

452 Basingstoke Road, Reading RG2 0QE
November 2016

Procter & Gamble Ltd

P&G Reading Innovation Centre

Energy Strategy



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This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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1 Introduction

This report is the Energy Strategy, produced by Arup on behalf of Procter and Gamble Ltd, to support a planning application for the new development at 452 Basingstoke Road, Reading.

Development of a two storey research and development facility within Procter and Gamble's existing Reading site is proposed. The facility will comprise laboratories, offices, storage warehousing, associated access, car parking and hard and soft landscaping works. The works comprise:

- Demolition of the south-western wing of the existing Gillette building, the ground floor security gatehouse and ancillary sub-station and external store buildings;
- Refurbishment of the southern half of the retained Gillette building and erection of a rear extension in the form of a new research and development office and laboratory accommodation (Class B1) and associated storage warehousing (Class B8);
- Refurbishment of the façade of the northern half of the retained Gillette building;
- Provision of a 190 space multi-storey car park to the south of the Gillette building formed of four storeys comprising eight levels. Further parking at grade, adjacent and in the currently vacant land to the north and rear of the existing Gillette building;
- Ancillary plant and engineering works including switch room, generator and transformer buildings;
- Associated hard and soft landscaping works, including access and circulation; and
- Formation of a new northern vehicular access to the application site.

This strategy summarise the regulatory and planning policies applicable to the proposed development, and sets targets commensurate with these policies, which the development shall seek to achieve.

The energy strategy for the building follows the energy hierarchy:

- **Be lean:** use less energy
- **Be clean:** supply energy efficiently
- **Be green:** use renewable energy.

Calculations for energy efficiency strategies have been based on results from Dynamic Simulation Modelling (DSM) undertaken using EDSL TAS Software Version 9.3.3b (latest version at the date of the work, compliant with CIBSE

AM11) in accordance with National Calculation Methodologies as required by Part L2A of the Building Regulations (2013).

2 Context

2.1 National Policy

The National Planning Policy Framework sets out the overarching planning policies for England, with guidance on how these are expected to be applied. The underlying theme running throughout this policy guidance is a presumption in favour of sustainable development.). At a national level, the British Government is committed to reduce greenhouse gas emissions by 34% by 2020 and by 80% by 2050 (Climate change Act, 2008).

2.1.1 Climate Change Act 2008

Following this summit's agreement of the EU Climate Change Package, passed by the European Parliament on 17 December, 2008, the UK has a target of a 20% contribution from renewable energy as enshrined in EU law, which translates into a 15% share for renewables for the UK (2008 -2012 EU Burden Sharing Agreement);

Key aspects of this agreement include:

- 20% cut in greenhouse gas emissions by 2020, against 1990 levels;
- 20% increase in use of renewable energy by 2020;
- 20% cut in energy consumption through improved energy efficiency by 2020.

2.1.2 EPC –DEC

The EU Energy Performance of Buildings Directive (EPBD) was introduced in the UK from January 2006 with a three year implementation period ending January 2009.

Its objective is to improve energy efficiency and reduce carbon emissions as part of the government's strategy to achieve a sustainable environment and meet climate change targets agreed under the Kyoto Protocol.

The EPBD introduced higher standards of energy conservation for new and refurbished buildings from April 2006 and requires energy performance certification for all buildings when sold or leased. In addition, it introduced regular inspections for larger air conditioning systems and advice on more efficient boiler operation for commercial property.

Energy Performance Certificates are required on construction, sale or lease of all buildings from October 2008. The certificate includes an energy rating, as well as advice on how to make cost effective improvements to the building to make it

more energy efficient. The ratings are similar to those currently used for white goods, ranging from A to G, with A the best and G the worst.

Public buildings over 1000m² occupied or part occupied by public authorities or by institutions providing public services and therefore frequently visited by the public, require Display Energy Certificates (DECs). This form of certificate must be publicly displayed within the building and is different in form and content from an Energy Performance Certificate. Display certificates are produced using a different methodology and are based on actual energy usage over a three year period (if available). The building is given an operational rating which assesses how well it has been operated based on actual energy consumption information.

From 2016 a tenant will be entitled to ask the landlord to carry out the measure recommended on the EPC and the landlord will have a legal obligation to do so. The landlord must be prepared to carry out any outstanding measures if the tenant request to do so, and from 2018 it will be illegal to let a property which has an EPC rating below E.

2.1.3 Part-L 2013 Compliance

The current edition of Approved Document Part-L of the UK Building Regulation has been enforceable since April 2013.

Due to the fact that the development concerns an extension of an existing building, thus it falls under Building Regulations Part L2B 2013. According to the Approved Document L2B (incorporating 2010, 2011, 2013 and 2016 amendments), because the retained building has a total useful floor area greater than 1,000 m² and the new addition's floor area is greater than 25% of the existing floor area (9,000 m² for the new building, 1,500 m² for the existing building), the development is classified as "*large extension*". Therefore, the work must in addition comply with Approved Document L2A. Furthermore, *consequential improvements* need to be undertaken in order to make the existing building more energy efficient, as reported in Approved Document L2B, pages 12 and 22. This means that a compliance model is required to assess the building's Building Emission Rate (BER), as required in Part L2A.

2.1.3.1 Approved Document L2A

The Approved Document L2A needs to be followed for the new blocks. It provides five key criteria which must be satisfied:

- Criterion 1:** Achieving the Target Emission Rate (TER)
- Criterion 2:** Limits on design flexibility
- Criterion 3:** Limiting the effects of heat gains in summer
- Criterion 4:** Building performance consistent with the Building Emission Rate (BER)
- Criterion 5:** Provision for energy efficient operation of the building.

This Energy Strategy shall address criteria 1, 2 and 3, related to the design stage. Criterion 4 and 5 are only relevant post construction.

Criterion 1

The actual Building BER must be no greater than the TER, calculated in accordance to paragraphs 2.2 and 2.6 of Approved Document L2A.

Criterion 2

The building elements must meet U-value limits specified in Table 3 of the Approved Document, shown in Figure 1 below, and fixed building services must meet efficiency requirements standards outlined in the Table 1 of *Non-Domestic Building Services Compliance Guide 2013*.

Table 3 Limiting fabric parameters	
Roof	0.25 W/(m ² ·K)
Wall	0.35 W/(m ² ·K)
Floor	0.25 W/(m ² ·K)
Swimming pool basin ¹	0.25 W/(m ² ·K)
Windows, roof windows, roof-lights ² , curtain walling and pedestrian doors ^{3,4}	2.2 W/(m ² ·K)
Vehicle access and similar large doors	1.5 W/(m ² ·K)
High-usage entrance doors	3.5 W/(m ² ·K)
Roof ventilators (inc. smoke vents)	3.5 W/(m ² ·K)
Air permeability	10.0 m ³ /(h·m ²) at 50 Pa

Figure 1: Limiting fabric parameters (Approved Document L2A).

Criterion 3

Commercial buildings must not be subject to excessive solar gains during the summer period in order to either:

- Reduce the need for air-conditioning, or
- Reduce the installed capacity of any air-conditioning system that is installed.

2.1.3.2 Approved Document L2B: Consequential improvements

Consequential improvements reported in Approved Document L2B must be adopted for the existing block. The requirements are reported in Table 6 of the Approved Document L2B 2010 (incorporating 2010, 2011, 2013 and 2016 amendments), shown in Figure 2. In particular, thermal elements must comply with Table 5 in the Approved Document, reported in Figure 3.

The design of the building will need to meet these measures in order to demonstrate full compliance with Building Regulations Part L in further stages.

Table 6 Improvements that in ordinary circumstances are practical and economically feasible

Items 1 to 7 will usually meet the economic feasibility criterion set out in paragraph 6.5. A shorter payback period is given in item 8 because such measures are likely to be more capital intensive or more risky than the others.

No.	Improvement measure
1	Upgrading heating systems more than 15 years old by the provision of new plant or improved controls
2	Upgrading cooling systems more than 15 years old by the provision of new plant or improved controls
3	Upgrading air-handling systems more than 15 years old by the provision of new plant or improved controls
4	Upgrading general lighting systems that have an average lamp efficacy of less than 40 lamp-lumens per circuit-watt and that serve areas greater than 100 m ² by the provision of new luminaires or improved controls
5	Installing energy metering following the guidance given in CIBSE TM 39
6	Upgrading thermal elements which have U-values worse than those set out in column (a) of Table 5 following the guidance in paragraphs 5.12 and 5.13
7	Replacing existing windows, roof windows or rooflights (but excluding display windows) or doors (but excluding high-usage entrance doors) which have a U-value worse than 3.3 W/m ² .K following the guidance in paragraphs 4.23 to 4.28
8	Increasing the on-site low and zero carbon (LZC) energy-generating systems if the existing on-site systems provide less than 10% of on-site energy demand, provided the increase would achieve a simple payback of 7 years or less
9	Measures specified in the Recommendations Report produced in parallel with a valid Energy Performance Certificate

Figure 2: Consequential improvements on existing buildings (BR Part L2B).

Table 5 Upgrading retained thermal elements

Element ¹	U-value W/(m ² .K)	
	(a) Threshold	(b) Improved
Wall – cavity insulation	0.70	0.55 ²
Wall – external or internal insulation	0.70	0.30 ³
Floors ^{4,5}	0.70	0.25
Pitched roof – insulation at ceiling level	0.35	0.16
Pitched roof – insulation at rafter level ⁶	0.35	0.18
Flat roof or roof with integral insulation ⁷	0.35	0.18

Figure 3: U-values limits for retained thermal elements (BR Part L2B).

2.2 Local Policy

On the local level, the site falls under the jurisdiction of the Reading Borough Council (RBC).

2.2.1 RBC Local Plan Documents

The policies of Reading Borough Council (RBC) are contained within the Local Plan documents. Those relevant for the Energy Strategy are:

- Reading Borough Council Core Strategy (Alteration adopted January 2015) Sites and Detailed Policies Document (Alteration adopted January 2015)
- Sustainable Design and Construction Supplementary Planning Document (SPD) (July 2011)

2.2.1.1 Reading Borough Council Core Strategy

The *Core Strategy (2008 - Alteration adopted January 2015)* outlines a series of strategic policies for development in Reading. The Core Strategies policy relevant to the P&G Energy Strategy is **Policy CS1 Sustainable Construction and Design**, stating the following:

- All new commercial developments are required to meet the most up to date BREEAM 'Very Good' as a minimum standard;
- On larger developments of more than 1,000 m² of floor space, ensure that 50% of the provision meets the most up to date BREEAM 'Excellent' standards;
- All new developments maximise the use of energy efficiency and energy conservation measures in their design, layout and orientation to reduce overall energy demand;
- All developments of more than 1000m² floor space incorporate on-site generation of energy from renewable sources and energy efficient design measures (including the use of CHP where appropriate) to off-set at least 20% of predicted carbon dioxide emissions from the estimated energy usage of the completed and occupied development;
- All developments reduce mains water use and demonstrate that water conservation measures are incorporated so that predicted per capita consumption does not exceed the appropriate levels set out in the BREEAM Standards
- Developments incorporate sustainable urban drainage facilities and techniques

2.2.1.2 Sites and Detailed Policies Document

The *Sites and Detailed Policies Document (2012)* sets out a range of borough-wide policies which help to guide development and planning applications. The relevant policy for the Energy Strategy is **Policy DM2 - Decentralised Energy**,

which states that any development of more than 20 dwellings and/ or non-residential development of over 1,000 sq m shall consider the inclusion of a CHP plant, or biomass-fuelled heating scheme, or other form of decentralised energy provision, within the site, unless it can be demonstrated that the scheme is not suitable or feasible for this form of energy provision.

The document also mentions that the NPPF promotes the use of decentralised energy. Decentralised energy is a term that covers a variety of technologies, including various renewable technologies, and more efficient energy generation such as CHP. This policy promotes the use of decentralised energy, which has particular applications to a dense urban area such as Reading.

2.2.1.3 Sustainable Design and Construction SPD

The Sustainable Design and Construction SPD issued in 2011 states the following:

'Recent changes to the Building Regulations mean that the requirement in policy CS1 to 'off-set at least 20% of predicted carbon dioxide emissions' has now been superseded for both residential and non-residential developments. All other parts of policy CS1 are still relevant. For this reason, the requirement to off-set at least 20% of predicted carbon dioxide emissions from the estimated energy usage of the completed and occupied development in adopted policy CS1 is not mentioned further in this SPD'.

2.3 Energy Hierarchy

The Energy Hierarchy approach is a procedure laid out by the document titled “Energy Planning – Greater London Authority guidance on preparing energy assessments (April 2015)”. Although the proposed development does not fall under the Greater London Authority jurisdiction, this document has been used as a guideline for the strategy as it offers an effective framework to guide energy policy and decision making. By prioritising demand-side activities to reduce wastage and improve efficiency, the hierarchy links closely to the principles of sustainable development and offers an integrated, easy-to-use approach to the management of energy demand and supply.

The document follows the Mayor of London’s Energy Hierarchy:

- Priority 1 – Energy Conservation & Energy Efficiency (Be Lean)
- Priority 2 – Exploitation of Low Carbon Technologies (Be Clean)
- Priority 3 – Exploitation of renewables, sustainable sources of energy (Be Green).

Priority 1 – Energy Conservation & Energy Efficiency (Be Lean)

The reduction or elimination of unnecessary energy use: conservation is often achieved through behavioural changes such as switching appliances off when they are not being used, or the introduction of passive design features, an example of

which would be to implement shading devices in order to reduce the need for cooling in summer etc.

Energy efficiency improvements are usually achieved through the application of engineering principles.

Priority 2 – Exploitation of low carbon technologies (Be Clean)

Finite natural resources such as oil, coal, gas and uranium provide the vast majority of global and UK energy supply. The current transport systems, buildings and power generation infrastructure have been built such that they are all largely dependent on the continued supply of these resources. Examples of low carbon technologies are Heat Pumps, Combined Heat & Power and District Heating/Cooling, etc.

Priority 3 – Exploitation of Renewables, Sustainable Sources of Energy (Be Green)

Having taken all reasonable steps to minimise energy demand and improve efficiency, this next priority is to supply that demand from clean energy sources that are effectively infinite. Effective, sustainable energy provision, though, is not just about resource availability, it must also embrace wider issues such as affordability, societal acceptability and environmental impact.

2.4 BREEAM Ene01 - Reduction of energy use and carbon emissions

It is the aspiration of the client that the development is set out to achieve BREEAM 'Very Good' rating under the BREEAM UK New Construction 2014.

The relevant section for

For 'Very Good' rating level, no specific minimum standards are set for 'Ene01 – Reduction of energy use and carbon emissions'. However, the credits achieved under this issue can contribute to achieve the required level overall.

3 Methodology

3.1 Software

In order to demonstrate compliance with the regulations and analyse the efficacy of the energy strategy, the whole development has been modelled using EDSL TAS Version 9.3.3b, which was the most recent release at the time of performing the calculations. EDSL TAS is an accredited software and can be used to demonstrate UK Building Regulation Part-L Compliance.

Calculations are based on first-principle methods of heat transfer and are driven by real weather data. The weather file used for the simulations is the new released CIBSE Test Reference Year (TRY) weather file for Swindon (CIBSE, 2016), which is the closest location to the site with an available weather file.

3.2 Building Geometry

The geometry of the thermal model is based on architectural general arrangement layout drawings dated October 2016. Figure 4 shows a view of the compliance thermal model for the whole building after the extension.

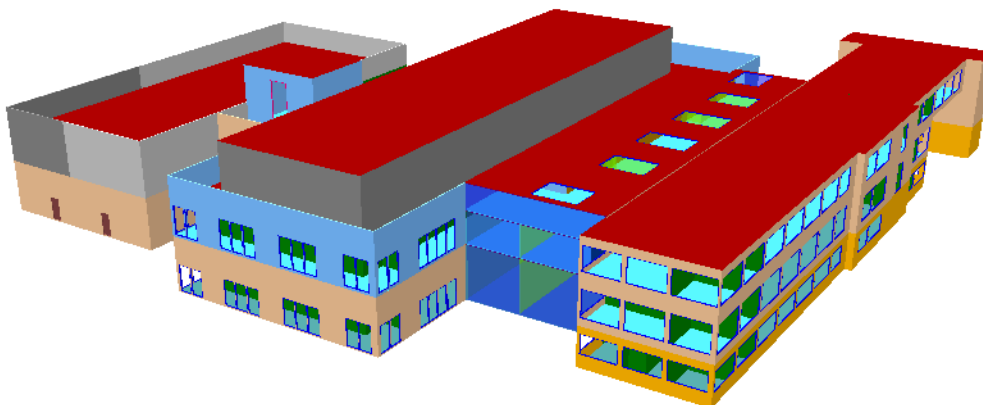


Figure 4: Screenshots of compliance thermal model in EDSL TAS.

4 Notional Baseline

The Notional Baseline represents the energy consumption and carbon dioxide emissions baseline associated with a typical industrial building built to 2013 standards. The Notional Baseline in this case represents the building with typical 2013 controlled services efficiencies:

- Typical Gas fired boilers seasonal efficiency of 91%;
- Typical Water Cooled Chillers SEER of 2.7;

- Average luminaire efficacy of 60 lm/cW;
- Manual lighting controls;
- Air Handling Units Specific Fan Power (SFP) of 1.6 W/(l*s);
- Mechanical Ventilation Heat Recovery (MVHR) of 50%;
- Power Factor Correction 0.90 to 0.95.

According to the compliance thermal model, the *Notional Baseline* emissions have been estimated as follows:

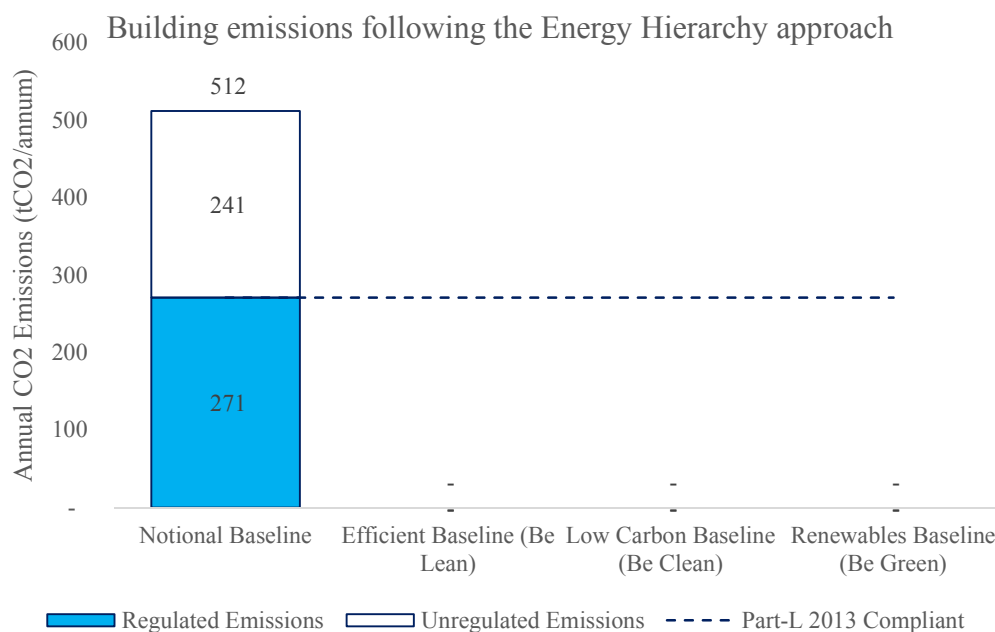


Figure 5: Building emissions for the notional baseline.

The results indicate that the development with typical MEP services would yield a 'Regulated' baseline carbon dioxide emission of 512 tCO₂/annum, based on a Target Emission Rate (TER) of 27.3 KgCO₂/m²annum.

5 Energy Conservation & Energy Efficiency (Be Lean)

The second stage of the Energy Hierarchy approach focus on Energy Efficiency, to reduce energy losses and eliminate waste

5.1 Thermal envelope

5.1.1 Existing building

For the existing building, no detailed information were available regarding the thermal envelope; this data should be updated with more detail for further stages of the design. For the purpose of an early stage analysis, the same U-values and air permeability values as the new building have been assumed, considering that improvements on the existing building are expected.

However, for the next stages, it will be necessary to update the model with more realistic values, according to the information available. For this purpose, it is worth underlining that the retained building elements of the existing block will need to be improved if their U-values are lower than the ones reported in the first column of table 4 in BR Part L2B.

5.1.2 New building

Due to the early stage of the design, no detailed information regarding the building elements were available. Therefore, standard NCM materials have been considered (UK's National Calculation Method for Non Domestic Buildings). The related U-values used for the thermal modelling are reported in Table 1.

Table 1: U-values compliance with BR Part L2B for new elements.

Thermal Element	Required U-value (W/m ² K)	Assumed U-value (W/m ² K)
External walls	0.28	0.24
Ground floor	0.22	0.16
Roof	0.18	0.16
Windows	1.8	1.5

In order to reduce the cooling loads, a low G-value for windows has been considered, namely 0.367.

5.2 Controlled Services

Minimising energy consumption for P&G Reading project can be accommodated by driving down energy consumption through energy efficient plant and controls.

Therefore, a list of design considerations has been applied to the thermal model:

- Gas fired boiler(s) with seasonal efficiency = 91%;
- High efficiency water cooled chiller(s) with SEER = 4.2;

- Low energy lighting i.e. T5 Fluorescent and LEDs with average luminaire efficacy of = 85 lm/cW for all the areas;
- Auto Presence Detection for lighting control in the service areas;
- Efficient heat recovery on all air handling units (50%);
- Low Specific Fan Power (SFP) for air handling units and air distribution systems, target average SFP of 1.5 W/(l*s);
- Time & temperature zone control, occupancy demand controlled ventilation, optimum start/stop and weather compensation to optimise plant performance;
- Use of free cooling wherever possible;
- BMS system with automatic meter reading, energy monitoring and targeting facilities;
- Power factor correction higher than 0.95.

5.3 Efficient Baseline (Be Lean)

According to the compliance thermal model, the Efficient Baseline has been estimated as shown in Figure 6.

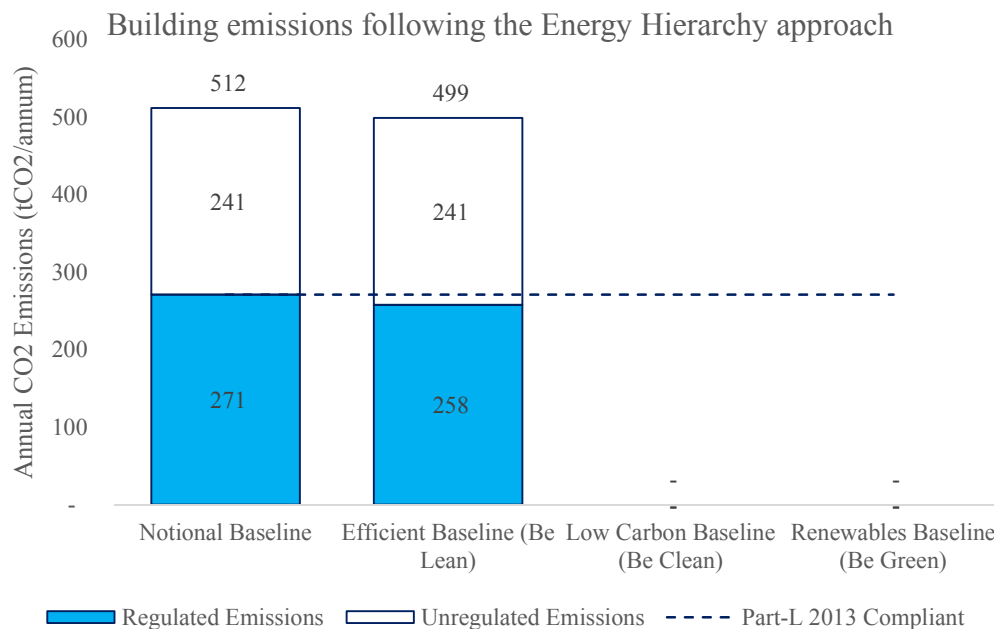


Figure 6: Building emissions for the notional building and the efficient baseline.

The results indicate that P&G Reading project, with energy efficient MEP services, would yield a 'Regulated' carbon dioxide emission of 258 tCO₂/annum, based on a Building Emission Rate (BER) of 25.9 kgCO₂/m²annum.

6 Exploitation of Low Carbon Technologies (Be Clean)

The successful integration of low carbon technologies with buildings depends on a number of technical, economic and social factors. This section illustrates the viability of different low carbon technologies in relation to the context of the project.

6.1 Decentralised energy system

6.1.1 District Heat Network

The most common form of local area energy network is community or district heating (DH). This is where space heating and hot water is delivered to multiple occupants from a local plant via a network of insulated pipes buried in the ground. The pipe network can be installed at the same time as other services (water, drainage and other below ground services) to minimise costs in new development.

Connecting to a local area energy network is feasible where a heat network is provided or in the case of large development. The P&G building will rise within an area of relatively low heat density, as shown in Figure 7, where no DH networks exist or are expected at the moment (August 2016), according to the documents available from the Reading Borough Council. Therefore, District Heat Network is not a viable option in this case.

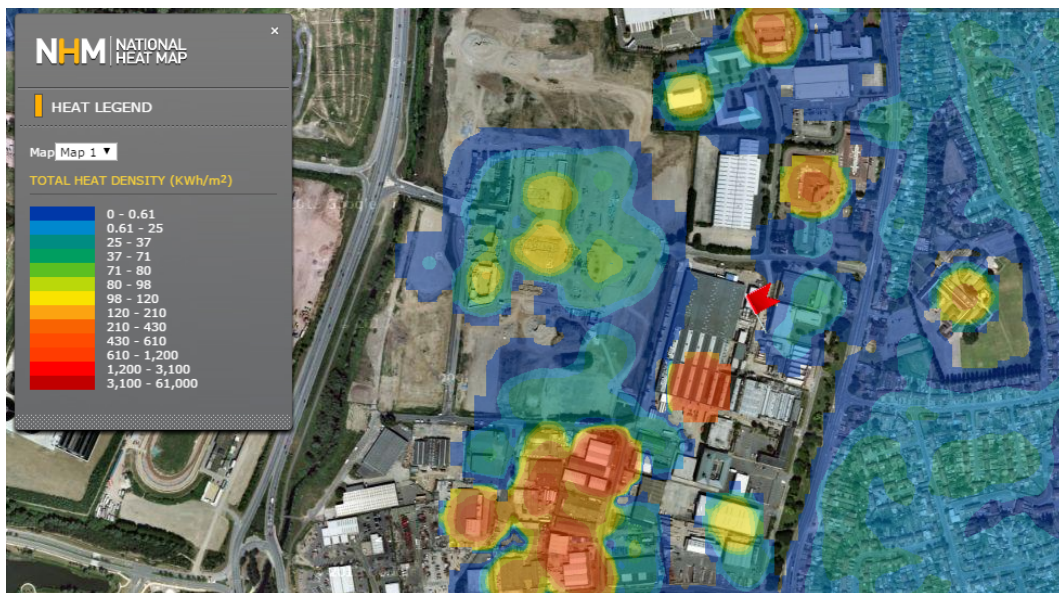


Figure 7: Heat density in proximity to P&G Reading.

6.1.2 Combined Heat and Power

The successful integration of low carbon technologies with buildings depends on a number of technical, economic and social factors.

Combined Heat & Power (CHP) Plants, also known as cogeneration, uses conventional stationary internal combustion engines or turbines to generate both electricity and heat, using large proportion of waste heat.

Assuming the CHP plant is well-designed, the system is usually significantly more efficient than typical conventional engine. However, although they can provide energy with very high efficiency, CHP plants rely on matched building electrical and heat demands. Therefore, if these do not follow a similar trend over the course of the day, and throughout the year, then the CHP plant may frequently be generating large proportions of heat when it is not required. If there is no demand then this heat is essentially wasted, or 'dumped', implying a significant decrease in the seasonal efficiency and therefore in the carbon emissions reduction.

In addition, CHP plants are typically economically feasible only if they operate for at least 5,000 hours per year. To ensure steady operation of the CHP plant, and to prevent heat being dumped, it is recommended that CHP plants are designed to meet the building's base heating demand, exporting electricity to the grid when electrical demand is lower than the CHP electrical output.

In the case of P&G building, at this stage it is expected that the base heat load is relatively low in comparison to the total heat load of the building, as the domestic hot water demand is negligible in comparison to seasonal space heating demand, in addition, the lab hot water usage is unknown until further on down the design stages. Therefore, it is estimated that a regular CHP plant is not applicable as there may not be sufficient heat load to sustain the CHP engine for any meaningful output. A mini-CHP, such as the Baxi Dachs shown in Figure 8, maybe feasible, with a thermal output of around 30 kW. However, electrical efficiencies of such engines are low, coupled with the fact that low outputs due to low base heat load in the building, this may imply a lower financial effectiveness of the overall CHP system.

Due to the reasons above, CHP plant is considered not a practical solution, primary concern is the likelihood of mothballing, and therefore, other low carbon technologies are to be preferred.



Figure 8: Example Mini-CHP Engines.

6.1.3 VRF system – Heat recovery

Variable Refrigerant Flow (VRF) comfort cooling systems are based on heat pump technology and usually comprise an externally-mounted unit and a number of internal units that serve individual rooms or zones. The external and internal units are linked via a network of pipes that transfer refrigerant between them.

There are two common types of VRF systems:

- Heat Pump (HP) type: the most general type that can be used for either cooling or heating, but not simultaneously;
- Heat Recovery (HR) type: can deliver simultaneous heating and cooling to different zones by transferring heat between the cooling and heating indoor units. This generally occurs in the winter season in medium-sized to large-sized commercial buildings with a substantial core such as computer rooms.

An advantage of simultaneous VRF systems is their ability to allow the simultaneous operation of indoor units in either cooling or heating mode. This allows for direct heat recovery to be performed. Where different indoor units are in cooling mode can be used to supply heat to those in heating mode.

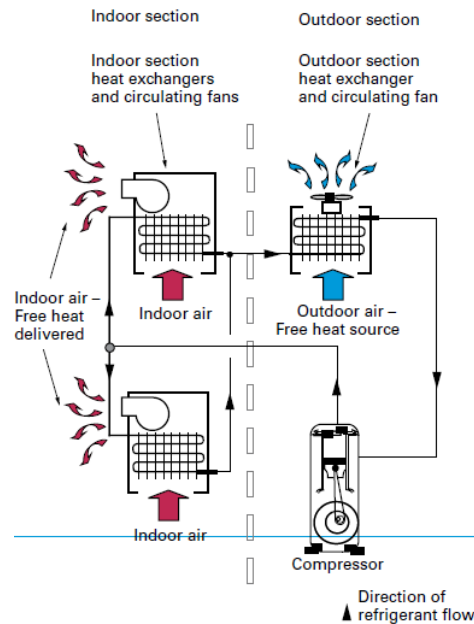


Figure 9: Scheme of a heat pump VRF in heat mode.

6.1.3.1 Heat pump VRF

Operationally, single-mode VRF systems will be similar to traditional multi-splits (aside from their ability to service more extensive systems). They can take advantage of the diversity of the timing of loads (for example, the temporal variation in peak cooling required for east- and west-facing office zones) to reduce the main system size. While operating in heating mode, all the internal coils will be acting as condensers, and the heating will be controlled by the electronic ‘expansion’ valve (sometimes referred to as a ‘linear expansion valve’) metering the flow. This will maintain an appropriate level of sub cooling in the refrigerant as it leaves the room coil to return via the common return pipe to the external condensing unit. Conversely, when operating as cooling devices the internal units would function as evaporators, and the degree of cooling provided will be controlled through the local expansion valve maintaining appropriate superheat (and so coil temperature) at the exit of the local coil.

6.1.3.2 Heat recovery VRF

Where there are concurrent loads for heating and cooling in different zones, dual-mode (heat recovery) systems allow heat to be moved around the building between areas that require heat and those that require cooling. Heat would effectively be moved from areas that require cooling to those that require heating without the need for the refrigerant to pass through the condenser/evaporator coil in the external unit. The external compressor will still operate (to provide the compression for the cycle), and will adjust capacity to satisfy the total cooling being delivered by the sum of the individual units.

VRF systems can have multiple indoor units served by a single outdoor unit, in both heating and cooling modes simultaneously. This mixed mode operation leads to energy savings as both ends of the thermodynamic cycle are delivering useful

heat exchange. If a system has a cooling COP (Coefficient of Performance) of 3, and a heating COP of 4, then heat recovery operation could yield a COP as high as 7. It should be noted that this perfect balance of heating and cooling demand is unlikely to occur for many hours each year, but whenever mixed mode is used energy is saved. In mixed mode the energy consumption is dictated by the larger demand (heating or cooling), and the lesser demand (cooling or heating) is delivered free.

The cost of installing a VRF system is similar to that of a three or four pipe water-based fancoil system. Particularly where there are opportunities for heat recovery, which may include using excess space heat for low and higher temperature hot water production, this electrically powered system can be both straightforward and flexible to install and operate, and provide competitive seasonal efficiencies and operating costs.

The P&G new building presents several zones with different activities and conditions; therefore, it is likely that cooling and heating will be required simultaneously in one moment. For this reason, a heat recovery VRF seems to be appropriate. In particular, a VRF system has been defined for all office, labs and circulation areas.

The system has been simulated in EDSL-TAS and the results in terms of carbon savings are shown in 6.2.

6.2 Low Carbon Baseline (Be Clean)

According to the compliance thermal model, the Low Carbon Baseline has been estimated as shown in **Error! Reference source not found..**

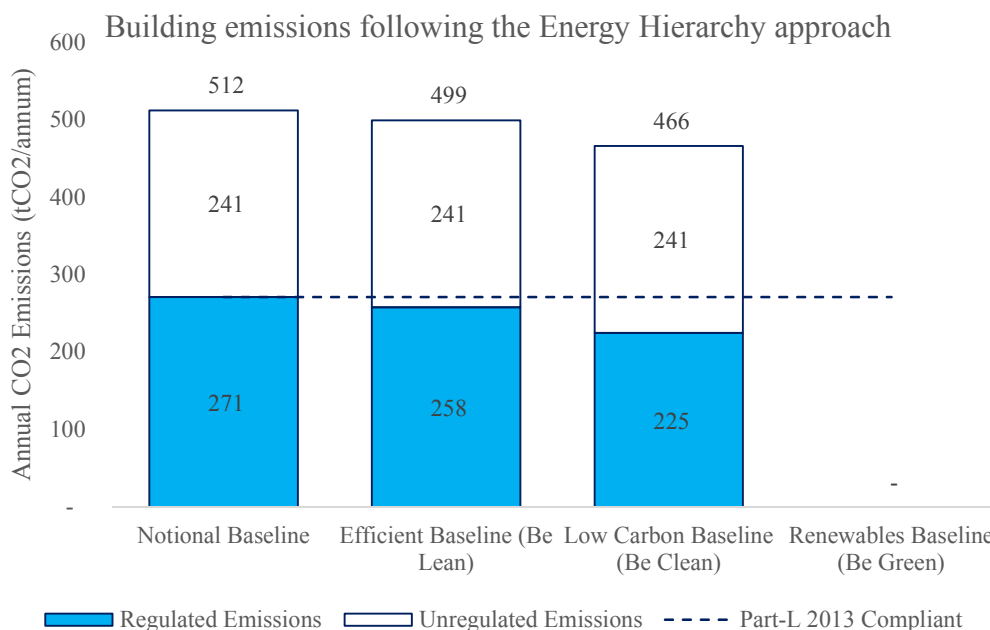


Figure 10: Building emissions for the notional building, the efficient baseline and the low carbon baseline.

The results indicate that the building with energy efficient MEP services and a heat recovery VRF system for office, labs and circulation areas would yield a 'Regulated' carbon dioxide emission of 225 tCO₂/annum, based on a Building Emission Rate (BER) of 22.6 kgCO₂/m².annum.

7 Exploitation of renewable resources (Be Green)

The successful integration of renewable energy technologies with buildings depends on a number of technical, economic and social factors.

The key technologies analysed and the findings from this feasibility study are summarised below:

Table 2 shows the key figures for each technology.

Table 2: Summary of Renewable Energy Technologies investigated

Technology	Feasible?	Practical Solution?	Comments
Small Scale Hydro	✗	✗	No hydro source
Tidal/ Wave Power	✗	✗	No tidal/ wave source
Solar Water Heating	✓	✗	Not effective if compared with other technologies
Wind Turbines	✓	✗	Insufficient capacity or contribution / urban environment
Biomass Boilers	✓	✗	High NOx emissions, delivery issues
Photovoltaic	✓	✗	No roof area available

7.1 Hydro and wave power

This site is not located near the coast or any rivers which could provide a source of moving water for hydro power generation, and therefore these technologies are not considered.

7.2 Solar Water Heating

Solar Thermal technology can provide hot water to buildings by pumping incoming cold water supply through collectors, typically located on the building roof or façade.

Solar Thermal technology is a proven technology, is silent in operation (does not cause any noise pollution) and does not require frequent access or maintenance. It is therefore considered to be a feasible option on technical and practical grounds.

However, the carbon reduction per m² of solar panel related to SWH is lower than the one for PV panels (described in paragraph 7.5), and the relative implementation cost is higher. Therefore, this technology has been considered not effective in this case.

7.3 Wind Turbines

Due to the city centre location, the historic facade of this building and the close proximity of residential properties, wind turbines are not considered an effective renewable technology for this project.

7.4 Biomass Heating

Biomass boilers could be used to provide hot water heating to the buildings. Carbon emissions associated with biomass boilers are low compared to a gas, oil or electric heating system. However, they present significant technical challenges and also require many additional components, such as a storage facility, handling, delivery access, ash removal, thermal storage etc.

Fuel can be delivered via trucks; the wood pellets can be pumped directly into the Storage facility via blowers. Therefore, careful consideration must be given to space requirements on site, vehicle turning radius and location of fuel store.

In addition, wood chips/pellets are usually housed indoor in order to avoid decay due to humidity and rain; therefore storage facilities would have to be built inside the energy centre, thereby increasing the cost and reducing the useful floor area.

Whilst Biomass Heating systems can result in a significant carbon mitigation, they can produce a large amount of NO_x, typically around 200kg/kWh of delivered heating energy, and so they have a negative impact on the local air quality and may cause problems with obtaining planning consent. In addition to air quality issues, in an urban environment, logistics and security of fuel delivery can also be an issue, as well as fuel storage.

Due to the reasons listed above, it is determined that Biomass Heating cannot be practically implemented as part of the P&G Reading project.

7.5 Photovoltaic Panels

Photovoltaic (PV) systems work by converting solar energy directly into electricity. PV panels generate Direct Current (DC) electricity and are arranged in modules that include inverters to convert electricity into Alternating Current (AC) that can be used by the building systems. The panels should be mounted in a location that receives good access to the sun and is not overshadowed by surrounding parts of the building, adjacent buildings or other PV Panels. As such, they are typically either installed on the roof or integrated into the building facade.

PV arrays can also be installed at ground level if space is available, but will be more susceptible to reduced output due to overshadowing, and will also be a greater risk of damage due to increased activity at ground level.

PV panels can generate electricity by either direct or diffuse radiation (i.e. sunlight that has been scattered/ reflected by the atmosphere or surrounding objects). The amount of power that can be generated varies depending on a number of factors; include type of cell, orientation, sunlight conditions, etc. Typically, peak outputs in the UK may be achieved by panels which are orientated around 30 degrees above the horizontal southerly direction. Alternate orientations are possible, but relative output of the PV arrays will decrease.

PV panels are proven technology, are silent in operation (do not cause any noise pollution) and do not require frequent access or maintenance. However they are still a relatively expensive renewable technology and they require a considerable free area for implementation.

According to the architectural drawings, the roof area is completely used for roof terrace and green roof, therefore no available space is left for PVs. Also, the development doesn't present available areas at the ground floor. Therefore, this technology is considered to not be viable.

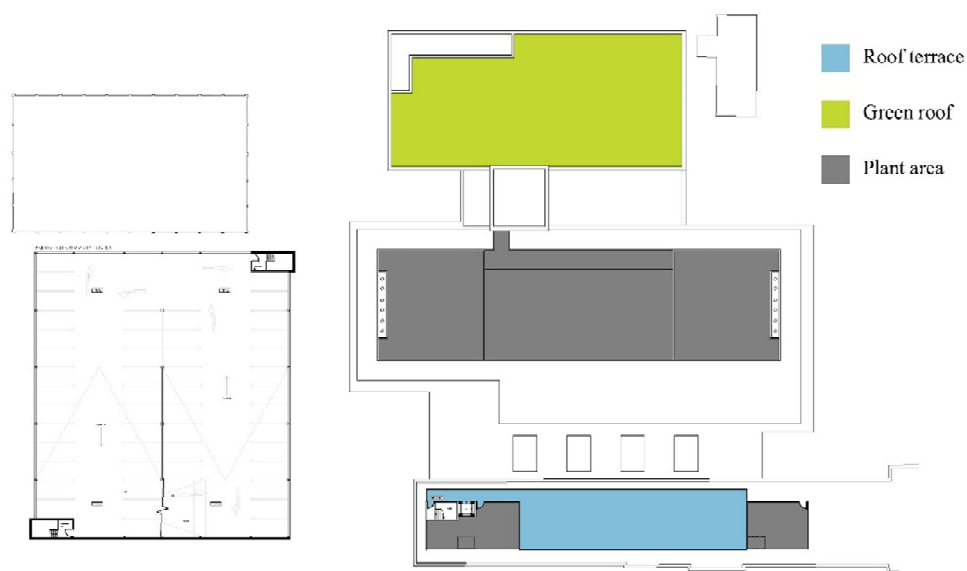


Figure 11: Roof layout.

7.6 Renewable Baseline (Be Green)

According to the analysis above, no renewable technology is practically feasible, therefore the Renewable Baseline figures are the same as the Low Carbon Baseline, as shown in

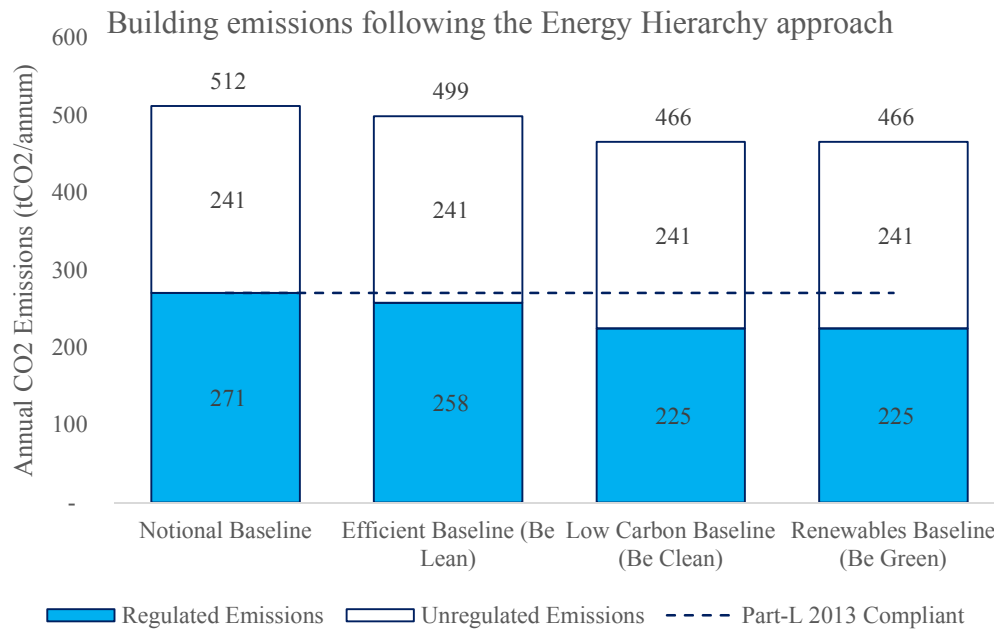


Figure 12: Building emissions for the notional building, the efficient baseline, the low carbon baseline and the renewable baseline.

8 BREEAM Ene01 - Reduction of energy use and carbon emissions

The energy consumption and carbon emissions figures have been checked through the BREEAM calculator.

The exercise shows that the reduction in energy consumption and carbon emissions related to the use of energy efficiency measures and low carbon technologies leads to the achievement of 6 credits out of 10 for the BREEAM Ene01, as shown in Figure 13.

Ene 01 Reduction of energy use and carbon emissions			
No. of BREEAM credits available	12	Available contribution to overall score	6.00%
No. of BREEAM innovation credits available	5	Minimum standards applicable	Yes

Ene 01 Calculator			
Country of the UK where the building is located	England	Confirm building regulation and version used:	England Part L2A 2013

New Construction (Fully fitted)			
Building floor area	9934	m2	
Notional building heating and cooling energy demand	128.84	MJ/m2yr	
Actual building heating and cooling energy demand	103.25	MJ/m2yr	
Notional building primary energy consumption	144.62	kWh/m2yr	
Actual building primary energy consumption	132.82	kWh/m2yr	
Target emission rate (TER)	24.50	kgCO2/m2yr	
Building emission rate (BER)	22.6	kgCO2/m2yr	
Building emission rate improvement over TER	7.8%		
Heating & cooling demand energy performance ratio (EPR _{td})	0.226		
Primary consumption energy performance ratio (EPR _{pc})	0.169		
CO ₂ Energy performance ratio (EPR _{co2})	0.105		
Overall building energy performance ratio (EPR _{nc})	0.500		

Where specified, please confirm the energy production from onsite or near site energy generation technologies	0
Equivalent % of the building's 'regulated' energy consumption generated by carbon neutral sources and used to meet energy demand from 'unregulated' building systems or processes?	
Is the building designed to be 'carbon negative'?	
If the building is defined as 'carbon negative' what is the total (modelled) renewable/carbon neutral energy generated and exported?	

Total BREEAM credits achieved	6
Total contribution to overall building score	3.00%
Total BREEAM innovation credits achieved	0
Minimum standard(s) level	Excellent level

Figure 13: Ene01 BREEAM calculator.

9 Summary

An energy assessment has been undertaken for the P&G Reading building following the procedure of the Energy Hierarchy:

Priority 1	Energy conservation & efficiency
Priority 2	Exploitation of non-sustainable resources using low carbon technologies
Priority 3	Exploitation of renewable, sustainable resources & technologies

The emission baselines for the proposed redevelopment (Be Lean, Be Clean & Be Green) have been estimated on a 'Regulated Energy' approach.

The implementation of Energy Efficiency measures in the form of fabric performance improvements, energy efficient building services and intelligent monitoring & controls etc. can result in a 4.8% reduction in 'Regulated Energy' carbon dioxide emissions, from 271 tCO₂/annum down to 258 tCO₂/annum.

A preliminary assessment indicates that a heat recovery VRF system is capable of reducing the 'Regulated Energy' carbon dioxide emissions further from the Efficient Baseline 258 tCO₂/annum down to 225 tCO₂/annum, a total reduction of 17.1% from the Notional Baseline.

Table 3: Carbon dioxide emissions after each stage of the Energy Hierarchy.

	Carbon dioxide emissions (Tonnes CO ₂ per annum)	
	Regulated Emissions	Unregulated Emissions
Baseline: Part-L 2013 of the Building Regulations Compliant Development	271	241
After energy demand reduction	258	241
After Low Carbon technologies	225	241
After renewable energy	225	241

Table 4: 'Regulated' carbon dioxide savings from each stage of the Energy Hierarchy.

	Regulated Carbon dioxide savings	
	(Tonnes CO ₂ per annum)	(%)
Savings from energy demand reduction	13	4.8%
Savings from Low Carbon technologies	33	12.2%
Savings from renewables	-	0.0%
Total Cumulative Savings	46	17.1%

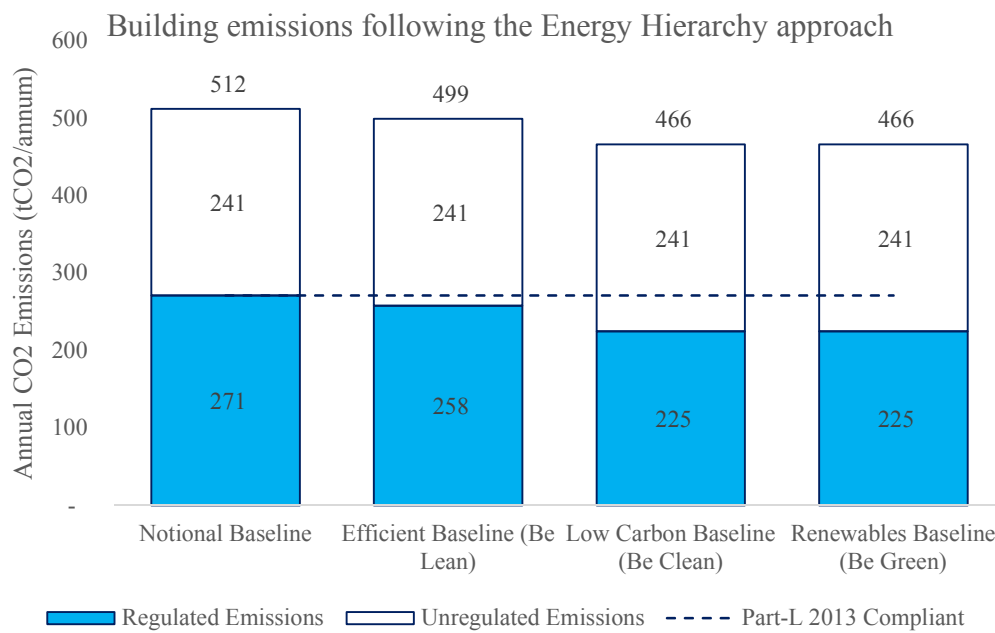


Figure 14: Summary chart following the Energy Hierarchy methodology.

In terms of EPC rating, Figure 15 illustrates an EPC Asset Rating of 34 (Band B) expected to be achievable with energy efficient Mechanical, Electrical and Public Health services installation.

Figure 16 illustrates an EPC Asset Rating of 30 (Band B) expected to be achievable with new energy efficient Mechanical, Electrical and Public Health services installation, as well as a heat recovery VRF system.

The reduction in energy consumption and carbon emissions allows to achieve 6 credits out of 10 for BREEAM Ene01.

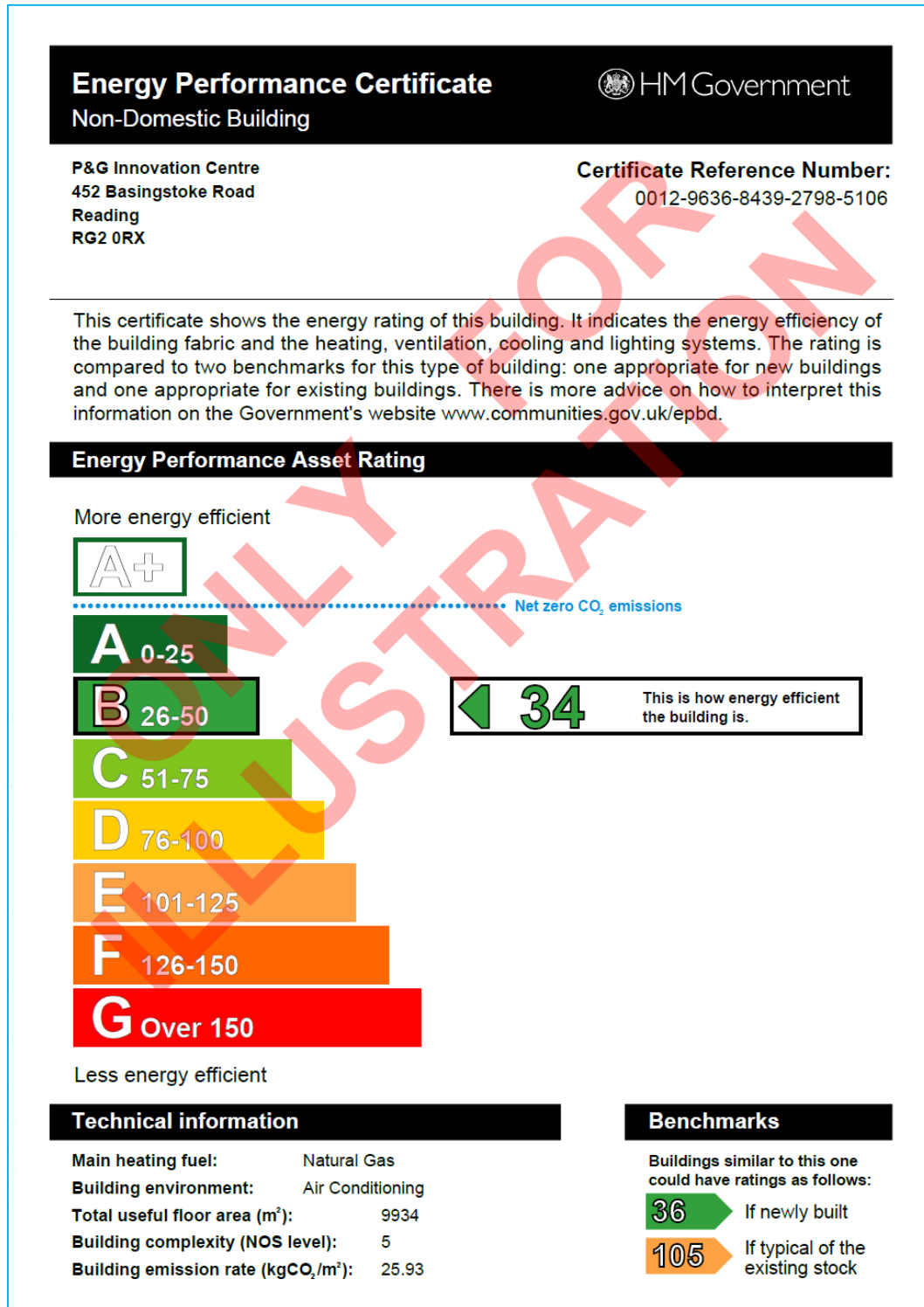


Figure 15: Draft EPC rating of Efficient Baseline for the new addition (with energy efficient MEP system only).

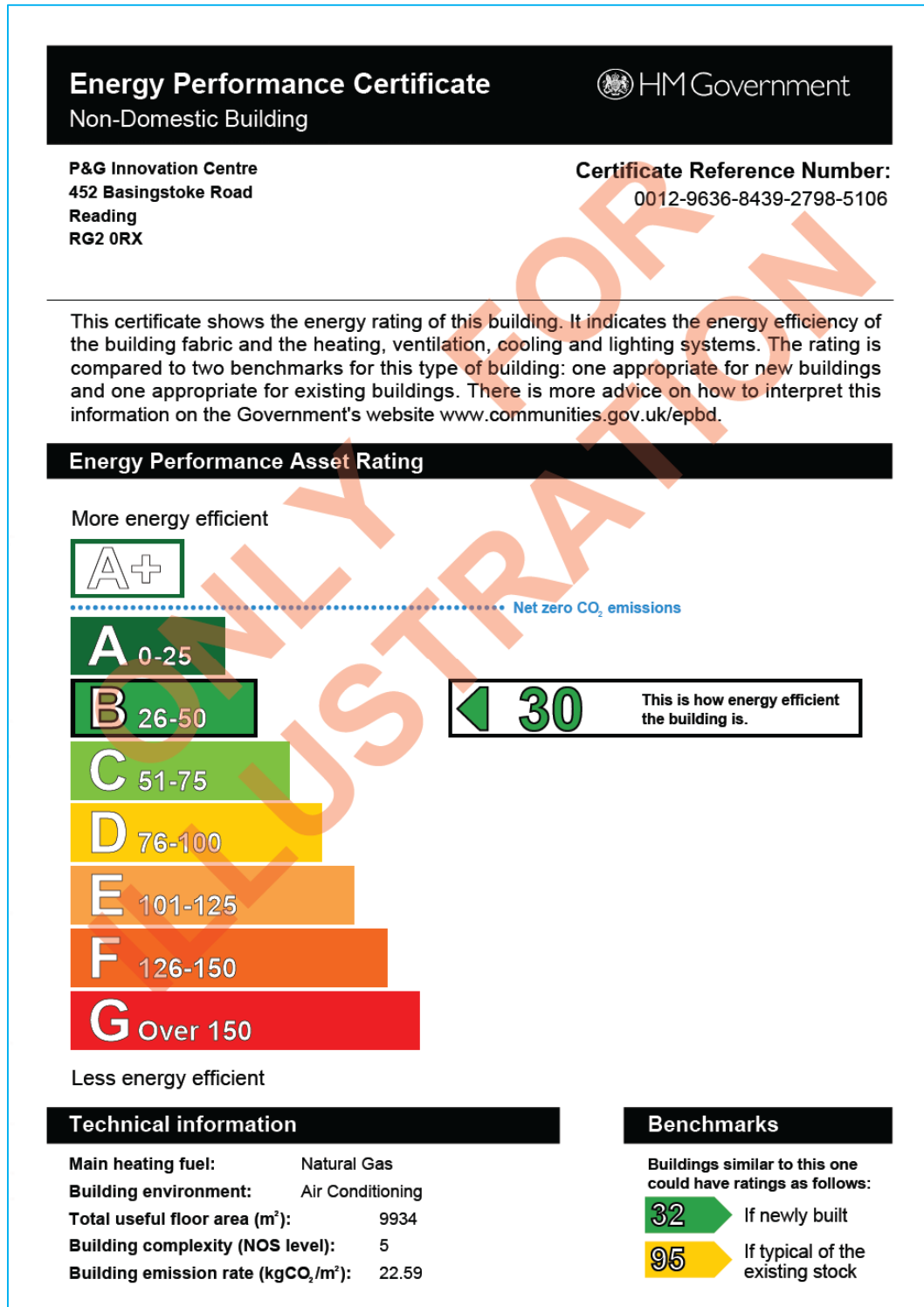


Figure 16: Draft EPC rating of Renewable Baseline (with energy efficient MEP system and heat recovery VRF system).

Appendix A

Glossary

A1 Glossary

Building Emission Rate (BER) – The building CO₂ emission rate expressed as kgCO₂/m²/year. The BER is calculated in accordance with the National Calculation Methodology (NCM) and the Simplified Buildings Energy Model (SBEM)

District Heating Network (DHN) – DHN is a distribution network of heat generated in a centralised location for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biofuel. DHN can provide higher efficiencies and better pollution control than heat generated by localised boilers.

Near-site LZC – a low or zero carbon source of energy generation located near to the site of the assessed building. The source is most likely to be providing energy for all or part of a local community of buildings, including the assessed building e.g. decentralised energy generation linked to a community heat network or renewable connected via private wire.

NO_x – a generic term for mono-nitrogen oxides NO and NO₂. They are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperature in an engine etc.

On-site LZC – a low or zero carbon source of energy generation which is located on the same site as the assessed building.

‘Regulated Energy’ – Building energy consumption resulting from the specification of a ‘controlled’, fixed building service’ i.e. space heating and cooling, water heating, ventilation and lighting, as a result of requirements imposed by Building Regulations.

Target Emission Rate (TER) – The target emission rate is the minimum energy performance requirement (required by Building Regulation) for a new non domestic building (kgCO₂/m²/year). The TER is calculated in accordance with the National Calculation Methodology (NCM) and the Simplified Buildings Energy Model (SBEM).

‘Unregulated Energy’ – Building energy consumption resulting from a system or process that is not ‘controlled’ i.e. energy consumption from systems in the building on which the Building Regulations do not impose a requirement. For example, this may include energy consumption from systems integral to the building and its operation e.g. lifts, escalators, refrigeration systems, ducted fume cupboards; or energy consumption from operational related equipment e.g. servers, printers, desktops, mobile fume cupboards, cooking and other appliances etc.

V

‘Whole Energy’ – energy consumption covered by the Building Regulation as well as energy consumption from any other part of the development, including plant or equipment that is not covered by the Building Regulations.