

# Energy Strategy

## Penrhyn Road

2494 Rev 01

March 22



# Revision Record

| Revision | Revision Notes / Comments | Date     | Prepared<br>By | Checked<br>By | Approved<br>By |
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| 01       | Initial Issue             | 02/03/22 | ER             | SH            | NBE            |

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We disclaim any responsibility to the client and others of any matters outside the scope above.

Whilst the simulations have been undertaken in good faith using reasonable skill and care, Yonder Limited can take no responsibility for differences between the computer simulations and the actual performance of the completed building due to the inherent complexity and variability of the physics in a building and its environment.

This report is confidential to the client and we accept no responsibility of whatsoever nature to third parties to whom this report, or part thereof, is made known. Any such party relies on the report at its own risk.

# Executive Summary

The following Energy Statement sets out the strategy for the proposed Penrhyn Road project, addressing the Knowsley City Council Core Strategy (2016), with the development expected to achieve 2018 BREEAM Excellent and to prove a meaningful reduction in operational carbon emissions through fabric improvements and on-site low zero carbon energy technology. The report details the following:

In summary, the recommendation for this development, as the most technically and economically viable option, is as follows:

- Passive design measures in the form of improved U-values, solar controlled glazing and reduced air permeability have been applied to reduce the base energy demand of the building
- Rooflights between 10%-15% of warehouse floor area to enhance natural light, reducing the need for artificial light.
- Energy efficiency measures in the form of low energy fans, high efficiency LED lighting, etc. have been applied to reduce the energy consumption of the building
- Air source heat pumps supplying the office heating & cooling
- The building roofs are to be designed with a structural integrity capable of mounting PV to offset the proposed developments operational carbon in future allowing the building to meet the future zero carbon targets.

The Part L compliance assessment demonstrates a reduction in predicted annual carbon emissions of 27.4% when improvements to fabric U values and design enhancements are considered, as detailed in the summary table below.

## Criterion 1: The calculated CO<sub>2</sub> emission rate for the building must not exceed the target

|                                                                                                    |                     |
|----------------------------------------------------------------------------------------------------|---------------------|
| CO <sub>2</sub> emission rate from the notional building, kgCO <sub>2</sub> /m <sup>2</sup> .annum | 21                  |
| Target CO <sub>2</sub> emission rate (TER), kgCO <sub>2</sub> /m <sup>2</sup> .annum               | 21                  |
| Building CO <sub>2</sub> emission rate (BER), kgCO <sub>2</sub> /m <sup>2</sup> .annum             | 13.3                |
| 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 |

Figure 1 - Criterion 1, L2A Compliance – Penrhyn Road

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# Introduction

The following Energy Statement sets out the strategy for the proposed Penrhyn Road base build development, to achieve 2018 BREEAM Excellent and to provide a meaningful reduction in carbon emissions through fabric improvements, energy efficiency measures and on-site low zero carbon energy technology. The report details the following:

- Planning policy
- The methodology to determining the baseline predicted carbon emissions
- The energy efficiency measures incorporated into the design of the development to reduce carbon emissions.
- The carbon emissions and energy savings that can be derived from the incorporation of low carbon or renewable technologies.
- The ENE01 BREEAM scores for each unit
- The recommended approach for this project.

## Project Overview

The proposed site consists of one warehouse unit, providing a gross internal area of 9,940 m<sup>2</sup>. This is split into office accommodation and warehouse areas.

External works include the construction of car parks and service areas.

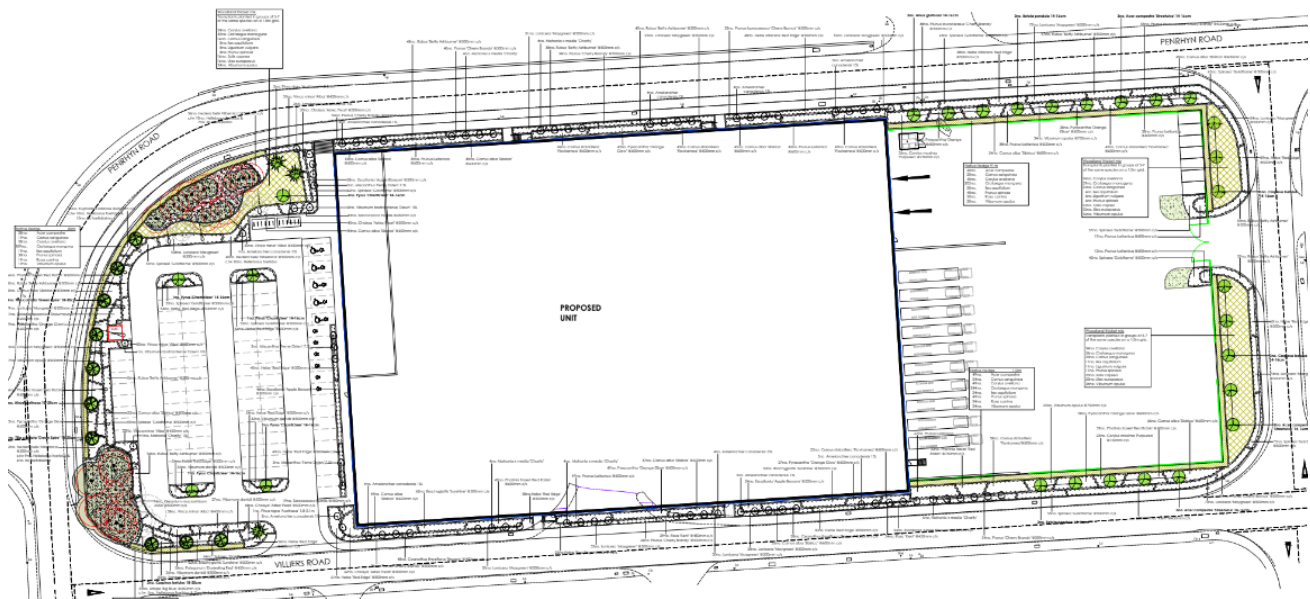


Figure 2 – Site Masterplan

The proposed base build development has been designed to operate without the need for fossil fuels, opting for a grid supplied electric solution.

As the development is designed to be electric only, the scheme is well equipped to be carbon neutral in line with the government's target of net zero by 2050.

The building roofs are to be designed with a structural integrity capable of mounting PV to offset the proposed developments carbon in future allowing the building to meet future zero carbon targets, whilst also reducing demand on the grid.

The national grid is continually reducing its carbon factor, targeting being carbon neutral by 2050 at the latest, Figure 3 below demonstrates the carbon factor of electricity [blue] vs natural gas [yellow] from current policy though to 2050.

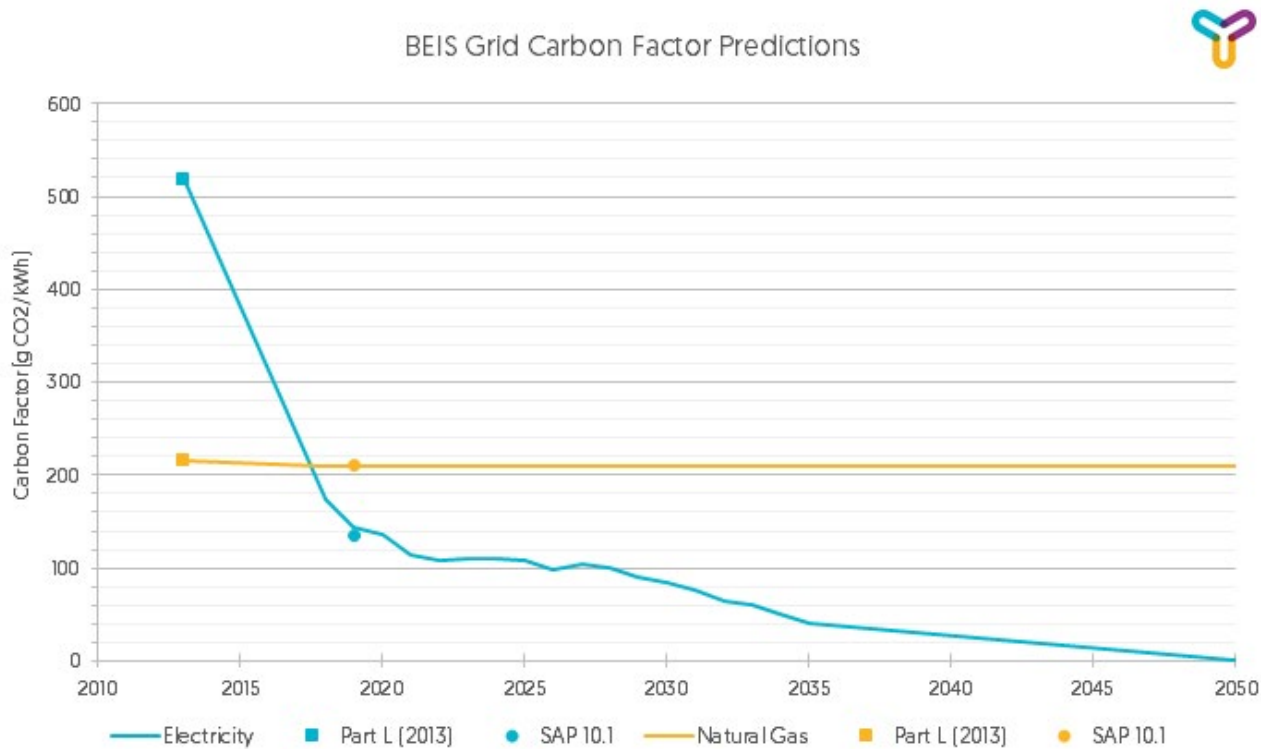


Figure 3- Grid vs Gas Carbon Factor

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# Planning Policy

## Knowsley Local Plan Core Strategy (2016)

### Policy CS22: Sustainable and Low Carbon Development

1) New development will be required to meet high standards of sustainable design and construction and minimise carbon emissions. This should be achieved by:

- Designing new buildings for flexible uses throughout their lifetime;
- b) Avoiding the creation of adverse local climate conditions by using natural systems to avoid internal overheating and excessive heat generation.
- Ensuring developments are comfortable and safe for users.
- Making the most effective and sustainable use of water, aggregates and other resources.
- Limiting energy use by incorporating high standards of insulation, heat retention, natural ventilation and passive solar techniques.
- Landscaping (including measures such as green walls or roofs) to create shelter and reduce any heat island effect.
- Using sustainable materials from local suppliers where possible.
- Supplying energy efficiently and incorporating decentralised energy systems, using renewable and low carbon energy where feasible.
- Managing flood risk, including through the use of Sustainable Drainage Systems (SuDS) and flood resilient design for infrastructure and property; and
- Promoting sustainable waste practices in new and existing developments.

Policy CS22 is consistent with the Government's planned programme for ensuring that new development is zero carbon. The policy adheres to the principles of carbon compliance, which are viewed by the Government as being key to reducing carbon emissions. Under the Carbon Compliance Pyramid, carbon emissions will be reduced as a first priority by minimising energy demand through an energy efficient approach to building design. This is followed by the use of low or zero carbon technologies for on-site energy generation and connected heat systems. These first two steps together are referred to as Carbon Compliance. Any remaining carbon emissions which cannot be managed on-site are likely to be capable of being mitigated through the Government's proposed Allowable Solutions mechanism, under which developers would contribute towards off site delivery of carbon reduction measures.

### Policy CS23: Renewable and Low Carbon Infrastructure

The Council will support proposals that will produce and distribute decentralised, low carbon and renewable energy, provided that they do not cause significant harm (in terms of their number, scale, siting or cumulative impacts).

# BREEAM Requirements

The developments will be designed to meet the requirement of BREEAM NC Industrial 2018 and achieve a rating of Excellent.

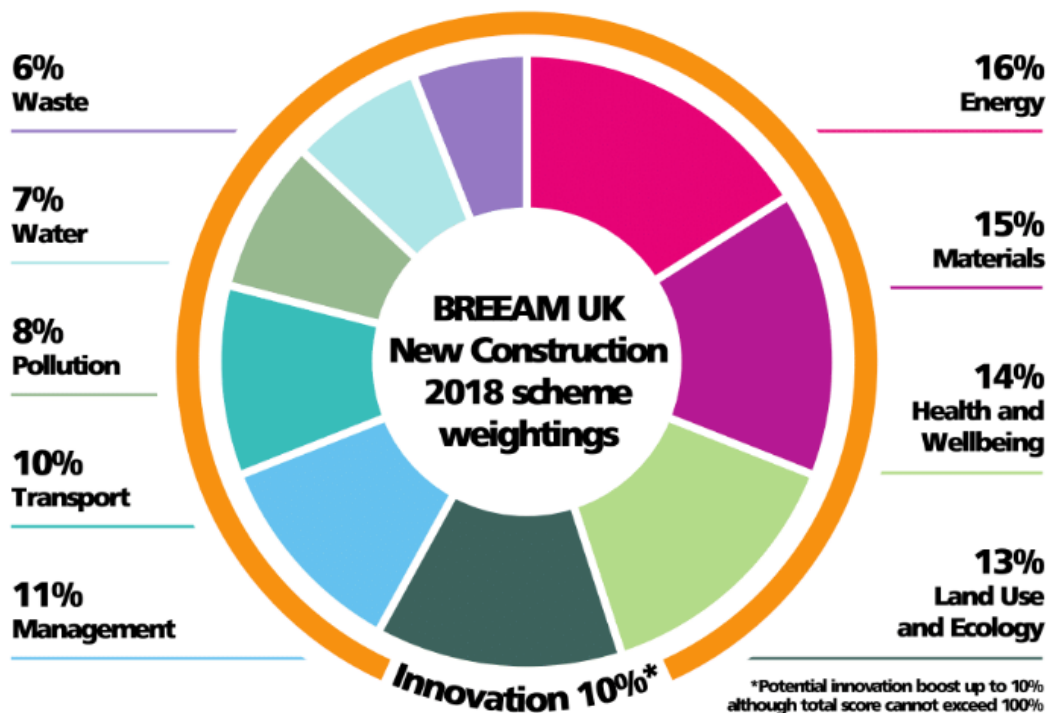


Figure 4- BREEAM Scheme Weightings

The advantages of employing formal assessment methods, such as BREEAM, lie in three main areas:

1. Recognition: A BREEAM certification is the most widely recognised measure of Environmental Performance in the UK Building Industry, as well as around much of Europe and beyond.
2. Formalisation / Contractual Obligations: A BREEAM requirement within formal, contractual documentation is an easily understood, and easily monitored method of ensuring that project tendering, as well as delivery, is inclusive of and carried out in accordance with the client's embodied sustainability objectives.
3. Standardisation: BREEAM requirements are based on a tried and tested methodology, encompassing well-thought out and broad-reaching academic and practical, evidence-based measures, addressing all areas of environmental performance in buildings.

Calculate an Energy Performance Ratio for New Construction (EPR<sub>NC</sub>). Compare the EPR<sub>NC</sub> achieved with the benchmarks in Table 6.1 and award the corresponding number of BREEAM credits.

ENE 01 EPR<sub>NC</sub> benchmark scale

|                |                                                            | Minimum standards |                                                                                                                                                                                                                              |
|----------------|------------------------------------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BREEAM credits | EPR <sub>NC</sub>                                          | Rating            | Minimum requirements                                                                                                                                                                                                         |
| 1              | 0.1                                                        |                   | Requires a performance improvement progressively better than the relevant national building regulations compliant standard (see <a href="#">Energy performance</a> ).                                                        |
| 2              | 0.2                                                        |                   |                                                                                                                                                                                                                              |
| 3              | 0.3                                                        |                   |                                                                                                                                                                                                                              |
| 4              | 0.4                                                        | Excellent         | Requires 4 credits to be achieved (equivalent to an EPR <sub>NC</sub> of at least 0.4) or 4 credits for Prediction of operational energy consumption (where operational energy performance has been substantially improved). |
| 5              | 0.5                                                        |                   |                                                                                                                                                                                                                              |
| 6              | 0.6                                                        | Outstanding       | Requires 6 credits to be achieved (equivalent to an EPR <sub>NC</sub> of at least 0.6) and 4 credits for prediction of operational energy consumption.                                                                       |
| 7              | 0.7                                                        |                   |                                                                                                                                                                                                                              |
| 8              | 0.8                                                        |                   |                                                                                                                                                                                                                              |
| 9              | 0.9 AND zero net regulated CO <sub>2</sub> -eq emissions*. |                   |                                                                                                                                                                                                                              |

# Energy Hierarchy

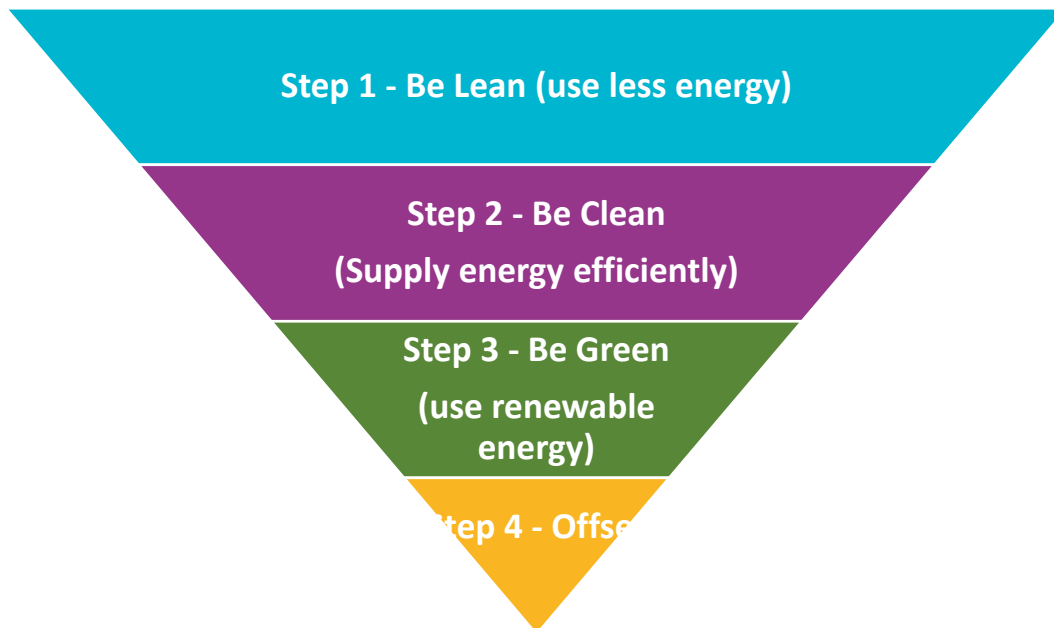


Figure 5- Energy Hierarchy

The process of the energy strategy is delivered most effectively by applying the energy hierarchy (Figure 5). By assessing and improving the building in this order, carbon emissions can be effectively reduced to the building's maximum potential and enable a net-zero carbon ready building for 2050.

## Be Lean

The first step of the energy strategy is to reduce the energy consumption in the building through means of passive design strategies:

- Building Fabric U-values
- Thermal bridging
- Air permeability
- Passive solar design

Reducing the U-values of each fabric will help to reduce heat losses especially during the winter months, while increased solar glazing reduces the building's lighting loads. Building regulations require that the air

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permeability is no greater than  $10.0\text{m}^3/\text{hr}/\text{m}^2$  @50Pa; reducing this value reduces the space heating demand of the building.

## Be Clean

The second step of the energy strategy is to provide clean energy to the building. The proposed base build development has been designed to operate without the need for fossil fuels, opting for a grid supplied electric solution. As the development is designed to be electric only, the scheme is well equipped to be carbon neutral in line with the government's target of net zero by 2050.

## Be Green

The third step to the energy strategy is to generate the building's remaining energy demands using green technology, or low/zero carbon technologies. This report assesses available technologies based on their cost and payback period, applicability, CO<sub>2</sub> emissions reductions, and technical and planning issues.

# Baseline Predicted Energy Demand

Annual carbon emissions for the site have been calculated using IES Virtual Environment, which is approved energy modelling software by Communities and Local Government to produce Energy Performance Certificates [EPC] and check compliance with the Building Regulations. The buildings have been modelled as to develop a base building in line with Part L 2013. The building modelling reflects the proposed geometry improvements of the building and has typical building services systems. This gives a baseline carbon emission, from which we can demonstrate a reduction in carbon emissions.

## Baseline Building Fabric Summary

| Parameter      | Baseline Building Value |
|----------------|-------------------------|
| Wall U-value   | 0.26                    |
| Floor U-value  | 0.22                    |
| Roof U-value   | 0.18                    |
| Window U-value | 1.60                    |
| Door U value   | 2.20                    |

|               |      |
|---------------|------|
| Rooflights    | 2.10 |
| Air tightness | 3.00 |

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## Baseline Building Services Summary

Air Sourced Heat Pumps (ASHP) are provided to the office accommodation to provide heating and cooling, the ASHP is accompanied via Mechanical Ventilation Heat Recovery (MVHR). Electric Panel Heaters (EPH) are provided to the ancillary areas with a combination of natural and mechanical ventilation. The warehouse will have frost protection only. LED lighting will be provided throughout with daylight dimming in the office areas.

## Baseline Carbon Emissions Summary

|           | Tonnes CO <sub>2</sub> per annum |
|-----------|----------------------------------|
| Site Wide | 208.74                           |

The baseline carbon emissions have been taken from the Target Emissions Rate (TER) from part L2a 2013 building regulations.

# Passive Design & Energy Efficiency Measures

## Building Fabric Summary

| Parameter      | Building regulations maximum | Actual |
|----------------|------------------------------|--------|
| Wall U-value   | 0.35                         | 0.35   |
| Floor U-value  | 0.25                         | 0.25   |
| Roof U-value   | 0.25                         | 0.23   |
| Window U-value | 2.20                         | 1.50   |
| Door U value   | 2.20                         | 2.20   |
| Rooflights     | 2.20                         | 1.30   |
| Air tightness  | 10.00                        | 2.50   |

## Passive Design Summary

- Improved air permeability of  $2.5\text{m}^3/(\text{h}\cdot\text{m}^2)$  @ 50Pa to reduce heating demand
- Rooflights between 10% and 15% of warehouse floor area to enhance natural light, reducing the need for artificial light.
- Solar control glazing to reduce solar gain, thus reducing cooling requirements

## Building Services Strategy Summary

- Heating and cooling throughout office areas provided by VRF, with a minimum SCOP of 3.5 and a minimum SEER of 4.0
- Heating throughout circulation & toilet areas provided by EPH
- MVHR to office areas, with a maximum SFP of  $1.6\text{W}/\text{l/s}$  and a minimum heat recovery efficiency of 75%, all heat recovery units are to be speed controlled based on  $\text{CO}_2$  levels
- Mechanical extract ventilation to toilet areas with a maximum SFP of  $0.5\text{W}/\text{l/s}$
- LED lighting throughout with a minimum efficacy of  $100\text{lm}/\text{W}$
- Daylight dimming and PIR control to offices and warehouse areas
- PIR Controls to warehouse areas

# Low & Zero Carbon Technology Assessment

## Summary of Technologies

| LZC Technology | Situations in which technology is best used                                                                                                       | Costs (all costs are approximate and exclude grants and discounts available) | Basic technical information                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Technical and planning issues                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | To Be Considered |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Wind Turbines  | Modern, quiet wind turbines are becoming viable in suburban areas, where they may be cost effective despite lower wind speeds than in open areas. | Cost: £2,500 to £5,000 per kWe installed.                                    | The blades drive a generator to produce electricity. The electricity can either link to the grid or charge batteries. An inverter is required to convert the electricity from direct current to alternating current for feeding into the grid. Turbines are available with outputs ranging from 600W to 2MW and are able to power the equivalent of up to 1,200 homes. The main factor affecting output of a particular turbine is the wind speed. Small building-mounted turbines are becoming more widely available. | Wind speed monitoring needed. Potential impact of noise from turbine blades and components, particularly on housing and schools, should be considered, considering background noise. Buildings and other obstructions can cause turbulence and decrease efficiency. Potential visual impact and impact on local ecology should be assessed. Developers should take account of any landscape designates/Conservation Areas. Planning permission required for each turbine [consultation with interest groups and residents can assist this]. | YES              |

| LZC Technology   | Situations in which technology is best used                                                                                                                                | Costs (all costs are approximate and exclude grants and discounts available)                            | Basic technical information                                                                                                                                                                                                                                                                                                                                                                               | Technical and planning issues                                                                                                                                                                                                                                                                                                                                                                                                                                                   | To Be Considered |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Solar power (PV) | Particularly suited to sites that use electricity during the day - offices, retail and schools. In the UK, even flat roofs receive 90% of the energy of an optimum system. | Cost: £5,000 to £8,000/kWp for a roof mounted system, £10,000 to £15,000/kWp for façade/atrium systems. | A solar power system consists of a set of interconnected photovoltaic modules, plus:<br>• For off-grid applications: a control, storage (eg battery), cables and a load (eg lights, television).<br>• For grid-connected applications: an inverter to convert the direct current, generated by the PV-modules, into alternating current. A 1kWp system in London could produce 850 kWh/yr of electricity. | Systems should ideally face between south-east and south-west to maximise the amount of light on the photovoltaics. Unshaded at all times of day if possible. Consider loading capacity of the roof. Ensure the building's metering system allows export of energy if needed. Birds may need to be discouraged from perching near the systems. There are no licensing requirements relating to PV systems, but consent must be obtained from the Distribution Network Operator. | YES              |
| Solar heating    | Suited to sites which require hot water, particularly during the day - housing, leisure centres or retail units and offices with canteens, washrooms and showers.          | Cost: Household system (4m <sup>2</sup> ) £2,500 - £4,000                                               | Systems comprise solar collectors (tubes or hot plates), a heat transfer system (a fluid in pipes) and a hot water store (eg domestic hot water cylinder). A 4m <sup>2</sup> collection area will provide between 50% and 70% of a typical home's hot water. Drawing water off during the day and using less hot water, for example with                                                                  | Systems should:<br>• Ideally face between south-east and south-west to maximise the amount of light on the tubes or panels.<br>• Be unshaded at all times of day if possible                                                                                                                                                                                                                                                                                                    | YES              |

| LZC Technology  | Situations in which technology is best used                                                                       | Costs (all costs are approximate and exclude grants and discounts available)                             | Basic technical information                                                                                                                                                                                                                                                                                                                                                          | Technical and planning issues                                                                                                                                                                                                                               | To Be Considered |
|-----------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
|                 |                                                                                                                   |                                                                                                          | showers instead of baths, increases this percentage.<br>Systems savings average at around:<br>• 454kWh/year saving per m2 of flat plate collector, or<br>• 582 kWh/yr per m2 for an evacuated tube system.                                                                                                                                                                           |                                                                                                                                                                                                                                                             |                  |
| Biomass heating | Any site requiring heat. Most applicable to some less dense suburban areas due to fuel supply and storage issues. | Costs; from £2,000 for a house to £30,000 to supply 33% of the heating for a standard office of 3,000m2. | <i>Domestic applications:</i><br>• Single room heaters or stoves.<br>• Boilers that replace traditional gas or oil boilers.<br><i>Non-domestic applications:</i><br>• Biomass boilers that replace traditional fossil fuel boilers, often as one or more boilers in a sequenced (multi-boiler) system. Biomass boilers are available in most size ranges and with automatic feeders. | Consider early in the design process so that fuel storage/delivery facilities can be factored in.<br>• Arrangements for ash disposal and de-coking must be made.<br>• Consider fuel sourcing and delivery arrangements.<br>• Accommodate space requirements | YES              |
| ASHP            | All sizes of building where heating is required                                                                   | £5,000 per unit                                                                                          | A heat exchanger extracts the heat from the air. A heat pump raises the temperature of the refrigerant via the compression cycle (also used in refrigerators) to supply hot water to the building.                                                                                                                                                                                   | External room to locate the external condensers. Noise from the external condenser maybe an issue in built up residential areas                                                                                                                             | YES              |

| LZC Technology        | Situations in which technology is best used                                                                                | Costs (all costs are approximate and exclude grants and discounts available)                                                                                | Basic technical information                                                                                                                                                                                                                                                                                                                                                                                   | Technical and planning issues                                                                                                                                                                                                                                                                                                                                                                                                                              | To Be Considered |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| VRF                   | All cases where cooling and heating are required                                                                           | £5,000 per unit                                                                                                                                             | The same technology as ASHP is used, but in reverse cycle to provide cooling to the internal environment in the summer.                                                                                                                                                                                                                                                                                       | External room to locate the external condensers. Noise from the external condenser maybe an issue in built up residential areas                                                                                                                                                                                                                                                                                                                            | YES              |
| Ground source heating | All sizes of building where heating is required. Access to suitable ground is necessary.                                   | Cost: £50,000 to supply 50% of the heating demand of a 3,000m <sup>2</sup> office building.                                                                 | Water (or another fluid) is circulated through pipes buried in the ground or is extracted from the ground (borehole). A heat exchanger extracts the heat from this fluid. A heat pump raises the temperature of the second fluid via the compression cycle (also used in refrigerators) to supply hot water to the building. Most suitable with lower temperature heating systems such as underfloor heating. | Technical feasibility depends on:<br><ul style="list-style-type: none"> <li>• Access for the ground pipe system.</li> <li>• An area for a horizontal system or access to drill for vertical pipes. (For a single house, a horizontal system would require garden area of at least 100m<sup>2</sup>. A license may be required to drill vertical systems.)</li> <li>• Ground conditions will affect ease of construction and system performance.</li> </ul> | YES              |
| GSHP                  | All cases where there is access to suitable ground and cooling and heating are required, as with offices, shops and hotels | Cost: £50,000 for 50% of the cooling load of a 2,000m <sup>2</sup> floor space, to £90,000 for 50% of the cooling of a 3,000m <sup>2</sup> prestige office. | This uses the same technology as ground sourced heating. The temperature of the ground remains fairly constant and well below peak temperatures in the summer.                                                                                                                                                                                                                                                | <ul style="list-style-type: none"> <li>• Technical feasibility depends on ground conditions (solid rock is unsuitable).</li> <li>• Permission is likely to be required for ground drilling or bore hole use.</li> </ul>                                                                                                                                                                                                                                    | YES              |

| LZC Technology                | Situations in which technology is best used    | Costs (all costs are approximate and exclude grants and discounts available) | Basic technical information                                                                                                                                                                              | Technical and planning issues                                                                                                                              | To Be Considered |
|-------------------------------|------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| CHP [Combined heat and Power] | Cases where a base heating demand is required. | Cost: £2,000 per kW <sub>e</sub> installed.                                  | Combined heat and power [CHP] is a highly efficient process that captures and utilises the heat that is a by-product of the electricity generation process. By generating heat and power simultaneously. | Technical feasibility depends on: <ul style="list-style-type: none"> <li>• Base heating demand</li> <li>• Sufficient plant space for the system</li> </ul> | YES              |

## Discussion of LZC Technologies

Table 1.1: LZC Recommendations

| LZC Technology              | Recommendation |        |     | Comments                                                                             |
|-----------------------------|----------------|--------|-----|--------------------------------------------------------------------------------------|
|                             | High           | Medium | Low |                                                                                      |
| Wind Turbine                |                |        | ✓   | Low annual CO <sub>2</sub> saving<br>High capital cost<br>Long payback period        |
| Photovoltaics [PV]          | ✓              |        |     | Good annual CO <sub>2</sub> saving<br>Medium capital cost<br>Moderate payback period |
| Solar Water Heating         |                | ✓      |     | Low annual CO <sub>2</sub> saving<br>Medium capital cost<br>Moderate payback period  |
| Biomass Heating             |                |        | ✓   | Low annual CO <sub>2</sub> saving<br>High capital cost<br>Long payback period        |
| Combined Heat & Power [CHP] |                |        | ✓   | Low CO <sub>2</sub> saving<br>Moderate capital cost<br>Moderate payback period       |
| Heat Pump                   | ✓              |        |     | Good annual CO <sub>2</sub> saving<br>Medium capital cost<br>Short Payback period    |

The desktop feasibility study results as summarised in Table 1.1 shows that there are a number of technologies that can provide annual CO<sub>2</sub> emission reductions.

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A wind turbine potentially offers a 5% annual CO<sub>2</sub> emission reduction, but at a high capital cost. There is potential to export electrical energy generated by this technology back to the grid. However, this option has been discounted due to low CO<sub>2</sub> reduction, the implications on space within the site, planning considerations and the cost of on-going maintenance.

Photovoltaics offer the potential to save over 30% in CO<sub>2</sub> emissions; whilst these systems come at high capital cost and long payback, they are easily incorporated into building of this type. This system is feasible due to the amount of roof space available and the times that the warehouse is in operation coincides with the peak electricity generation and provisions are recommended to allow for a roof photovoltaic system in future.

Solar Thermal offers the potential to save 10% in CO<sub>2</sub> emissions; for this type of building solar water heating is easily incorporated into the building, this technology would be utilised for on-site generation only. The system is recommended due to the low cost and high efficiency of the system.

Biomass heating offers the potential to save 10% in CO<sub>2</sub> emissions. This technology would be utilised for on-site generation only. This option has been discounted due the low carbon annual CO<sub>2</sub> emission saving, low payback period, additional space requirement for the location of the boiler and fuels store, and a potential legacy issue for the supply of fuel for the end user. In addition, this option would require a backup heating source, increasing costs and payback periods.

Combined Heat and Power offers the potential to save 4% in CO<sub>2</sub> emissions; whilst these systems come at a medium capital cost and moderate payback, they can be incorporated into building of this type. The system has been discounted due to its low reduction in CO<sub>2</sub> emissions, this is due to the intermittent load of the building and small base demand of a residential development, this does not give enough running hours for a system to provide higher CO<sub>2</sub> emission reductions.

Heat pump heating offers the potential to save over 20% in CO<sub>2</sub> emissions; the system has been recommended to supply the office heating and hot water generation due to its low capital cost and ease of incorporation into the scheme.

Excess on site generated energy can be stored in onsite battery storage. Though this option increases the building's energy security off-grid, it may not be cost-effective compared to selling the excess energy generated back to the grid and receiving payments through the feed-in-tariff.

# Predicted Energy Saving Due to Energy Efficiency Measures and Zero Carbon Technologies

The following table outlines the carbon emission results when implementing the improved fabric U values, improved air permeability and 5m<sup>2</sup> of solar thermal panels to each unit.

| Tonnes CO <sub>2</sub> per annum |          |                                       |                                         |                                                         |
|----------------------------------|----------|---------------------------------------|-----------------------------------------|---------------------------------------------------------|
|                                  | Baseline | After low carbon technologies applied | Reduction in predicted carbon emissions | % Reduction in predicted carbon emissions over baseline |
| Site Wide                        | 208.74   | 132.20                                | 76.54                                   | 36.67                                                   |

The Part L compliance assessment demonstrates a reduction in predicted annual carbon emissions of 36.7%, considering all units, when improvements to fabric U values and design enhancements are considered, as detailed in the summary table below.

## Criterion 1: The calculated CO<sub>2</sub> emission rate for the building must not exceed the target

|                                                                                                    |                     |
|----------------------------------------------------------------------------------------------------|---------------------|
| CO <sub>2</sub> emission rate from the notional building, kgCO <sub>2</sub> /m <sup>2</sup> .annum | 21                  |
| Target CO <sub>2</sub> emission rate (TER), kgCO <sub>2</sub> /m <sup>2</sup> .annum               | 21                  |
| Building CO <sub>2</sub> emission rate (BER), kgCO <sub>2</sub> /m <sup>2</sup> .annum             | 13.3                |
| 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 |

Figure 6- Criterion 1, L2A Compliance – Penrhyn Road

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# Recommendations

In summary, the recommendation for this development, as the most technically and economically viable option, is as follows:

- Passive design measures in the form of improved U-values, solar controlled glazing (with a g-value of 0.35 to windows and 0.55 to rooflights) and reduced air permeability of  $2.5\text{m}^3\text{(h.m}^2\text{)} @ 50\text{Pa}$  have been applied to reduce the base energy demand of the building
- Rooflights between 10%-15% of warehouse floor area to enhance natural light, reducing the need for artificial light
- Energy efficiency measures in the form of low energy fans, high efficiency LED lighting, etc. have been applied to reduce the energy consumption of the building
- Air source heat pumps supplying the office heating & cooling
- Provisions made for the installation of roof mounted photovoltaic panels and solar thermal collectors in the future

# Appendix – BRUKL Document

Project name

Shell and Core

Penryhn Road

As designed

Date: Thu Feb 24 14:07:56 2022

## Administrative information

## Building Details

Address: Penryhn Road, City, Postcode

## Certification tool

Calculation engine: Apache

Calculation engine version: 7.0.13

Interface to calculation engine: IES Virtual Environment

Interface to calculation engine version: 7.0.13

BRUKL compliance check version: v5.6.b.0

## Certifier details

Name: Nathan Evans

Telephone number: 01134 931 280

Address: Third Floor, Concordia Works, 30 Sovereign Street, Leeds, LS1 4BA

Criterion 1: The calculated CO<sub>2</sub> emission rate for the building must not exceed the target

|                                                                                                    |                     |
|----------------------------------------------------------------------------------------------------|---------------------|
| CO <sub>2</sub> emission rate from the notional building, kgCO <sub>2</sub> /m <sup>2</sup> .annum | 21                  |
| Target CO <sub>2</sub> emission rate (TER), kgCO <sub>2</sub> /m <sup>2</sup> .annum               | 21                  |
| Building CO <sub>2</sub> emission rate (BER), kgCO <sub>2</sub> /m <sup>2</sup> .annum             | 13.3                |
| 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 fixed building services should achieve reasonable overall standards of energy efficiency

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

## Building fabric

| Element                                  | U <sub>a</sub> -Limit | U <sub>a</sub> -Calc | U <sub>i</sub> -Calc | Surface where the maximum value occurs*  |
|------------------------------------------|-----------------------|----------------------|----------------------|------------------------------------------|
| Wall**                                   | 0.35                  | 0.35                 | 0.35                 | 00000000:Surf[11]                        |
| Floor                                    | 0.25                  | 0.11                 | 0.39                 | 00000000:Surf[0]                         |
| Roof                                     | 0.25                  | 0.25                 | 0.25                 | 00000012:Surf[49]                        |
| Windows***, roof windows, and rooflights | 2.2                   | 1.5                  | 1.5                  | 00000012:Surf[29]                        |
| Personnel doors                          | 2.2                   | 2.08                 | 2.2                  | 00000012:Surf[1]                         |
| Vehicle access & similar large doors     | 1.5                   | 1.5                  | 1.5                  | 00000012:Surf[6]                         |
| High usage entrance doors                | 3.5                   | -                    | -                    | No High usage entrance doors in building |

U<sub>a</sub>-Limit = Limiting area-weighted average U-values [W/(m<sup>2</sup>K)]U<sub>a</sub>-Calc = Calculated area-weighted average U-values [W/(m<sup>2</sup>K)]U<sub>i</sub>-Calc = Calculated maximum individual element U-values [W/(m<sup>2</sup>K)]

\* 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 <sup>3</sup> /(h.m <sup>2</sup> ) at 50 Pa | 10                        | 3             |

## Building services

The standard values listed below are minimum values for efficiencies and maximum values for SFPs. Refer to the Non-Domestic Building Services Compliance Guide for details.

|                                                                                              |      |
|----------------------------------------------------------------------------------------------|------|
| Whole building lighting automatic monitoring & targeting with alarms for out-of-range values | NO   |
| Whole building electric power factor achieved by power factor correction                     | <0.9 |

### 1- HVAC 01 - VRF MVHR

|                                                                                                                                                                   | Heating efficiency | Cooling efficiency | Radiant efficiency | SFP [W/(l/s)] | HR efficiency |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|--------------------|--------------------|---------------|---------------|
| This system                                                                                                                                                       | 3.5                | 3.5                | 0                  | 0             | 0.7           |
| Standard value                                                                                                                                                    | 2.5*               | 2.6                | N/A                | N/A           | 0.5           |
| Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system                                                                         |                    |                    |                    |               | NO            |
| * Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps. For types <=12 kW output, refer to EN 14825 for limiting standards. |                    |                    |                    |               |               |

### 2- HVAC 03 - EPH NV

|                                                                                           | Heating efficiency | Cooling efficiency | Radiant efficiency | SFP [W/(l/s)] | HR efficiency |
|-------------------------------------------------------------------------------------------|--------------------|--------------------|--------------------|---------------|---------------|
| This system                                                                               | 1                  | -                  | 0.67               | 0             | -             |
| Standard value                                                                            | N/A                | N/A                | N/A                | N/A           | N/A           |
| Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system |                    |                    |                    |               | NO            |

### 3- HVAC 02 - EPH EV

|                                                                                           | Heating efficiency | Cooling efficiency | Radiant efficiency | SFP [W/(l/s)] | HR efficiency |
|-------------------------------------------------------------------------------------------|--------------------|--------------------|--------------------|---------------|---------------|
| This system                                                                               | 1                  | -                  | 0.67               | 0             | -             |
| Standard value                                                                            | N/A                | N/A                | N/A                | N/A           | N/A           |
| Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system |                    |                    |                    |               | NO            |

### 1- DHW 01 - SAWH

|                | Water heating efficiency | Storage loss factor [kWh/litre per day] |
|----------------|--------------------------|-----------------------------------------|
| This building  | 1                        | 0.04                                    |
| Standard value | 1                        | N/A                                     |

## Local mechanical ventilation, exhaust, and terminal units

| ID | System type in Non-domestic Building Services Compliance Guide                                          |
|----|---------------------------------------------------------------------------------------------------------|
| A  | Local supply or extract ventilation units serving a single area                                         |
| B  | Zonal supply system where the fan is remote from the zone                                               |
| C  | Zonal extract system where the fan is remote from the zone                                              |
| D  | Zonal supply and extract ventilation units serving a single room or zone with heating and heat recovery |
| E  | Local supply and extract ventilation system serving a single area with heating and heat recovery        |
| F  | Other local ventilation units                                                                           |
| G  | Fan-assisted terminal VAV unit                                                                          |
| H  | Fan coil units                                                                                          |
| I  | Zonal extract system where the fan is remote from the zone with grease filter                           |

| Zone name            | SFP [W/(l/s)]     |     |     |     |     |     |     |     |     |   | HR efficiency |          |
|----------------------|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|---|---------------|----------|
|                      | ID of system type | A   | B   | C   | D   | E   | F   | G   | H   | I | Zone          | Standard |
|                      | Standard value    | 0.3 | 1.1 | 0.5 | 1.9 | 1.6 | 0.5 | 1.1 | 0.5 | 1 |               |          |
| 00.00 Reception      |                   | -   | -   | -   | 1.6 | -   | -   | -   | -   | - | -             | N/A      |
| 00.05 Visitor Toilet |                   | -   | -   | 0.5 | -   | -   | -   | -   | -   | - | -             | N/A      |
| 00.06 DWC            |                   | -   | -   | 0.5 | -   | -   | -   | -   | -   | - | -             | N/A      |
| 01.00 Office         |                   | -   | -   | -   | 1.6 | -   | -   | -   | -   | - | -             | N/A      |

| Zone name              | SFP [W/(l/s)] |     |     |     |     |     |     |     |   | HR efficiency |          |
|------------------------|---------------|-----|-----|-----|-----|-----|-----|-----|---|---------------|----------|
| ID of system type      | A             | B   | C   | D   | E   | F   | G   | H   | I |               |          |
| Standard value         | 0.3           | 1.1 | 0.5 | 1.9 | 1.6 | 0.5 | 1.1 | 0.5 | 1 | Zone          | Standard |
| 01.05 WC               | -             | -   | 0.5 | -   | -   | -   | -   | -   | - | -             | N/A      |
| 01.06 WC               | -             | -   | 0.5 | -   | -   | -   | -   | -   | - | -             | N/A      |
| 01.07 WC               | -             | -   | 0.5 | -   | -   | -   | -   | -   | - | -             | N/A      |
| 01.08 WC               | -             | -   | 0.5 | -   | -   | -   | -   | -   | - | -             | N/A      |
| 01.10 Kitchenette      | -             | -   | -   | 1.6 | -   | -   | -   | -   | - | -             | N/A      |
| 01.11 Open Plan Office | -             | -   | -   | 1.6 | -   | -   | -   | -   | - | -             | N/A      |

#### Shell and core configuration

| Zone                       | Assumed shell? |
|----------------------------|----------------|
| 00.00 Reception            | NO             |
| 00.01 Stairs               | NO             |
| 00.03 Store                | NO             |
| 00.05 Visitor Toilet       | NO             |
| 00.06 DWC                  | NO             |
| 00.07 Warehouse Undercroft | NO             |
| 00.08 Distribution Centre  | NO             |
| 00.09 Shower               | NO             |
| 01.00 Office               | NO             |
| 01.01 Lobby                | NO             |
| 01.02 Stairs               | NO             |
| 01.05 WC                   | NO             |
| 01.06 WC                   | NO             |
| 01.07 WC                   | NO             |
| 01.08 WC                   | NO             |
| 01.09 Cleaners Store       | NO             |
| 01.10 Kitchenette          | NO             |
| 01.11 Open Plan Office     | NO             |

#### General lighting and display lighting

| Zone name                  | Luminous efficacy [lm/W] |      |              | General lighting [W] |
|----------------------------|--------------------------|------|--------------|----------------------|
|                            | Luminaire                | Lamp | Display lamp |                      |
| Standard value             | 60                       | 60   | 22           |                      |
| 00.00 Reception            | -                        | 100  | 100          | 173                  |
| 00.01 Stairs               | -                        | 100  | -            | 22                   |
| 00.03 Store                | 100                      | -    | -            | 5                    |
| 00.05 Visitor Toilet       | -                        | 100  | -            | 23                   |
| 00.06 DWC                  | -                        | 100  | -            | 34                   |
| 00.07 Warehouse Undercroft | 100                      | -    | -            | 1810                 |
| 00.08 Distribution Centre  | 100                      | -    | -            | 41903                |
| 00.09 Shower               | -                        | 100  | -            | 8                    |
| 01.00 Office               | 100                      | -    | -            | 212                  |
| 01.01 Lobby                | -                        | 100  | -            | 49                   |
| 01.02 Stairs               | -                        | 100  | -            | 45                   |
| 01.05 WC                   | -                        | 100  | -            | 23                   |

| General lighting and display lighting |                | Luminous efficacy [lm/W] |      |              | General lighting [W] |
|---------------------------------------|----------------|--------------------------|------|--------------|----------------------|
| Zone name                             |                | Luminaire                | Lamp | Display lamp |                      |
|                                       | Standard value | 60                       | 60   | 22           |                      |
| 01.06 WC                              |                | -                        | 100  | -            | 25                   |
| 01.07 WC                              |                | -                        | 100  | -            | 23                   |
| 01.08 WC                              |                | -                        | 100  | -            | 25                   |
| 01.09 Cleaners Store                  |                | 100                      | -    | -            | 6                    |
| 01.10 Kitchenette                     |                | 100                      | -    | -            | 49                   |
| 01.11 Open Plan Office                |                | 100                      | -    | -            | 2293                 |

### Criterion 3: The spaces in the building should have appropriate passive control measures to limit solar gains

| Zone                       | Solar gain limit exceeded? (%) | Internal blinds used? |
|----------------------------|--------------------------------|-----------------------|
| 00.00 Reception            | NO (-42%)                      | NO                    |
| 00.07 Warehouse Undercroft | NO (-65.6%)                    | NO                    |
| 00.08 Distribution Centre  | NO (-12.4%)                    | NO                    |
| 01.00 Office               | NO (-47.5%)                    | NO                    |
| 01.10 Kitchenette          | NO (-73.5%)                    | NO                    |
| 01.11 Open Plan Office     | NO (-37.6%)                    | NO                    |

### Criterion 4: The performance of the building, as built, should be consistent with the calculated BER

Separate submission

### Criterion 5: The necessary provisions for enabling energy-efficient operation of the building should be in place

Separate submission

### EPBD (Recast): Consideration of alternative energy systems

|                                                                                        |     |
|----------------------------------------------------------------------------------------|-----|
| Were alternative energy systems considered and analysed as part of the design process? | YES |
| Is evidence of such assessment available as a separate submission?                     | YES |
| Are any such measures included in the proposed design?                                 | YES |

# Technical Data Sheet (Actual vs. Notional Building)

## Building Global Parameters

|                                                       | Actual  | Notional |
|-------------------------------------------------------|---------|----------|
| Area [m <sup>2</sup> ]                                | 10512.2 | 10512.2  |
| External area [m <sup>2</sup> ]                       | 24643.7 | 24643.7  |
| Weather                                               | MAN     | MAN      |
| Infiltration [m <sup>3</sup> /hm <sup>2</sup> @ 50Pa] | 3       | 3        |
| Average conductance [W/K]                             | 7469.29 | 6647.55  |
| Average U-value [W/m <sup>2</sup> K]                  | 0.3     | 0.27     |
| Alpha value* [%]                                      | 9.99    | 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          |
| 100    | <b>B8 Storage or Distribution</b>                                  |
|        | C1 Hotels                                                          |
|        | C2 Residential Institutions: Hospitals and Care Homes              |
|        | C2 Residential Institutions: Residential schools                   |
|        | C2 Residential Institutions: Universities and colleges             |
|        | C2A Secure Residential Institutions                                |
|        | Residential spaces                                                 |
|        | D1 Non-residential Institutions: Community/Day Centre              |
|        | D1 Non-residential Institutions: Libraries, Museums, and Galleries |
|        | D1 Non-residential Institutions: Education                         |
|        | D1 Non-residential Institutions: Primary Health Care Building      |
|        | D1 Non-residential Institutions: Crown and County Courts           |
|        | 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/m<sup>2</sup>]

|                 | Actual       | Notional     |
|-----------------|--------------|--------------|
| Heating         | 0.7          | 0.41         |
| Cooling         | 0.62         | 0.63         |
| Auxiliary       | 0.53         | 0.22         |
| Lighting        | 19.65        | 36.52        |
| Hot water       | 7.03         | 5.93         |
| Equipment*      | 43.52        | 43.52        |
| <b>TOTAL **</b> | <b>28.53</b> | <b>43.71</b> |

\* Energy used by equipment does not count towards the total for consumption or calculating emissions.

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

## Energy Production by Technology [kWh/m<sup>2</sup>]

|                       | Actual | Notional |
|-----------------------|--------|----------|
| Photovoltaic systems  | 2.98   | 0        |
| Wind turbines         | 0      | 0        |
| CHP generators        | 0      | 0        |
| Solar thermal systems | 0      | 0        |

## Energy & CO<sub>2</sub> Emissions Summary

|                                               | Actual | Notional |
|-----------------------------------------------|--------|----------|
| Heating + cooling demand [MJ/m <sup>2</sup> ] | 10.95  | 10.66    |
| Primary energy* [kWh/m <sup>2</sup> ]         | 87.57  | 119.08   |
| Total emissions [kg/m <sup>2</sup> ]          | 13.3   | 21       |

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

## HVAC Systems Performance

| System Type                                                                                                           | Heat dem<br>MJ/m2 | Cool dem<br>MJ/m2 | Heat con<br>kWh/m2 | Cool con<br>kWh/m2 | Aux con<br>kWh/m2 | Heat<br>SSEFF | Cool<br>SSEER | Heat gen<br>SEFF | Cool gen<br>SEER |
|-----------------------------------------------------------------------------------------------------------------------|-------------------|-------------------|--------------------|--------------------|-------------------|---------------|---------------|------------------|------------------|
| [ST] Split or multi-split system, [HS] Heat pump (electric): air source, [HFT] Electricity, [CFT] Electricity         |                   |                   |                    |                    |                   |               |               |                  |                  |
| Actual                                                                                                                | 66.1              | 138.3             | 5.6                | 13.5               | 6.8               | 3.26          | 2.84          | 3.5              | 4                |
| Notional                                                                                                              | 27.1              | 186.7             | 2.9                | 13.7               | 3.6               | 2.56          | 3.79          | ----             | ----             |
| [ST] Other local room heater - unfanned, [HS] Direct or storage electric heater, [HFT] Electricity, [CFT] Electricity |                   |                   |                    |                    |                   |               |               |                  |                  |
| Actual                                                                                                                | 208.2             | 0                 | 57.8               | 0                  | 17                | 1             | 0             | 1                | 0                |
| Notional                                                                                                              | 86.5              | 0                 | 27.9               | 0                  | 18.7              | 0.86          | 0             | ----             | ----             |
| [ST] Other local room heater - unfanned, [HS] Direct or storage electric heater, [HFT] Electricity, [CFT] Electricity |                   |                   |                    |                    |                   |               |               |                  |                  |
| Actual                                                                                                                | 210.3             | 0                 | 58.4               | 0                  | 0                 | 1             | 0             | 1                | 0                |
| Notional                                                                                                              | 128.8             | 0                 | 41.5               | 0                  | 0                 | 0.86          | 0             | ----             | ----             |
| [ST] No Heating or Cooling                                                                                            |                   |                   |                    |                    |                   |               |               |                  |                  |
| Actual                                                                                                                | 0                 | 0                 | 0                  | 0                  | 0                 | 0             | 0             | 0                | 0                |
| Notional                                                                                                              | 0                 | 0                 | 0                  | 0                  | 0                 | 0             | 0             | ----             | ----             |

### Key to terms

|                   |                                                                                                       |
|-------------------|-------------------------------------------------------------------------------------------------------|
| Heat dem [MJ/m2]  | = Heating energy demand                                                                               |
| Cool dem [MJ/m2]  | = Cooling energy demand                                                                               |
| Heat con [kWh/m2] | = Heating energy consumption                                                                          |
| Cool con [kWh/m2] | = Cooling energy consumption                                                                          |
| Aux con [kWh/m2]  | = Auxiliary energy consumption                                                                        |
| Heat SSEFF        | = Heating system seasonal efficiency (for notional building, value depends on activity glazing class) |
| Cool SSEER        | = Cooling system seasonal energy efficiency ratio                                                     |
| Heat gen SSEFF    | = Heating generator seasonal efficiency                                                               |
| Cool gen SSEER    | = Cooling generator seasonal energy efficiency ratio                                                  |
| ST                | = System type                                                                                         |
| HS                | = Heat source                                                                                         |
| HFT               | = Heating fuel type                                                                                   |
| CFT               | = Cooling fuel type                                                                                   |

## Key Features

The Building Control Body is advised to give particular attention to items whose specifications are better than typically expected.

### Building fabric

| Element                                                                  | U <sub>i-Typ</sub> | U <sub>i-Min</sub> | Surface where the minimum value occurs*                            |
|--------------------------------------------------------------------------|--------------------|--------------------|--------------------------------------------------------------------|
| Wall                                                                     | 0.23               | 0.35               | 00000000:Surf[11]                                                  |
| Floor                                                                    | 0.2                | 0.09               | 00000012:Surf[0]                                                   |
| Roof                                                                     | 0.15               | 0.25               | 00000012:Surf[49]                                                  |
| Windows, roof windows, and rooflights                                    | 1.5                | 1.5                | 00000000:Surf[1]                                                   |
| Personnel doors                                                          | 1.5                | 1.5                | 00000000:Surf[30]                                                  |
| Vehicle access & similar large doors                                     | 1.5                | 1.5                | 00000012:Surf[6]                                                   |
| High usage entrance doors                                                | 1.5                | -                  | No High usage entrance doors in building                           |
| U <sub>i-Typ</sub> = Typical individual element U-values [W/(m²K)]       |                    |                    | U <sub>i-Min</sub> = Minimum individual element U-values [W/(m²K)] |
| * There might be more than one surface where the minimum U-value occurs. |                    |                    |                                                                    |

| Air Permeability   | Typical value | This building |
|--------------------|---------------|---------------|
| m³/(h.m²) at 50 Pa | 5             | 3             |

