.10 Building Management

The development shall be provided with a Building Energy Management System (BEMS) to fully control, monitor and record the various Mechanical, Electrical and Public Health systems.

The BEMS has full stand-alone intelligent outstation and/or local controllers, linked via main LAN to an operator terminal. The BEMS shall not only control the Mechanical, Electrical and Public Health systems but also fully monitor the energy usage by the installation of local energy monitors. This shall be linked to software so that the building manager can record energy usage and identify where improvement to energy consumption can be made.

6 ANNUAL ENERGY CONSUMPTION AND CO_2 EMISSIONS

This section describes the computational modelling process used to establish the baseline CO2 emissions from which any improvements are measured and to then calculate the resulting CO2 emissions once the 'Be Lean' enhancements are implemented.

6.1 Design Standards used in Energy Model

The table below sets out the design criteria used for the stadium energy model to establish the 'baseline' emissions.

System Description	Proposed
Boiler Seasonal Efficiency	88%
Cooling Plant System Seasonal Energy Efficiency Ratio (SSEER)	2.8
Ventilation Plant (Specific Fan Power)	0.5 W/(m^3.s)
Heat Recovery Efficiency	0.7
Building Air Permeability @ 50 Pa	3 m^3/(m^2.hr)

6.2 Fuel Loads and CO_2 Emissions

Conversion factors for calculating carbon dioxide emissions are shown in the table below, these are the factors used in calculating compliance with Part L of UK Building Regulations 2013.

	CO_2 Emissions (kg/kWh)
Natural Gas	0.216
Grid Supplied Electricity	0.519

6.3 Development Total Calculated Energy Emissions:

Areas:	Treated Floor Area (m^2)	Carbon Emissions (kgCO_2/m^2.year)				Reduction
		TER	TER Annual CO_2 Emissions (tonnes)	BER	BER Annual CO_2 Emissions (Tonnes)	
Thermally Enclosed Areas	9409.5	43.9	413.08	41.4	389.55	5.69%

7 FEASIBILITY ASSESSMENT OF CHP AND DISTRICT HEATING 'BE CLEAN'

7.1 District Heating

The London heat map shows there are no existing heating or cooling networks close to the stadium site.

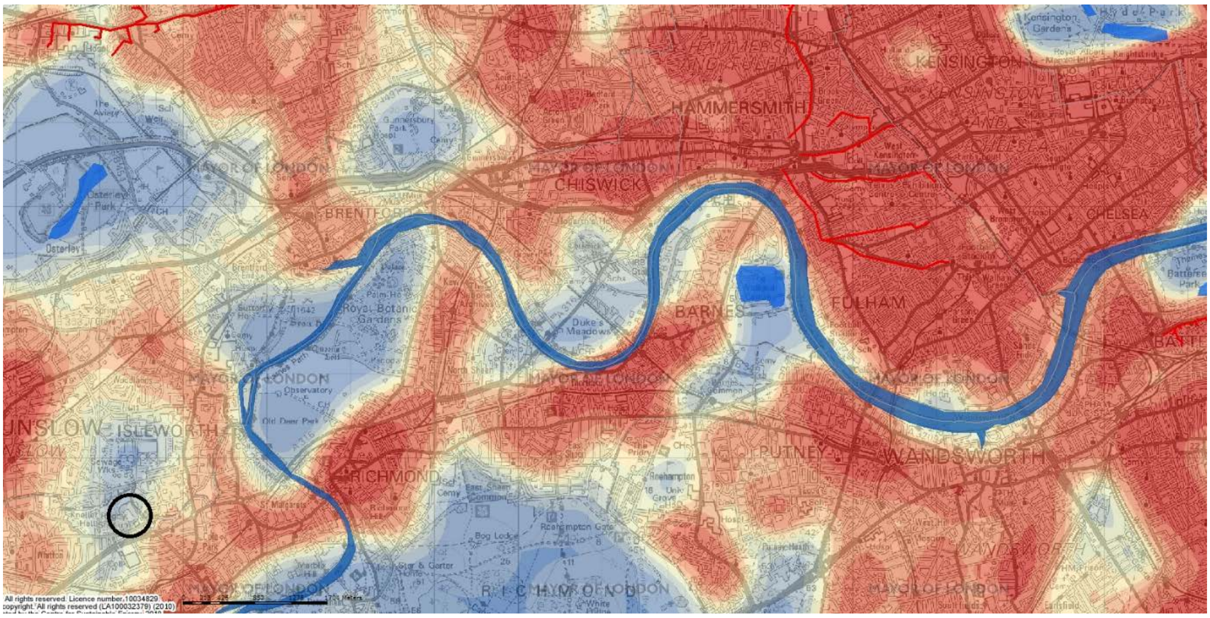


Figure 2 London Heat map indicating the location of the stadium

7.2 Combined Heat and Power (CHP)

A combined heat and power (CHP) generator suitable for this type of application typically comprises a natural gas fuelled generator coupled directly to the buildings electrical distribution system with heat exchangers to recover heat from the cooling system, exhaust gasses and sometimes the engines lubricating oil.

CHP plant can reduce the yearly CO2 emissions, by providing improved efficiencies as a result of utilising the waste heat from the electrical generation engine. These systems can result in efficiencies of up to 85/90% under ideal operating conditions. It is necessary to have a fairly constant electrical and heating demand throughout the year. The CHP systems are sized on either the base electrical or the heating load.

Heat is recovered at 70 to 90°C, depending on the manufacturer's specification, and may be used for the buildings space heating and generation of domestic hot water.

For gas spark ignition engines the recoverable heat to power ratio is in the region of 1.2:1 with a total efficiency of approximately 80 to 90%.

So that the capital investment is viable the aim is to size the CHP plant to run for the maximum number of hours at or near maximum electrical rating with as much of the available heat being utilised as possible.

CIBSE gives a rule of thumb that a CHP generator should run for a minimum of 4000 hours per year whilst recovering all waste heat to be considered viable. The simplest way to guarantee this is to size the CHP generator, based on its recoverable heat output, to meet the base heating load of the building. The base heating load is defined as the minimum constant load that can be expected throughout the year during the operation hours of the building, in many cases amounts to the domestic hot water load.

7.2.1 Sizing the CHP

The stadium itself is unlikely to have a reliable or continuous base load that is high enough to warrant a CHP to be installed for the stadium only. Therefore, it is proposed that the CHP be connected via heat exchangers to the adjacent hotel and gym facilities in the south stand.

For this initial assessment it is considered that the CHP generator should run for a minimum of 5,110 hour/year to prove feasible. This is based on a 14 hour day. As the detailed design develops a more in depth analysis of the daily CHP plant operation will be carried out, this may impact on the actual CHP capacity selected.

Based on an assumed load of the hotel and gym, a provisional CHP size of 79kWt has been considered for this assessment. The final size of the CHP would be subject to future load monitoring.

A CHP engine with the following inputs was then applied to the model, and rerun to determine the contribution of the CHP to the Carbon Emissions reductions that can be expected.

Efficiencies	
CHP Efficiency	90%
CHP Outputs	
kW Electric	50
kW Thermal	79

Based on the CHP plant operating for 5,110 hours per year, the calculation shows that an annual saving of **35.76 Tonnes of CO_2** can be expected.

The following table incorporates this saving into the carbon emissions calculations for the stadium.

Areas:	Treated Floor Area (m^2)	Carbon Emissions ($kgCO_2/m^2$.year)				Reduction
		TER	TER Annual CO2 Emissions (tonnes)	BER	BER Annual CO2 Emissions (Tonnes)	
Thermally Enclosed Areas – Be Lean	9409.5	43.9	413.08	41.3	389.55	5.69%
CHP Contribution					-35.76	
Totals After CHP	9409.5	43.9	413.08	37.6	**353.8**	**14.38%**

8 ASSESSMENT OF SUITABLE RENEWABLE ENERGY TECHNOCLOGIES 'BE GREEN'

This section analyses potential onsite renewable energy generation and considers their technical feasibility.

8.1 Renewable energy Systems

The following technologies are considered as possible renewable energy sources.

- Photovoltaic Panels
- Ground Source Heat Pump
- Solar Thermal, Hot water Generation
- Biomass Boilers
- Wind
- Hydrogen Fuel Cell

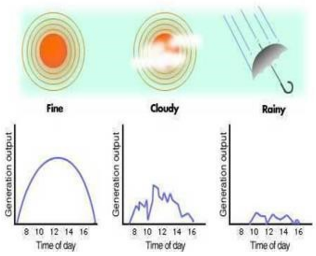
8.2 Photovoltaic Panels

Photovoltaic (PV) modules convert solar radiation into DC electricity. The PV modules are made up of several PV cells consisting of a thin layer of semiconductor material such as silicon. A semiconductor consists of two layers referred to as p-type and n-type. A flow of electrons is created between these two layers through the absorption of solar radiation, this flow of electrons produces a DC current.

The majority of PV panels are made from silicon based materials and are categorised as crystalline silicon cells of thin film cells.

Crystalline cells are available as monocrystalline or polycrystalline; monocrystalline cells have a solar energy to electricity conversion efficiency of 15-18% whilst polycrystalline cells are typically 13-16% efficient.

Photovoltaic panels should be mounted facing between southeast and southwest at an ideal angle of between 30° and 40°. Architectural and planning constraints will limit the amount of area available for such an array.



The area of photovoltaic cells required is dependent on the efficiency of the type cells used, at present there are a number of varying operating efficiencies available, which directly affects the area coverage required to give the same output (1kWp).

Types of PV modules and associated energy yield:

Photovoltaic Technologies	m2 Required to Generate 1kWp	Energy Yield per Year
Monocrystalline PV Modules	6.2	137.1kWh/m2/year

Photovoltaic panels should be mounted facing between south-east and south-west at an ideal angle of between 30° and 40°. Architectural and planning constraints will limit the amount of area available for such an array.

A lack of sufficient unshaded south facing roof area on the east stand has led to a 40kWp system to be considered for on roof space on the south stand of the stadium. The following table sets out the contribution of PV's to the reduction of Carbon emissions.

Areas:	Treated Floor Area (m^2)	Carbon Emissions ($kgCO_2/m^2$.year)				Reduction
		TER	TER Annual CO2 Emissions (tonnes)	BER	BER Annual CO2 Emissions (Tonnes)	
Thermally Enclosed Areas – Be Lean	9409.5	43.9	413.08	41.3	389.55	5.69%
CHP Contribution					-35.76	
Totals After CHP	9409.5	43.9	413.08	37.6	353.8	14.38%
PV Contribution					-26.35	
	9409.5	43.9	413.08	34.8	**327.45**	**20.73%**

8.3 **Solar Thermal, Hot Water Generation**

The use of solar heating for hot water generation would require the installation of solar panels at roof level. Ideally the panels should be aligned in a southerly direction with a tilt of between 30° and 40°. Practical and planning constraints will limit the amount of roof area available for such an array.

Solar thermal panels will also require to be mounted in areas that are unshaded. The potential therefore of incorporating solar thermal is limited for the same reasons as those discussed in the PV section.

There is also no benefit in using solar heating for this development as the proposed CHP system shall provide hot water heating throughout the year and the installation of solar panels will mean that both systems shall be competing for the same load.

8.4 Biomass Boilers

Biomass technology could be installed as part of the central heating provision. The most economical option and the best for reducing CO2 emission levels would normally be to install Biomass Boilers to act as the lead boiler to cater for the base hot water heating load with the remaining gas fuelled boilers sized to meet the total heating load and to form a standby facility.

The Bio-energy boiler system will require the installation of additional components for the storage of the wood chips or pellets used as fuel, along with the necessary transportation components to link between the storage hoppers and the boiler.

Wood chips or pellets would need to be stored in external or internal hoppers. The amount of wood chips or pellets stored will affect the choice of the silo or bunker storage types. Storage systems require sufficient space for large delivery vehicle to 'shoot' the wood fuel directly into the storage facility.

The wood chips or pellets are transferred from the storage facility by screw or similar transportation system linking between the wood hoppers and the boiler house.

The waste combustion products from the boilers (in the form of ash) can either be removed manually or automatically by the use of screw feed units direct to a collection skip. This plant ash is an inert ash and can be used as fertiliser assuming that the wood is obtained from clean sources (i.e. non industrial and not contaminated with plastics). The use of automatic removal of the plant ash will reduce maintenance costs but increase the initial capital installation costs.

Wood burning boilers have comparable combustion efficiencies as basic gas fired systems. The fluing requirements for modern wood fired boilers are comparable with those of gas fired systems and the emissions are similar to that of gas fired units. Where the heat output to water is above 300kW (400kW input) there is a requirement under the clean air regulations when using waste wood to install continuous flue monitoring of the waste gas products. These systems are relatively expensive to install and maintain.

Biomass Boilers can also operate on a modulating basis to vary the heat output. Boilers can operate as low as 30% of their maximum load they do, however require additional plant room area then the standard models.

The installation of Biomass Boiler with pellet storage as the main heating boiler is not usually a viable option when CHP plant is proposed, as the majority of the base heating would be provided by CHP. Biomass boilers also cause other issues such as fuel storage, which need to be maintained in a dry storage area. With space being at a high premium in the proposed stadium, it is not anticipated that biomass fuel store will be a provision that is easy to make.

Biomass boilers will require the associated flues to terminate above the highest point of the building presenting obvious issues in this high rise development. This will mean that the architectural character of the building will be fundamentally changed to these flu requirements.

Biomass is therefore discounted as a feasible and viable option for the stadium.

8.5 Ground Source Heat Pump

Ground source systems provide the opportunity to obtain both heating and cooling via water to water or water to refrigerant heat pumps. This technology can reduce the demand for conventional energy and thus reduce overall CO2 emissions. They do however have limited effect in reducing CO2 emission levels compared to the other renewable energy technologies.

Geothermal technology can be utilised virtually anywhere in the UK and be installed under landscape areas and car parks. A more efficient and less expensive option is to utilise a nearby body of water for heat extraction/rejection.

Geothermal systems provide the opportunity to connect to water-to-water heat pump units for heat rejection and to VRF heat pump units for cooling and heating.

VRF system heat pumps using inverter controls on the compressors can provide improved energy efficient operation, where the heating and cooling input are mixed so that the actual load is limited to the resultant difference thereby further reducing the energy input.

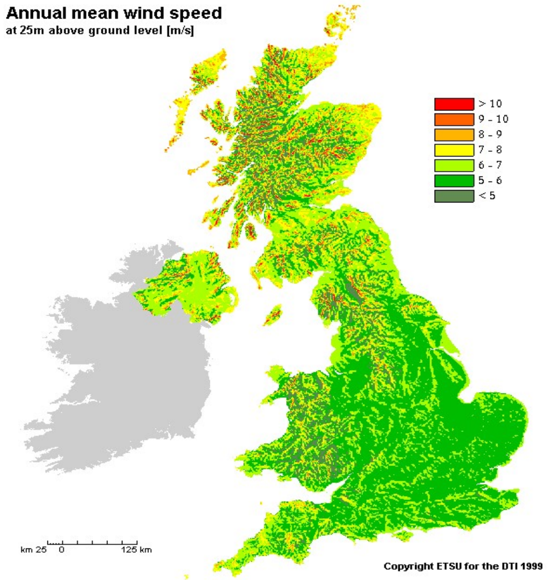
Because the site footprint for this development is limited a solution of directionally drilled boreholes has been considered as the only viable option. However, the drilling of boreholes and installation of the system would create disruption to programme, and come at a very high cost for a relatively low gain.

Additionally, installing a ground source system will require approval from the environment agency to pump heat in and out of the ground. As a large system would be required for the stadium, it is not known how the ground conditions will react to such a large system, and there are risks associated with ecology that will affect the size of system that will be possible.

It has been concluded that a GSHP is not viable due to constrained site, ecological implications and conflict with CHP for base heating load.

8.6 Wind Power.

To evaluate the suitability for wind power generation it is necessary to undertake a full survey and analysis for the site, to ascertain the likely wind speeds available on the site to support the viability of wind generation.



British Wind Energy Association (BWEA) wind data base suggests that wind speed at the site would be around 4-6m/s at 25m could support small wind turbine, however, annual load generation will be relatively low.



Installation of wind turbines would certainly impact negatively on the architectural character of the stadium. This issue aside, wind turbines can have a detrimental effect on telecommunications in the vicinity of their location. Given the extent of telecommunication that would be installed in the stadium (Wifi, Mobile phone operators, TV broadcasting, etc.), the size of possible turbines is limited for this reason.

Another limiting factor in the installation of wind turbines would be location of the site in an urban area. Wind patterns in urban areas can be very turbulent, and are not the best conditions to yield a good output from small scale wind turbines.

In addition, planning requirements from the local authority regarding potential noise from the wind generators would have to be considered. It is likely that during the day sound levels would not be noticeable but at night with lower background levels this could be invasive to the buildings particularly for the residential blocks.

Other important considerations, would be the potential impact on wild birds.

It would therefore be reasonable to conclude that based on the above information, even without a technical review the installation costs, the requirements for maintenance and the installation restraints are unlikely to support the installation of electrical wind generation for this development.

8.7 Hydrogen Fuel Cells

Hydrogen fuel cells have been considered for use within the hotel and serviced apartment building but have been discounted due to the current lack of a commercially viable source of hydrogen. Many current installations are known to be running on natural gas until the hydrogen becomes available.

There is currently no commercially available fuel cell technology in Europe.

9 OVERHEATING RISK ASSESSMENT

In accordance with the new greater London Authority guidance, an overheating risk assessment has been carried out for the proposed development.

9.1 TM52

The risk of overheating is determined through a TM52 assessment. A space is considered to have no risk of overheating where at least two of the criteria are met.

Criteria 1: Hours of Exceedance

The number of hours that the actual operative temperature in any given occupied zones one degree (K) or more above the limiting (maximum) temperature shall not occur for more than 3 percent of occupied hours, for the period 1st May to 30th September.

Criteria 2: Daily Weighted Exceedance

The weighted Exceedance shall be less than or equal to 6 in any given day.

Criteria 3: Upper Limit Temperature

To set an absolute maximum value for the indoor operative temperature, the operative temperature shall never be greater than 4 degrees (k) above the maximum acceptable temperature.

9.2 Overheating Risk

The TM52 assessment was carried out for thermally enclosed spaces in accordance with the guidance set out in TM49.

The assessment was carried out within IES VE software, and based on NCM profiles applied to each relevant space.

The TM52 assessment is summarised below:

Total number of Occupied thermally enclosed spaces	92
Number of Spaces Passing TM52	91
Number of Spaces Failing TM52	0
Number of Unoccupied Spaces	1

10 USAGE PROFILE REDUCTION

The unique usage of the Stadium and the East Stand is not reflected in the IES Software Modelling and standard usage profile templates prescribed by the National Calculation Methodology (NCM).

The building is only used to full capacity during Major Events and largely unoccupied for the remainder of the time when the environmental conditions are automatically set back by the BMS system to save energy. Only relatively small parts of the building will be in use for other, non-major, events such as conferences and banqueting.

ME Engineers have investigated sensible methods to estimate the equivalent Carbon shortfall when compared to the annual shortfall calculated by the standard NCM compliance methodology.

For the purposes of these calculations, the 2016 and 2017 events schedule has been utilised to form the basis of usage.

Although the majority of Major Events will not result in full utilisation of the proposed hospitality areas in the East Stand (for example, hospitality usage for a concert is likely to be low), a conservative 100% utilisation has been assumed for these approximation calculations as not to restrict future usage.

To allow for event build up, the same quantity of days has been assumed to allow partial occupation at 40% load.

For the remainder of the year the building will be mostly unoccupied, except for non-major events, however a conservative 20% utilisation has been assumed in the calculation.

This is consistent with the estimate, used elsewhere in the application, of 90% of non-major event days in the East Stand being attended by fewer than 300 people (see Transport Assessment, Section 5.2).

As this is approximately 5% of the East Stand's c.6,500 capacity, 20% usage allowance throughout the year except Major Event days is therefore robust.

The calculation criteria is summarised as follows:

- 52 major event days per year @ 100% utilisation
- 52 build-up days before/after major event days per year @ 40% utilisation
- 261 days per year when building is unoccupied/lightly used for non-major events @ 20% utilisation for plant set back mode.

Pro rata Building occupation and usage:

(52 x 100%) + (52 x 40%) + (261 x 20%) = 125 days

The total CO2 Shortfall calculated using the NCM methodology is 58.95 tonnes CO2 per year.

The equivalent daily pro rata energy shortfall equates to (58.95 / 365) 0.162 tonnes CO2 per day

Using the pro rata building occupation and usage of 125 days per year, the equivalent shortfall – based upon estimated utilisation **equates to 20.19 Tonnes of CO2 per year**.

11 CONCLUSION

The design solutions for the development will endeavour to maximise the provision of passive energy saving measures before considering any active techniques.

The Principle of 'Be Lean' has continued as the architectural form of the building has developed during this period to achieve as thermally efficient a building as possible without detracting from the architectural character of the stadium. This forms part of the passive design proposals, incorporated to reduce the base energy levels as reflected in the carbon emissions calculated for the stadium.

The east stand has been modelled to assess the energy consumption using a dynamic energy simulation, and from this the carbon emissions for the Thermally Enclosed has been calculated, and aggregated to give an overall stadium wide reduction of 5.69% over part L from 'Be Lean' measures alone.

As part of the 'Be Clean' requirement, a CHP scheme outputting 79kW thermal has been assessed. This provisional size of CHP is envisaged to provide for the base domestic hot water demand of the stadium.

With an overall efficiency of 90% for the CHP unit, and an expected running time of 5,110 hours annually, the calculated saving in carbon emissions due to CHP is 35,760 kg CO_2 per year. Factoring this saving into the 'Be Lean' measures this increases the reduction to 14.35% over part L baseline emissions rates.

Various renewable technologies have been reviewed for inclusion into the redevelopment of the grounds, as part of the London Plan Energy Hierarchy 'Be Green'. Following this review it was concluded that the potential of renewable energy technologies was extremely limited, and in some cases not viable at all.

However, it was considered that a PV installation was feasible on the roof of the adjacent south stand, and a 40kWp system was therefore incorporated. The 'Be Green' measures further reduced the carbon emissions by 26,350 kg CO_2 per year, bringing the reduction to 20.73% over part L baseline emission rates.

The London Plan requires a reduction of 35% of carbon emissions. This means that based on current designs, CHP and PV scheme, the stadium is expected to fall short of this target by 14.27%. This equates to 58,950 kg CO_2 per year.

When taking into account the actual usage profile of the stadium, the actual carbon emissions shortfall equates to 20,190 kg CO_2 per year.

12 APPENDIX A - BRUKL

12.1 BRUKL – Be Lean

12.2 BRUKL – Be Clean

12.3 BRUKL – Be Green