# Energy Statement

## Sondheim (Ambassadors) Theatre

For Delfont Mackintosh Theatres

May 2016

XCO2 energy

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About us:
XCO2 Energy are a low-carbon consultancy working in the built environment. We are a multi-disciplinary company consisting of both architects and engineers, with specialists including CIBSE low carbon consultants, Code for Sustainable Homes, EcoHomes and BREEAM assessors and LEED accredited professionals.

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## Executive Summary

This report assesses the predicted energy performance and carbon dioxide emissions of the proposed development at Sondheim (previously Ambassadors) Theatre, based on the information provided by the design team. The site is located along the north side of West Street in central London, close to both Covent Garden and Leicester Square stations, within the London Borough of Camden.

The project brief revolves primarily around the creation of a 450 seat theatre auditorium. Public areas and rehearsal facilities are also to be improved with the intention of retaining the facade and certain period features of the original architecture. This internal reworking consists of the demolition and rebuild of the existing Ambassadors Theatre, as renovation in its current form has been deemed unviable and unlikely to comply with Building Regulations.

The methodology used to determine the $CO_2$ emissions is in accordance with the London Plan's three-step Energy Hierarchy (Policy 5.2A) outlined below. The new building has been compared to a notional baseline constructed to current Part L 2013 Building Regulations.

**1. Be Lean - use less energy**
The first step deals with the reduction in energy use, through the adoption of sustainable design and construction measures.

In accordance with this strategy, this development will incorporate a range of energy efficiency measures including levels of insulation beyond Building Regulations, the installation of high performance glazing and a mixture of natural ventilation and mechanical ventilation with heat recovery. The implementation of these measures would potentially reduce regulated $CO_2$ emissions by 22.6%, when compared to the baseline.

**2. Be Clean - supply energy efficiently**
The second strategy takes into account the efficient supply of energy, by prioritising decentralised energy generation.

The London Heat Map indicates the proposed development is located approximately 700m from the Whitehall District Heating Scheme. In addition to the distance from the site to this existing network, which would render connection prohibitively expensive, it is expected that this network serves Government buildings only, and connection to a privately owned development would be unfeasible.

An alternative option of energy generation is on-site CHP system to meet domestic space heating and hot water demand. However the use of CHP is deemed not viable for such a small development. Therefore, heating will be provided by high efficiency condensing boilers, coupled with heat recovery from exhaust air from the auditorium and rehearsal areas. This efficient technology will ensure a reduction in regulated $CO_2$ emissions.

**3. Be Green - use renewable energy**
The third strategy covers the use of renewable technologies.

A feasibility study was carried out for this development and a range of renewable technologies were analysed. The analysis included a biomass heating system, ground-source heat pumps, air-source heat pumps, photovoltaic panels, solar thermal and wind turbines.

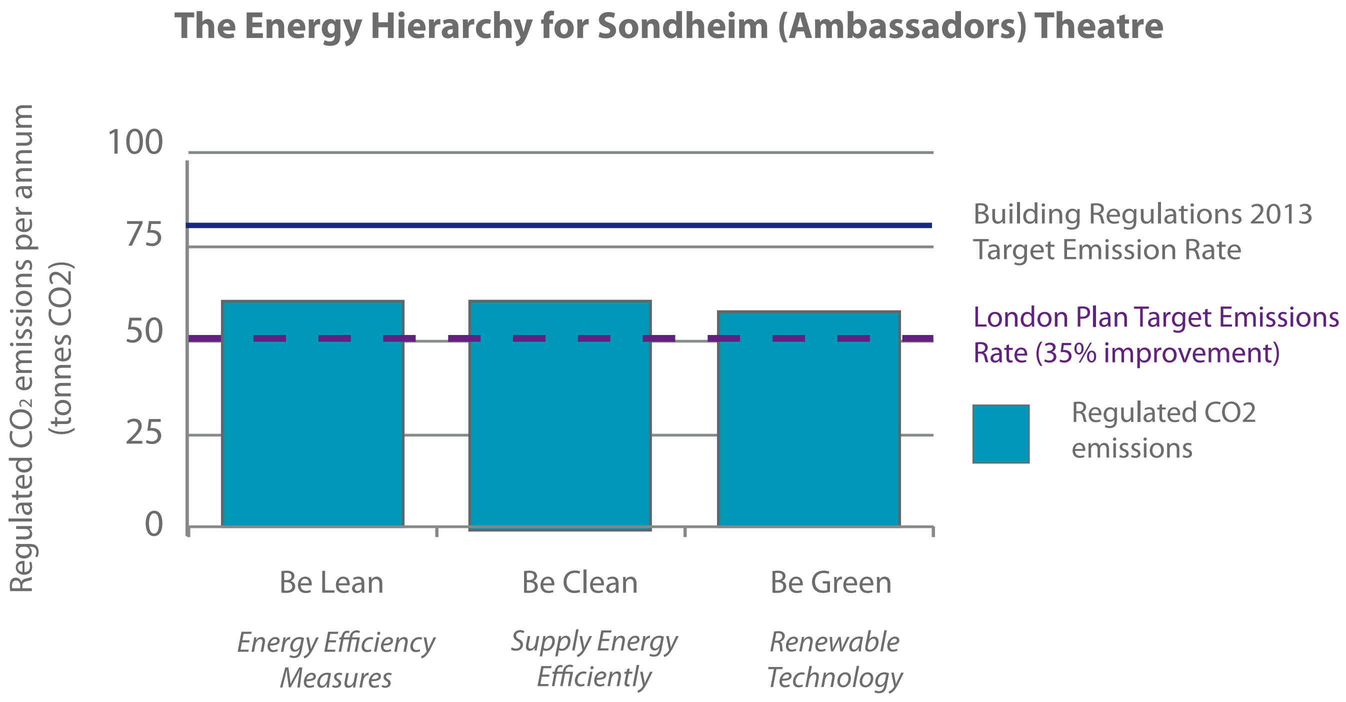
The analysis demonstrated that photovoltaic panels were the most suitable technology. The installation of approximately 35m$^2$ of photovoltaic panels will reduce the development's regulated $CO_2$ emissions by a further 3.1% over the baseline buildings.

## Conclusion

The graph below provides a summary of the regulated $CO_2$ savings at each stage of the London Plan Energy Hierarchy. The dashed blue line indicates the London Plan Target.

It can be seen on the graph that significant savings are made through the provision of efficient building fabric and services systems, with further reductions made through the installation of renewable technologies.

The table on the following page demonstrates the regulated and unregulated emissions.



**Carbon Dioxide Emissions After Each Stage of the Energy Hierarchy**

| | Carbon dioxide emissions (tonnes $CO_2$ per annum) | |
|---|---|---|
| | Regulated | Unregulated |
| Building Regulations 2013 Part L | 77.5 | 54.2 |
| After energy demand reduction | 60.0 | 54.2 |
| After efficient energy supply | 60.0 | 54.2 |
| After Renewable technologies | 57.5 | 54.2 |

The proposal will achieve a 25.7% reduction in regulated $CO_2$ emissions over the Part L 2013 baseline, which falls short of meeting the London Plan target of 35% set for all major developments.

Therefore a carbon offsetting payment of £19,442 will be owed based on London Borough of Camden's rate of £2,700/t$CO_2$. The table below illustrates the regulated $CO_2$ savings at each stage of the energy hierarchy.

**Regulated Carbon Dioxide Savings From Each Stage of the Energy Hierarchy**

| | Regulated Carbon Dioxide Savings | | |
|---|---|---|---|
| | Tonnes $CO_2$ / year | % over last stage | % over baseline |
| Savings from energy demand reduction | 17.5 | 22.6% | 22.6% |
| Savings from efficient energy supply | 0.0 | 0.0% | 0.0% |
| Savings from renewable energy | 2.4 | 4.0% | 3.1% |
| Total Cumulative Savings | 19.9 | 25.7% | 25.7% |

## Introduction

The application proposes a new dedicated theatrical transfer house to accommodate productions that have come to the end of their run in the subsidised sector. The proposed theatre will provide the opportunity for subsidised productions that would not otherwise have the opportunity to transfer to the West End.

It is currently very difficult for successful subsidised productions to transfer to the West End because the internal arrangement of most West End theatres differs substantially from more modern arrangements of the subsidised sector. The vast majority of West End theatres have traditional 'proscenium arch' stages whilst most originating theatres in the subsidised sector have more modern arrangements, such as thrust stages or are arranged 'in the round'. This means that a transfer has to be restaged, often at huge cost to the originating subsidised theatre and eroding the original artistic intention of the director, to the detriment of the audience experience.

There are currently no dedicated theatres in the West End to which productions arising in the subsidised theatre sector can transfer in the event of critical acclaim or audience demand. Typically, publically subsidised productions are pre-programmed in advance at the originating playhouses and run for a period of 6-8 weeks only. The proposed new theatre would provide an opportunity for successful subsidised shows to transfer to the West End for a further 8-16 weeks.

This increased run would provide the subsidised sector with an opportunity to increase revenue at a time of consistently squeezed funding pressures and cuts. It will also diversify the offer for theatre goers and open up a range of quality productions to be viewed as originally intended, enhancing the range and quality of productions and cementing London's status as a world cultural capital in theatre.

Such is the shortage of space in the West End that very many successful subsidised productions are simply never seen again after their original run. Others, due to the physical difficulties of restaging in a proscenium setting simply have no prospect of transfer at all, even if a space in the West End were available.

In order to create a modern and flexible internal arrangement, it is proposed that much of the building is demolished and rebuilt behind the retained West Street façade and the stucco return onto Tower Court. Historically significant elements of plasterwork are to be relocated within the new theatre.

The proposed theatre will then provide a much needed resource for the transfer of productions from the subsidised sector. In turn, the subsidised sector will be able to secure a longer run for critically acclaimed productions that would otherwise close for good, frustrating a large unmet demand from the audience. Thus, the cultural life of the West End will be enhanced along with the audience's opportunity to see good quality subsidised productions for a longer period of time. In their turn, the subsidised sector will realise the opportunity to increase their revenue in an environment of constantly reduced funding.

The proposals have attracted wide ranging support from within the industry. Nicholas Hytner (former Artistic Director of the National Theatre) summarised the situation as:

*"Over recent years, a large number of the most successful and ambitious productions in the subsidised theatre sector have been unable to find a venue for further life, leaving a significant potential audience without an opportunity to see work it would like to see. Very often this work would not justify the risks involved in a transfer to a large West End theatre. Cameron Mackintosh's plans for his new 450 seat theatre would greatly increase the chances of a future life for successful productions form theatres like the Dorfman, the Almeida, the Royal Court and the Donmar as well as offering a suitable venue for regional transfers."*

Full details of the need for a dedicated transfer house and how the proposed theatre meets that need is set out in the Design and Access Statement and Planning and Heritage Statement that accompany this application.

The site is located along the north side of West Street, near the popular Seven Dials area of central London's Theatreland, within the Borough of Camden.

The project brief revolves primarily around the creation of a 450 seat theatre auditorium. Public areas and rehearsal facilities are also to be improved with the intention of retaining the facade and certain period features of the original architecture. This internal reworking consists of the demolition and rebuild of the existing Ambassadors Theatre, as renovation in its current form has been deemed unviable. The redevelopment of the Ambassadors Theatre is aimed to improve the audience viewing experience during West End productions, offer educational opportunities in Camden, and provide rehearsal space for theatre companies.

This document demonstrates how the development addresses the relevant energy policies of the London Plan 2015 (Further Alterations to the London Plan) and the requirements of Camden Council as outlined in their Core Strategy 2010 - 2025.

London Plan Policy 5.2 and Camden's Local Development Framework set out the target reductions of regulated carbon dioxide emissions expected of major developments in London and in Camden. The target below is expressed as a minimum improvement over the Target Emission Rate (TER) outlined in the national Building Regulations Part L 2013:

- 2013-2016: 35% from Part L 2013

Camden Core Strategy (2010) Policy 13 states the following in relation to sustainable redevelopment in the local area:

*Given the large proportion of development in the borough that relates to existing buildings, we will expect proportionate measures to be taken to improve their environmental sustainability, where possible.*

The Camden Core Strategy also recommends the following on energy strategies for proposed developments within the Borough:

***Policy 13.11***
*Buildings can also generate energy, for example, by using photovoltaic panels to produce electricity, or solar thermal panels, which produce hot water. Once a building and its services have been designed to make sure energy consumption will be as low as possible and the used of energy efficient sources has been considered, the Council will expect developments to achieve a reduction in carbon dioxide emissions of 20% from on-site renewable energy generation (which can include sources of site-related decentralised renewable energy) unless it can be demonstrated that such provision is not feasible.*

***Policy 13.16***
*The Delivering a Low Carbon Camden report concludes that the most cost-effective way for Camden to meet its carbon reduction targets is through a local energy generation and distribution system served by combined heat and power (CHP). CHP systems typically supply buildings with heat and power (usually electricity) generated on-site or nearby, therefore avoiding the losses which occur in transmitting electricity from plants outside London.*

***Policy 13.17***
*New decentralised energy networks negotiated through the planning system are most likely to begin in, and expand out from, the growth areas of King's Cross, Euston, Tottenham Court Road, West Hampstead Interchange and Holborn due to the expected scale and mix of development.*

In particular this report refers to how the development addresses the energy policies of section 5 of the London Plan, including:

- Policy 5.2 Minimising Carbon Dioxide Emissions
- Policy 5.3 Sustainable Design and Construction
- Policy 5.5 Decentralised Energy Networks
- Policy 5.6 Decentralised Energy in Development proposals
- Policy 5.7 Renewable Energy where feasible
- Policy 5.9 Overheating and Cooling

The methodology employed to determine the potential $CO_2$ savings for this development is in accordance with the three step Energy Hierarchy outlined in the London Plan:

- Be Lean - Improve the energy efficiency of the development
- Be Clean - Supply as much of the remaining energy requirement with low-carbon technologies such as combined heat and power (CHP)
- Be Green - Offset a proportion of the remaining carbon dioxide emissions using renewable technologies.

Energy calculations were carried out using Dynamic Simulation Modelling in line with Building Regulations Part L 2013. The buildings have been compared to a notional building constructed to current Part L 2013 Building Regulations.

The data from DSM was used in order to give site wide energy consumption and $CO_2$ emissions. Sample DSM outputs are provided in Appendix B.

A BREEAM pre-assessment has been undertaken with a target to achieve an 'Excellent' rating, as detailed in Camden Council's Sustainability Planning Guidance (CPG 3, September/2013) and Local Development Framework (November/2010), details of which can be found in the accompanying Sustainability Statement.

## Demand Reduction (Be Lean)

### Passive Design Measures

**Enhanced Building Fabric**

The heat loss of different building elements is dependent upon their U-value. The lower the U-value, the better the level of insulation of a particular element. A building with low U-values has a reduced heating demand during the cooler months.

The new build portions of the proposed development at Sondheim (Ambassadors) Theatre will incorporate high levels of insulation and high-performance glazing on all of the facades to significantly reduce the demand for space heating. The retained facades will also be internally insulated (refer to the table below).

**Non-domestic U-Values (W/m²K)**

| Element | Building Regulations | Proposed | % Improvement |
|---|---|---|---|
| Walls | 0.35 | 0.15 | 57% |
| Floor | 0.25 | 0.10 | 60% |
| Roof | 0.25 | 0.10 | 60% |
| Windows | 2.2 | 1.60 | 37% |
| Retained walls | 0.7 | 0.15 | 78% |

**Air Tightness**

Heat loss may also occur due to air infiltration. Although this cannot be eliminated altogether, good construction detailing and the use of best practice construction techniques can minimise the amount of air infiltration into a building.

Current Part L Building Regulations (2013) sets a maximum air permeability rate of $10m^3/m^2$ at 50Pa. The development is likely to improve upon this to achieve $3m^3/m^{2.hr}$ at 50Pa through the application of best practice construction techniques.

**Daylight**

The building spaces will be supplied with natural light where possible, but the specific lighting needs of a theatre will demand tight control of the visual environment and hence will result in additional energy usage.

### Active Design Measures

**High Efficacy Lighting**

The development intends to incorporate low energy light fittings throughout the non-performance areas of the building. 100% of all non-performance light fittings will be specified as low energy lighting, and will accommodate LEDs, compact fluorescent (CFL's) or fluorescent luminaries where possible.

Internal areas of infrequent use will be fitted with occupant sensors, whereas day lit areas will incorporate daylight sensors where appropriate.

**Heat Recovery Ventilation**

Mechanical ventilation is proposed to keep the theatre at optimum comfort conditions, as stated in planning submission.

The ventilation systems will keep the auditoria slightly pressurised with respect to the outside air to prevent infiltration of unfiltered and untreated air into the space. Unfiltered air particularly from street level contains pollutant particulates and gases mainly from vehicle exhaust fumes. Allowing cold air into the theatre increases the winter heating load and allowing hot air to enter in the summer adds to the summer cooling load. The mechanical ventilation system will include heat recovery in order to achieve ventilation in the most energy-efficient way.

### Active Cooling

**Cooling Demand**

Although the theatre will be designed to reduce the risk of overheating as is deemed feasible, high efficiency air-cooled chillers will be installed for the provision of space cooling.

### Energy Demand

The table below shows a breakdown of energy consumption for heating and electricity demand. These figures indicate baseline figures and Lean figures, once energy efficiency measures have been applied.

This table demonstrates the energy savings achieved through energy efficiency measures (Lean stage of the Energy Hierarchy).

**Breakdown of Energy Consumption and $CO_2$ Emissions**

| | Baseline Buildings | | | Lean | | |
|---|---|---|---|---|---|---|
| | Energy (kWh/year) | $CO_2$ emissions ($kgCO_2$/year) | $CO_2$ ($kgCO_2$/$m^2$) | Energy (kWh/year) | $CO_2$ emissions ($kgCO_2$/year) | $CO_2$ ($kgCO_2$/$m^2$) |
| Hot Water | 12,500 | 2,700 | 1.1 | 13,260 | 2,860 | 1.2 |
| Space Heating | 36,680 | 7,920 | 3.4 | 16,080 | 3,470 | 1.5 |
| Cooling | 12,710 | 6,434 | 2.7 | 12,100 | 6,120 | 206 |
| Auxiliary | 65,340 | 33,060 | 14.0 | 53,120 | 26,880 | 11.4 |
| Lighting | 54,010 | 27,330 | 11.6 | 40,730 | 20,610 | 8.8 |
| Equipment (not incl. in Part L) | 104,450 | 54,210 | 23.0 | 104,450 | 54,210 | 23.0 |
| Total Part L | 181,260 | 77,440 | 32.9 | 135,290 | 59,940 | 25.5 |
| Total (incl. Equip) | 285,710 | 131,650 | 55.9 | 239,740 | 114,150 | 48.5 |

### $CO_2$ Emissions

The table below shows the regulated and unregulated carbon dioxide emissions for the baseline scheme and the emissions after the passive and active lean measures have been implemented.

A saving of 22.6% is expected from the regulated $CO_2$ emissions while an overall $CO_2$ savings of 13.3% is expected to be achieved based on the total $CO_2$ emissions of the development.

**$CO_2$ Emissions Breakdown**

| | Carbon Dioxide emissions (tonnes $CO_2$ per annum) | | |
|---|---|---|---|
| | Regulated | Unregulated | Total |
| Baseline building | 77.5 | 54.2 | 131.7 |
| After energy demand reduction (Lean) | 60.0 | 54.2 | 114.2 |

| | Carbon dioxide savings (tonnes $CO_2$ per annum) | | Carbon dioxide savings from baseline (%) | |
|---|---|---|---|---|
| | Regulated | Total | Regulated | Total |
| Savings from energy demand reduction | 17.5 | 17.5 | 22.6% | 13.3% |

## Heating and Cooling Infrastructure (Be Clean)

### Energy System Hierarchy

The energy system for the development has been selected in accordance with the London Plan decentralised energy hierarchy. The hierarchy listed in Policy 5.6 states that energy systems should consider:

1. Connection to existing heating and cooling networks
2. Site wide CHP network
3. Communal heating and cooling

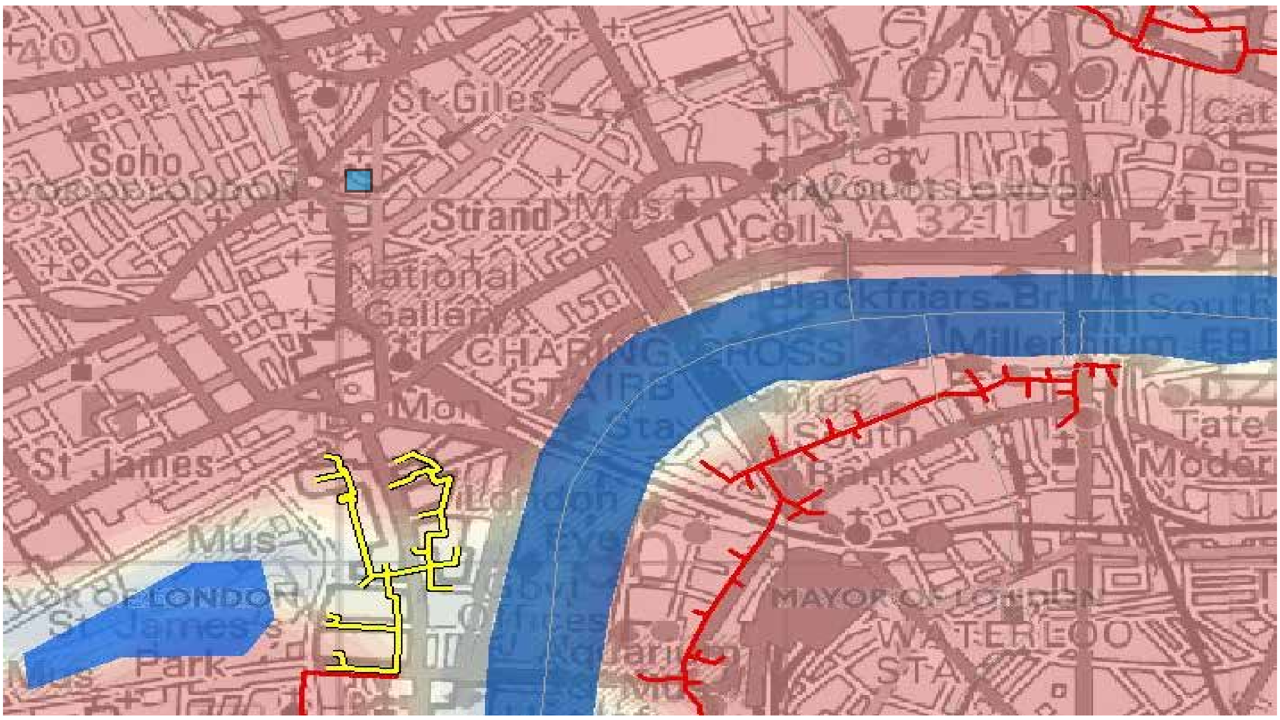
Local supply of heat and power minimise distribution losses, thereby achieving a greater efficiency and reducing $CO_2$ emissions, when compared to the individual systems.

In a communal energy system, energy in the form of heat, cooling, and/or electricity is generated from a central source and distributed via a network to surrounding residencies and commercial units.

### Connection to Existing Low Carbon Heat Distribution Networks

The London Heat Map identifies existing and potential opportunities for decentralised energy projects in London. It builds on the 2005 London Community Heating Development Study. An excerpt from the London Heat Map below shows the energy demand for different areas. The map also highlights any existing and proposed district heating systems within the vicinity of the development.

The proposed development is located approximately 700m from the nearest District Heating Scheme, located in Whitehall. In addition to the distance from the site to this existing network, which would render connection prohibitively expensive, it is expected that this network serves Government buildings only, and connection to a privately owned development would be unfeasible. Furthermore, the cost of connection, including civil works and pipeline construction, are not considered to be financially viable.




London Heat Map | Existing District heat networks in the area | Proposed District heat networks | Approximate site location

## Combined Heat and Power (CHP)

Combined Heat and Power (CHP) was considered as an option to create decentralised energy on the site. However due to the small scale of the project and few buildings the CHP would serve, it is not deemed an appropriate technology.

Micro CHPs are a relatively new technology and are currently an unproven way of reducing $CO_2$ emissions. They are an expensive and high maintenance solution for the small amount of electricity they generate in return. We would suggest that a larger portion of energy and $CO_2$ can be saved through the provision of alternative high efficiency systems and the installation of renewable technologies.

An example of a CHP engine (courtesy of Baxi)

## Most Appropriate Systems for this Building

The most efficient system for the production of hot water and space heating would be the installation of a high efficiency gas boilers, coupled with heat recovery from exhaust air from the auditorium and rehearsal areas. This will provide the theatre with a flexible and controlled method of heating water and creating optimum conditions within the auditorium.

Most spaces will be conditioned through high efficiency air cooled chillers. Both rehearsal spaces and front of house areas, such as the bar and foyer, will be heated and cooled by high efficiency air source heat pumps.

## $CO_2$ Emissions

The table below shows the regulated and unregulated carbon dioxide emissions for the baseline scheme as well as the reduced emissions once Lean (energy efficiency) and Clean (high efficiency condensing boilers) measures have been implemented.

The tables below illustrate that at the Clean stage of the energy hierarchy the reduction in regulated $CO_2$ emissions remains at 22.6% over the baseline buildings. This is due to the lack of suitable Clean technology. Therefore at Clean stage the reduction in total $CO_2$ emissions is expected to be 13.3%.

### $CO_2$ Emissions Breakdown

| | Carbon Dioxide emissions (tonnes $CO_2$ per annum) | | |
|---|---|---|---|
| | Regulated | Unregulated | Total |
| Baseline building | 77.5 | 54.2 | 131.7 |
| After energy demand reduction (Lean) | 60.0 | 54.2 | 114.2 |
| After efficient technology (Clean) | 60.0 | 54.2 | 114.2 |

| | Carbon dioxide savings (tonnes $CO_2$ per annum) | | Carbon dioxide savings from baseline (%) | |
|---|---|---|---|---|
| | Regulated | Total | Regulated | Total |
| Savings from energy demand reduction | 17.5 | 17.5 | 22.6% | 13.3% |
| Savings from clean technologies | 0.0 | 0.0 | 0.0% | 0.0% |

## Renewable Energy (Be Green)

Methods of generating on-site renewable energy (Green) were assessed, once Lean and Clean measures were taken into account.

The development at Sondheim (Ambassadors) Theatre will benefit from an energy efficient building fabric which will reduce the energy consumption of the proposed development in the first instance. A high efficiency condensing boiler and highly efficient chillers will be installed to further reduce $CO_2$ emissions in the development. A range of renewable technologies were subsequently considered including:

- Biomass
- Ground/water source heat pumps
- Air source heat pump
- Wind energy
- Photovoltaic panels
- Solar thermal panels

In determining the appropriate renewable technology for the site, the following factors were considered:

- $CO_2$ savings achieved
- The site constraints
- Pay back and maintenance costs
- Any potential visual impacts

The following pages discuss each of the renewable technologies listed above.

## Biomass - Not adopted

A biomass system designed for this development would be fuelled by wood pellets due to their high energy content. Wood pellets also require less volume of storage than other biomass fuels, require less maintenance and produce considerably less ash residue.

The options for this development include the use of biomass in the primary boiler as an alternative to gas, or a biomass CHP in place of the gas boiler.

### Biomass boiler

A biomass system would not be an appropriate low-carbon technology for the site for the following reasons:

- the burning of wood pellets releases substantially more NOx emissions than gas boiler equivalents. This would significantly reduce the air quality of the site which is located in central London
- storage and delivery of wood pellets would be difficult due to the site constraints and the lack of local biomass suppliers. Pellets would have to be transported from elsewhere in the UK

### Biomass CHP

For the size of system required for this development, a biomass CHP is still in its infancy and brings a number of financial and technological risks. Therefore this option is not considered feasible.

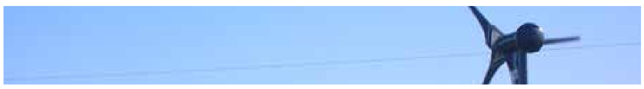
For the reasons listed above, biomass is not considered feasible for this development. Site specific analysis for biomass can be found in appendix A.

## Wind Energy - Not adopted

Due to the limited space on site, building-integrated turbines would be most suited to the development, as opposed to stand alone turbines.

Based on the current design of the development, the roof-mounted wind turbine would need to be located above the highest neighbouring buildings. Therefore it is estimated that only a very small number of turbines could be installed on site, which would only offer very low $CO_2$ savings. In addition, a roof-mounted wind turbine would have a significant visual impact and would not comply with the architectural vision of maintaining the original facade and building character.

For these reasons, wind turbines would not be feasible for this project. Site specific analysis for Wind turbines can be found in Appendix A.



### Photovoltaic Panels - Adopted

Four types of solar cells are available on the market at present and these are mono-crystalline, poly-crystalline, thin film and hybrid panels. Although mono-crystalline and hybrid cells are the most expensive, they are also the most efficient with an efficiency rate of 12-20%. Poly-crystalline cells are cheaper but they are less efficient (9-15%). Thin film cells are only 5-8% efficient but can be produced as thin and flexible sheets.

Photovoltaics are considered a suitable technology for this development for the following reasons:

- the development provides sufficient amount of roof space for the installation of PV panels
- PV arrays are relatively easy to install when compared to other renewable systems
- PV panels provide a significant amount of $CO_2$ savings

Based on the reasons above, photovoltaics would be the most suitable renewable technology for the proposed development. Site specific analysis for photovoltaics can be found in Appendix A

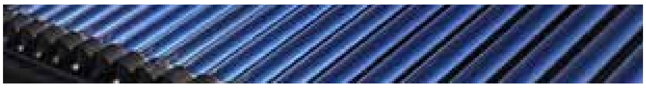
### Solar Thermal Panels - Not adopted

Solar thermal arrays include evacuated tubes and flat plate collectors. Evacuated tubes are more efficient, produce higher temperatures and are more suited to the UK climate when compared to flat plate collectors. Evacuated tubes tend to be more costly than flat plate collectors.

The use of solar thermal for this development would be limited to hot water only. The use of solar thermal for space heating would not be practical as it is not required when solar thermal is most effective (during the summer months).

Furthermore solar thermal arrays would require additional plumbing which is likely to increase financial costs.

For these reasons, solar thermal technology would not be the most feasible option for the proposed development. Site specific analysis for solar thermal can be found in Appendix A.



### Ground Source Heat Pumps (GSHP) - Not adopted

A ground source heat pump system for the site would include a closed ground loop where a liquid passes through the system, absorbing heat from the ground and relaying this heat via an electrically run heat pump within the building.

A ground source heat pump system would deliver space heating through a low temperature efficient distribution network such as underfloor heating. The installation of ground source loops significantly increases the construction time at the beginning of the project and adds to the capital cost of the project.

For this reason, GSHPs would not be feasible for this development. Site specific analysis for GSHPs can be found in Appendix A.

### Air Source Heat Pumps (ASHP) - Not adopted

Air source heat pumps (ASHPs) employ the same technology as ground source heat pump (GSHPs). However, instead of using heat exchangers buried in the ground, heat is extracted from the external ambient air.

The use of air source heat pumps would not be feasible for the following reasons:

- ASHP evaporators would need to be located externally. Any noise associated with the units could potentially be an issue given the performance-based purpose of the building
- there is also insufficient space to house all the ASHP units on the roof, and the position of the units externally is likely to have a significant visual impact

ASHPs would not be preferable for the proposed development due to the reasons listed above. Site specific analysis for ASHPs can be found in Appendix A.

## Renewable Energy Summary

The table below summarises the factors taken into account in determining the appropriate renewable technology for this project. This includes estimated capital cost, simple payback, lifetime, level of maintenance and level of impact on external appearance.

The final column indicates the feasibility of the technology in relation to the site conditions (10 being the most feasible and 0 being infeasible).

It is important to note that the information provided is indicative and are based upon initial estimates.

The feasibility study clearly demonstrates that photovoltaics would be the most feasible renewable technology for the redevelopment of Sondheim (Ambassadors) Theatre.

### Sondheim (Ambassadors) Theatre

| | | % Total $CO_2$ Reduced from baseline | Tonnes $CO_2$ per year | Lifetime | Maintenance | Impact on External Appearance | Site Feasibility |
|---|---|---|---|---|---|---|---|
| Biomass |  | | 2.7 | 20yrs | High | High | 3 |
| PV |  | | 3.1 | 25yrs | Low | Med | 9 |
| Solar Thermal |  | | 1.8 | 25yrs | Low | Med | 3 |
| GSHP |  | | 4.8 | 20yrs | Med | Low | 1 |
| ASHP |  | | 3.3 | 20yrs | Med | Med | 8 |
| Wind |  | | 2.1 | 25yrs | Med | High | 2 |

0 5 10 15 20
%

Adopted technology

## Layout of Photovoltaic Panels

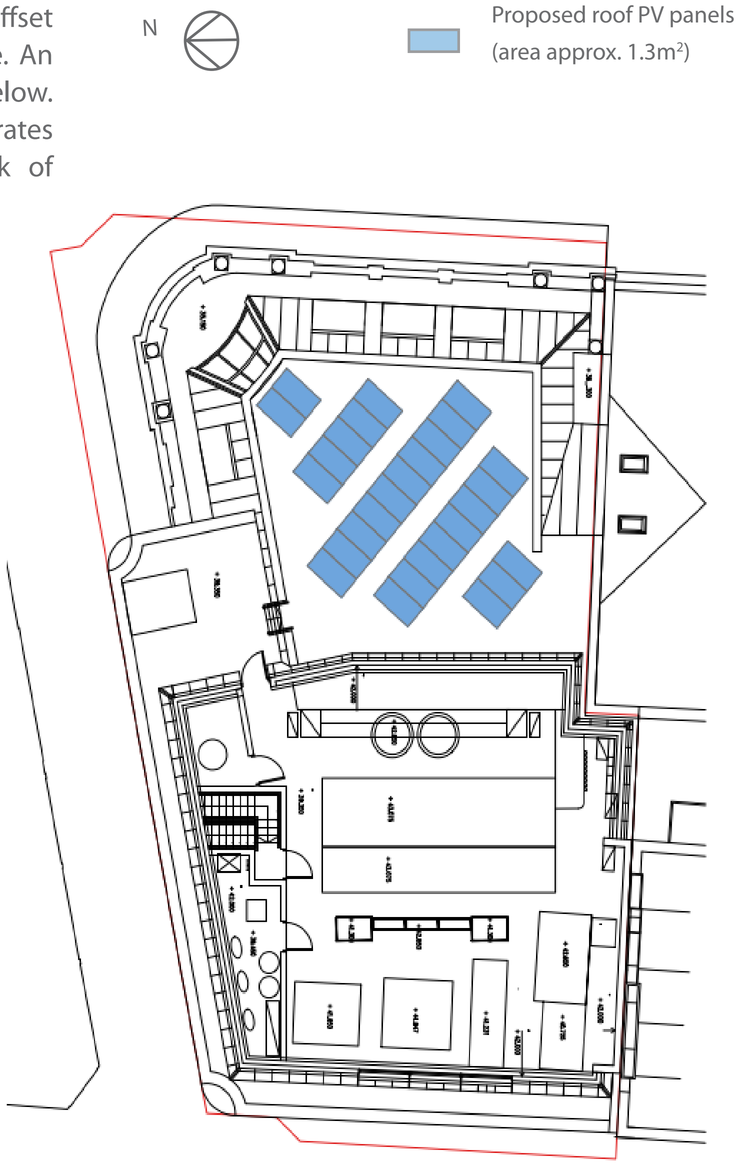
An appropriate location for the proposed photovoltaic panels was identified once the site constraints were taken into account. The factors taken into consideration included:

- avoiding any potential overshadowing from adjacent PV panels;
- space required for maintenance including all health and safety requirements for roof access;

A 35m² array of 19% efficiency PV modules, with a rated output of approximately 6.72kWp would offset 4.1% of regulated $CO_2$ emissions from baseline. An indicative PV layout is presented in the figure below. The West Street elevation image demonstrates that the photovoltaic panels are not at risk of overshadowing from neighbouring buildings.

| Proposed distribution of PV array at Sondheim (Ambassadors) Theatre | |
|---|---|
| Area of PV array (m²) | 35 |
| No. of PV panels | 28 |
| Peak power (kWp) | 6.72 |

Proposed West Street Elevation




Proposed roof PV plan at Sondheim Theatre. A full PV design will be made at design stage.

## Photovoltaic Panels

The feasibility study for Sondheim Theatre shows that photovoltaics are the most suitable renewable technology for the development for the following reasons:

- there is sufficient roof space to install enough PV modules to have a significant impact on carbon dioxide emissions
- the installation of photovoltaics is much simpler when compared to other renewable technologies
- photovoltaics sited on the roof are less visually intrusive when compared to wind turbines for generation of electricity.

In order to maximise $CO_2$ reductions, it is proposed that PV panels are installed on the roofs of the development. The panels will be installed on the unshaded areas of the roof to maximise array area.

In total, approximately 35m$^2$ of 19% efficiency PV panels, rated at 6.72kWp, would produce regulated $CO_2$ savings of 3.1% for the development at Sondheim (Ambassadors) Theatre after the lean and clean measures have been implemented.

| Photovoltaic Panels | | |
|---|---|---|
| Module Efficiency | 19 | % |
| Tilt of collectors | West 10° | |
| Predicted site solar energy | 990 | kWh/m$^2$/yr |
| System losses | 20 | % |
| System peak power | 6.65 | kWp |
| Array area | 35 | m$^2$ |
| Primary electricity offset by PV array | 6,065 | kWh/yr |
| Total $CO_2$ savings | 3.1 | t/yr |
| Regulated Clean $CO_2$ emissions | 60 | t/yr |
| Total clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 4.0 | % |
| Total $CO_2$ reduction from clean stage | 2.1 | % |
| Regulated $CO_2$ reduction from Baseline | 3.1 | % |
| Total $CO_2$ reduction from Baseline | 1.8 | % |

A monocrystalline PV Panel

A polycrystalline PV Panel

## $CO_2$ Emissions

The table below shows the regulated and unregulated carbon dioxide emissions for the baseline scheme and the emissions after the lean, clean and green measures have been implemented.

The savings achieved through renewable technologies are significant, amounting to an additional 3.1% reduction in regulated emissions and a 1.8% reduction in total carbon dioxide emissions.

Overall, the proposed redevelopment scheme at Sondheim (Ambassadors) Theatre achieves a reduction in regulated $CO_2$ emissions of 25.7% in comparison to the Part L2013 notional building baseline.

### $CO_2$ Emissions Breakdown

| | Carbon Dioxide emissions (tonnes $CO_2$ per annum) | | |
|---|---|---|---|
| | Regulated | Unregulated | Total |
| Baseline building | 77.5 | 54.2 | 131.7 |
| After energy demand reduction (Lean) | 60.0 | 54.2 | 114.2 |
| After efficient technology (Clean) | 60.0 | 54.2 | 114.2 |
| After PV (Green) | 57.5 | 54.2 | 111.8 |

| | Carbon dioxide savings (tonnes $CO_2$ per annum) | | Carbon dioxide savings from baseline (%) | |
|---|---|---|---|---|
| | Regulated | Total | Regulated | Total |
| Savings from energy demand reduction | 17.5 | 17.5 | 22.6% | 13.3% |
| Savings from clean technology | 0.0 | 10.0 | 0.0% | 0.0% |
| Savings from PV | 2.4 | 2.4 | 3.1% | 1.8% |
| Cumulative savings | 19.9 | 19.9 | 25.7% | 15.1% |

## Conclusion

In line with the London Plan's three step energy hierarchy the regulated $CO_2$ emissions for this development have been reduced by 25.7%, once energy efficiency measures, high efficiency systems and renewable technologies have been taken into account.

The tables on the following page provides a breakdown of the $CO_2$ savings made at each stage of the Energy Hierarchy. The reductions made through each step have been outlined below:

**1. Be Lean - use less energy**

In accordance with this strategy, this development will incorporate a range of energy efficiency measures including levels of insulation beyond Building Regulations, the installation of high performance glazing and mechanical ventilation with heat recovery. High efficiency condensing boilers will be used alongside heat recovery technology to reduce energy load for heating and cooling. The implementation of these measures would potentially reduce regulated $CO_2$ emissions by 22.6%, when compared to baseline buildings.

**2. Be Clean - supply energy efficiently**

The use of high efficiency boiler technology is better suited as an efficient heating strategy for a development of this size than the installation of a decentralised energy system.

**3. Be Green - use renewable energy**

The feasibility study analysed a number of renewable technologies for their suitability for the site. The analysis included a biomass heating system, ground-source heat pumps, air-source heat pumps, photo voltaic panels, solar thermal and wind turbines.

The analysis demonstrated that photovoltaic panels are the most suitable technology to be incorporated into the Ambassadors Theatre redevelopment. The installation of approximately 35m$^2$ of photovoltaic panels with a rated output of 6.72kWp will reduce the development's regulated $CO_2$ emission by a further 3.1% over the baseline buildings.

In total, the development is expected to reduce regulated $CO_2$ emissions by 25.7% when compared to the Part L 2013 notional baseline. This fails to meet the London Plan target of 35% set for all major developments. In line with Camden Borough's Carbon Offsetting Payments, the total carbon offsetting payment will stand at £19,442 for this shortcoming.

### $CO_2$ Emissions Breakdown

| | Carbon Dioxide emissions (tonnes $CO_2$ per annum) | | |
|---|---|---|---|
| | Regulated | Unregulated | Total |
| Baseline building | 77.5 | 54.2 | 131.7 |
| After energy demand reduction (Lean) | 60.0 | 54.2 | 114.2 |
| After efficient technology (Clean) | 60.0 | 54.2 | 114.2 |
| After PV (Green) | 57.5 | 54.2 | 111.8 |

### $CO_2$ Savings Breakdown

| | Carbon dioxide savings (tonnes $CO_2$ per annum) | | Carbon dioxide savings over baseline (%) | |
|---|---|---|---|---|
| | Regulated | Total | Regulated | Total |
| Savings from energy demand reduction | 17.5 | 17.5 | 22.6% | 13.3% |
| Savings from efficient technology | 0.0 | 0.0 | 0.0% | 0.0% |
| Savings from PV | 2.4 | 2.4 | 3.1% | 1.8% |
| Cumulative savings | 19.9 | 19.9 | 25.7% | 15.1% |

# Appendix A - Renewables Appraisal

## Biomass Heating - not adopted

A biomass system designed for this development would be fuelled by wood pellets which have a high energy content. Wood pellets require less volume of storage than other biomass fuels. Pellet boilers also require less maintenance and produce considerably less ash residue.

A biomass boiler could supply 50% of the space heating and hot water demand of the building. This would be equivalent to a regulated $CO_2$ savings of 3.5%. A biomass system, however, would not be an appropriate low-carbon technology for the site for the following reasons:

- the burning of wood pellets releases substantially more NOx emissions when compared to similar gas boilers.
- supplying a biomass boiler to the commercial buildings offsets the benefits from the CHP unit.
- pellets would need to be transported from other sites within the UK due to the lack of local pellet suppliers.

Example of wood pellet fuel

Example of pellet boiler and pellet storage room. Source: Energy Crops Limited

| Biomass | | |
|---|---|---|
| % of heating load supplied by biomass | 50 | % |
| Biomass System Efficiency | 90 | % |
| Carbon Intensity of Biomass | 0.039 | $kgCO_2$/kWh |
| Backup System Efficiency | 90 | % |
| Carbon Intensity of Backup | 0.216 | $kgCO_2$/kWh |
| Heating Demand Met | 13,752 | kWh/yr |
| Total $CO_2$ savings | 2.7 | t/yr |
| Regulated Clean $CO_2$ emissions | 60 | t/yr |
| Total Clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 4.5 | % |
| Total $CO_2$ reduction from clean stage | 2.4 | % |
| Regulated $CO_2$ reduction from Baseline | 3.5 | % |
| Total $CO_2$ reduction from Baseline | 2.1 | % |

## Solar Thermal - not adopted

Solar thermal arrays have similar requirements as PV arrays, in terms of their orientation and inclination. The most efficient use of solar thermal arrays would be to orientate them to the south at an inclination of about 30°.

Solar thermal arrays are available as evacuated tubes and flat plate collectors. Evacuated tubes are more efficient, produce higher temperatures and are more suited to the UK climate in general when compared to flat plate collectors.

For this development the use of solar thermal for space heating would not be practical as it is not required when solar thermal is at its most effective during the summer months.

If solar thermal were to be considered for this development, based on a solar fraction of 40%, 50m² solar thermal arrays would produce a regulated $CO_2$ saving of 2.4%.

The installation of solar thermal would require additional plumbing and space for hot water storage which would incur additional financial costs. A solar hot water system will also conflict with the CHP system. Therefore photovoltaics would be a more appropriate solution for this development.

| Solar Thermal | | |
|---|---|---|
| Collector Type | Evacuated Tube | |
| System Efficiency | 40 | % |
| Orientation | West 10° | |
| Predicted site solar energy | 990 | kWh/m²/yr |
| Solar fraction | 30 | % |
| Total collector area | 21 | m² |
| Primary gas energy offset by Solar Thermal system | 9,240 | kWh/yr |
| Total $CO_2$ savings | 1.8 | t/yr |
| Regulated Clean $CO_2$ emissions | 60.0 | t/yr |
| Total Clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 3.1 | % |
| Total $CO_2$ reduction from clean stage | 1.6 | % |
| Regulated $CO_2$ reduction from Baseline | 2.4 | % |
| Total $CO_2$ reduction from Baseline | 1.4 | % |

## Ground Source Heat Pumps - not adopted

The footprint of the development occupies a significant portion of the site. For this reason, a ground source loop would need to be incorporated within the foundations of the building.

A suitable ground source heat pump system for the site would include a number of closed ground boreholes, where a liquid passes through the system, absorbing heat from the ground and relaying this heat via an electrically run heat pump into the building.

Studies have shown that ground source boreholes located within close proximity of structural foundations may result in a reduction of the life span of the loops. Thermal testing would need to be carried out on the foundations to determine the implications to the ground boreholes over time.

Ground source heat pumps would deliver space heating through a low temperature efficient distribution network such as underfloor heating. Approximately 90% of the annual space heating demand would be supplied by a system sized to meet approximately 50% of the peak load. The number of ground boreholes required would require a significant amount of space on site and result in additional time and complication at the beginning of the construction process. In addition, the capital cost of installing these boreholes would be very high. For these reasons, ground source heat pumps were not considered to be an appropriate renewable technology for the site.

Energy piles within foundations of construction. Source: Geothermal International Italia

| GSHP | | |
|---|---|---|
| COP Heat | 4.0 | |
| COP Cooling | 4.0 | |
| Carbon Intensity of Electricity | 0.519 | $kgCO_2$/kWh |
| Proportion of Non-Domestic Space Heating met by ASHP | 90 | % |
| Proportion of Non-Domestic Cooling met by ASHP | 100 | % |
| Energy met by GSHP | 45,629 | kWh/yr |
| Energy used by GSHP | 11,407 | kWh/yr |
| Total $CO_2$ savings | 4.8 | t/yr |
| Regulated Clean $CO_2$ emissions | 60.0 | t/yr |
| Total Clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 7.9 | % |
| Total $CO_2$ reduction from clean stage | 4.2 | % |
| Regulated $CO_2$ reduction from Baseline | 6.1 | % |
| Total $CO_2$ reduction from Baseline | 3.6 | % |

## Air Source Heat Pumps - not adopted

Air source heat pumps (ASHPs) employ the same technology as ground source heat pump (GSHPs). However, instead of using heat exchangers buried in the ground, heat is extracted from the external ambient air.

The efficiency of heat pumps is very much dependent on the temperature difference between the heat source and the space required to be heated. The use of ASHPs at Sondheim Theatre for both space heating and cooling would result in regulated $CO_2$ savings of approximately 4.2%.

The ASHP is considered unsuitable for the development as ASHP evaporators would need to be located externally. Any noise associated with the units could potentially be an issue given the performance-based purpose of the building. There is also insufficient space to house all the ASHP units on the roof, and the position of the units externally is likely to have a significant visual impact and impede the architectural vision of the reconstruction.

| ASHP | | |
|---|---|---|
| COP Heat | 3.2 | |
| COP Cooling | 3.2 | |
| Carbon Intensity of Electricity | 0.519 | $kgCO_2$/kWh |
| Proportion of Space Heating met by ASHP | 90 | % |
| Proportion of Cooling met by ASHP | 25 | % |
| Energy met by ASHP | 45,629 | kWh/yr |
| Energy used by ASHP | 14,259 | kWh/yr |
| Total $CO_2$ savings | 3.3 | t/yr |
| Regulated Clean $CO_2$ emissions | 60.0 | t/yr |
| Total Clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 5.5 | % |
| Total $CO_2$ reduction from clean stage | 2.9 | % |
| Regulated $CO_2$ reduction from Baseline | 4.2 | % |
| Total $CO_2$ reduction from Baseline | 2.5 | % |

### Wind Turbines - not adopted

Building-integrated turbines would be most suited to this site due to the limited amount of roof space, as opposed to stand alone turbines.

$CO_2$ savings from wind turbine technologies take into account their mounting height, the turbine wind curve and wind data. This information was obtained from the BERR website and used in the Carbon Trust Wind Yield Estimation Tool. The average annual wind speed at a mounting height of 10m above the building canopy is estimated to be 4.3m/s.

Due to the spacing required between wind turbines, and the different heights of the buildings, it can only be assumed that 1 turbine could be sited on the roof. The two tables below outline $CO_2$ savings for 2.5kW and 6kW roof-mounted wind turbines.

The results show that the $CO_2$ savings are minimal for each option, offering 1.1% and 2.7% savings over regulated $CO_2$ emissions for the 2.5kW and 6kW turbines respectively.

This technology is not considered appropriate for this development due to the low $CO_2$ savings achieved, limited roof space and varied building heights. The installation of wind turbines also has a significant visual impact on the building.

A building-mounted 6kW Proven wind turbine

| Wind Power - 2.5kW | | |
|---|---|---|
| Average wind speed at site | 3.5 | m/s |
| Number of Turbines | 1 | |
| Electricity offset by turbine | 1,584 | kWh/yr |
| Carbon intensity of offset electricity | 0.529 | $kgCO_2$/kWh |
| Total $CO_2$ savings | 0.84 | t/yr |
| Regulated Clean $CO_2$ emissions | 60 | t/yr |
| Total Clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 1.4 | % |
| Total $CO_2$ reduction from clean stage | 0.7 | % |
| Regulated $CO_2$ reduction from Baseline | 1.1 | % |
| Total $CO_2$ reduction from Baseline | 0.6 | % |

| Wind Power - 6kW | | |
|---|---|---|
| Average wind speed at site | 3.5 | m/s |
| Number of Turbines | 1 | |
| Electricity offset by turbine | 3,987 | kWh/yr |
| Carbon intensity of offset electricity | 0.529 | $kgCO_2$/kWh |
| Total $CO_2$ savings | 2.11 | t/yr |
| Regulated Clean $CO_2$ emissions | 60.0 | t/yr |
| Total Clean $CO_2$ emissions | 114.2 | t/yr |
| Regulated $CO_2$ reduction from clean stage | 3.5 | % |
| Total $CO_2$ reduction from clean stage | 1.8 | % |
| Regulated $CO_2$ reduction from Baseline | 2.7 | % |
| Total $CO_2$ reduction from Baseline | 1.6 | % |

## Appendix B - DSM results

The DSM BRUKL document for the Sondheim (Ambassadors) theatre is presented in this appendix, which shows the TER and BER achieved after the Be Lean, Be Clean and Be Green measures have been applied.

The additional pages of the BRUKL report are available upon request.

# BRUKL Output Document

HM Government

Compliance with England Building Regulations Part L 2013

**Project name**

## Ambassadors Theatre

As built

**Date:** Wed Sep 09 13:03:12 2015

### Administrative information

**Building Details**

**Address:** West Street, London, WC2H 9ND

**Certification tool**

**Calculation engine:** Apache

**Calculation engine version:** 7.0.4

**Interface to calculation engine:** IES Virtual Environment

**Interface to calculation engine version:** 7.0.4

**BRUKL compliance check version:** v5.2.d.2

**Owner Details**

**Name:** Name

**Telephone number:** Phone

**Address:** Street Address, City, Postcode

**Certifier details**

**Name:** Name

**Telephone number:** Phone

**Address:** Street Address, City, Postcode

### Criterion 1: The calculated $CO_2$ emission rate for the building should not exceed the target

| | |
|---|---|
| $CO_2$ emission rate from the notional building, $kgCO_2/m^2$.annum | 30.5 |
| Target $CO_2$ emission rate (TER), $kgCO_2/m^2$.annum | 30.5 |
| Building $CO_2$ emission rate (BER), $kgCO_2/m^2$.annum | 24.6 |
| Are emissions from the building less than or equal to the target? | BER =< TER |
| Are as built details the same as used in the BER calculations? | Separate submission |

### Criterion 2: The performance of the building fabric and the building services should achieve reasonable overall standards of energy efficiency

Values not achieving standards in the Non-Domestic Building Services Compliance Guide and Part L are displayed in red.

**Building fabric**

| Element | $U_{a\text{-}Limit}$ | $U_{a\text{-}Calc}$ | $U_{i\text{-}Calc}$ | Surface where the maximum value occurs* |
|---|---|---|---|---|
| Wall** | 0.35 | 0.15 | 0.15 | 10000000:Surf[1] |
| Floor | 0.25 | 0.11 | 0.11 | 10000002:Surf[0] |
| Roof | 0.25 | 0.11 | 0.11 | 10000000:Surf[0] |
| Windows***, roof windows, and rooflights | 2.2 | 1.6 | 1.6 | 10000004:Surf[0] |
| Personnel doors | 2.2 | 2.2 | 2.2 | 11000006:Surf[0] |
| Vehicle access & similar large doors | 1.5 | - | - | No Vehicle access doors in building |
| High usage entrance doors | 3.5 | - | - | No High usage entrance doors in building |

$U_{a\text{-}Limit}$ = Limiting area-weighted average U-values [W/(m²K)]

$U_{a\text{-}Calc}$ = Calculated area-weighted average U-values [W/(m²K)]

$U_{i\text{-}Calc}$ = Calculated maximum individual element U-values [W/(m²K)]

* There might be more than one surface where the maximum U-value occurs.

** Automatic U-value check by the tool does not apply to curtain walls whose limiting standard is similar to that for windows.

*** Display windows and similar glazing are excluded from the U-value check.

N.B.: Neither roof ventilators (inc. smoke vents) nor swimming pool basins are modelled or checked against the limiting standards by the tool.

| Air Permeability | Worst acceptable standard | This building |
|---|---|---|
| $m^3/(h.m^2)$ at 50 Pa | 10 | 3 |

Page 1 of 13

# Technical Data Sheet (Actual vs. Notional Building)

## Building Global Parameters

| | Actual | Notional |
|---|---|---|
| Area [m²] | 2354.6 | 2354.6 |
| External area [m²] | 2729.6 | 2729.6 |
| Weather | LON | LON |
| Infiltration [m³/hm²@ 50Pa] | 3 | 3 |
| Average conductance [W/K] | 521.45 | 0 |
| Average U-value [W/m²K] | 0.19 | 0 |
| Alpha value* [%] | 10.06 | 10 |

* Percentage of the building's average heat transfer coefficient which is due to thermal bridging

## Building Use

| % Area | Building Type |
|---|---|
| | A1/A2 Retail/Financial and Professional services |
| | A3/A4/A5 Restaurants and Cafes/Drinking Est./Takeaways |
| | B1 Offices and Workshop businesses |
| | B2 to B7 General Industrial and Special Industrial Groups |
| | B8 Storage or Distribution |
| | C1 Hotels |
| | C2 Residential Inst.: Hospitals and Care Homes |
| | C2 Residential Inst.: Residential schools |
| | C2 Residential Inst.: Universities and colleges |
| | C2A Secure Residential Inst. |
| | Residential spaces |
| | D1 Non-residential Inst.: Community/Day Centre |
| | D1 Non-residential Inst.: Libraries, Museums, and Galleries |
| | D1 Non-residential Inst.: Education |
| | D1 Non-residential Inst.: Primary Health Care Building |
| | D1 Non-residential Inst.: Crown and County Courts |
| **100** | **D2 General Assembly and Leisure, Night Clubs and Theatres** |
| | Others: Passenger terminals |
| | Others: Emergency services |
| | Others: Miscellaneous 24hr activities |
| | Others: Car Parks 24 hrs |
| | Others - Stand alone utility block |

## Energy Consumption by End Use [kWh/m²]

| | Actual | Notional |
|---|---|---|
| Heating | 6.83 | 15.67 |
| Cooling | 5.14 | 5.4 |
| Auxiliary | 22.56 | 21.3 |
| Lighting | 17.3 | 22.94 |
| Hot water | 5.63 | 5.31 |
| Equipment* | 44.36 | 44.36 |
| **TOTAL**** | **57.46** | **70.61** |

* Energy used by equipment does not count towards the total for calculating emissions.
** Total is net of any electrical energy displaced by CHP generators, if applicable.

## Energy Production by Technology [kWh/m²]

| | Actual | Notional |
|---|---|---|
| Photovoltaic systems | 1.97 | 0 |
| Wind turbines | 0 | 0 |
| CHP generators | 0 | 0 |
| Solar thermal systems | 0 | 0 |

## Energy & $CO_2$ Emissions Summary

| | Actual | Notional |
|---|---|---|
| Heating + cooling demand [MJ/m²] | 82.51 | 140.08 |
| Primary energy* [kWh/m²] | 152.45 | 188.05 |
| Total emissions [kg/m²] | 24.6 | 30.5 |

* Primary energy is net of any electrical energy displaced by CHP generators, if applicable.