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Evidence Base for Carbon - Emissions Reduction Policies -

London Borough of Richmond upon Thames

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BDP.

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Evidence Base for Carbon Emissions Reduction Policies

London Borough of Richmond

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1 Executive Summary

Need for carbon reduction policies backed up by strong evidence

Recent national and regional climate change planning policies require local authorities to take a strategic approach to planning for sustainable energy measures. In particular Planning Policy Statement PPS1a calls for Development Plan Documents to expect that a proportion of the energy supply for new development to be delivered by decentralised and renewable or low carbon sources and expects area-based opportunities for such solutions to be identified. All policies relating to sustainable energy must be underpinned by a robust evidence base and viability assessment, and the purpose of this document is to meet that requirement.

Scope of the study

The Local Development Framework, for which this study is completed, aims to set the long term direction for the Borough. It is however difficult to provide robust evidence for CO_2 reduction measures over long time horizons as technologies evolve rapidly and the economics of both these technologies and the property market is very uncertain.

This study therefore investigates the sustainable energy measures that can be feasibly integrated into future developments, underpinned by the requirement to meet or exceed the requirements of Building Regulations, Housing Corporation targets for 2013 and 2012 and the London Plan. The provision of evidence is therefore limited to this timeframe.

As such, the following targets have been assessed:

- Residential: a 44% reduction in Dwelling Emissions Rate over Target Emissions Rate (equivalent to Code for Sustainable Homes Level 4) and a 20% reduction in overall CO_2 emissions from renewable energy sources.
- Offices and retail: 20% reduction in overall CO_2 emissions from renewable energy sources
- Schools: 40% reduction in overall CO_2 emissions from renewable energy sources
- No specific target has been assessed for works to existing / refurbishments. However, refurbishments are expected to make reasonable provisions to include renewable energy technologies, provided it is economically and technically feasible.

Opportunities and constraints in Richmond

The most commonly used low and zero carbon technologies have been assessed and proved to be feasible in the Borough, albeit with the following constraints:

- Wind turbines: due to local wind speeds and the large open space required for the efficient and cost-effective operation of a stand-alone wind turbine, it is expected that only schools could be appropriate for the integration of this technology.
- Solar technologies are expected to be feasible in the majority of the cases, although their use might be restricted on certain buildings or restricted areas.
- There is no limitation to the use of ground source heating and cooling, apart from access to drilling and subject to ground survey.
- In order to limit traffic nuisance and potential air quality issues, and in spite of the great CO_2 savings it represents, it is suggested that wood-fuel heating is considered only for major new build sites.
- Decentralised energy generation: there are a number of large developments in the London Borough of Richmond which might be considered for the integration of a decentralised heat / power network. By default, any new development

should consider the feasibility of connecting to an existing or planned heat network.

An overview of energy efficiency measures and low and zero carbon technologies is provided in sections 7 and 8 of this report.

Methodology
In order to justify sustainable energy targets the following methodology was adopted:

- Development groups representative of the Borough's development objectives were identified, combining development types and other criteria (such as new build or refurbishment).
- Appropriate sustainable energy measures were defined for each development group, based on future national targets. Costs were estimated to achieve the relevant targets.
- Costs were then compared to financial elements of the development, including the residual land value[1] for residential and offices, build cost for schools and retail, and costs for refurbishment.

Sustainable energy standards for new build
Residential

The Core Strategy policy is suggesting that the Council will seek Code for Sustainable Homes Level 3. This study looked at Code level 4 as the next stage in tightening the policy. It confirms current Core Strategy requirements are practicably achievable at the given costs and the Council could consider Code level 4 at the next stage of the LDF production

Sustainable energy measures to achieve a 44% reduction[2] in DER over TER and 20% renewable energy target in addition to SPG and affordable housing planning obligations are deliverable when the sales value is higher than[3]:

- £5,200 per m^2 for blocks of 2-10 flats
- £4,900 per m^2 for blocks of 11 flats or more
- £5,200 per m^2 for houses

This means that in theory not all developments would be able to achieve these standards. However, these thresholds could be lowered to take into account the following elements:

- Conservative construction and CO_2 reduction costs were used..
- The methodology assumes that the minimum land value acceptable to the landowner (Existing Use Value) does not vary with the sales values. In reality it is likely that developments achieving a lower sales value will be developed in areas with lower existing use values, resulting in sustainable energy measures being feasible at these lower sales values.

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[1] The London Borough of Richmond has required CEN to use the results of a previous study conducted by Chris Marsh on the thresholds for affordable housing and employment redevelopment.
MARSH, C. *Financial Viability Assessment for affordable housing thresholds and employment redevelopment,* 2007. Available from: http://www.richmond.gov.uk/home/environment/planning/planning_guidance_and_policies/local_development_framework/local_development_framework_research/financial_viability_assessment.htm

[2] Minimum mandatory energy requirement for level 4 of the Code for Sustainable Homes

[3] The range of residential sales value in the London Borough of Richmond used in Chris Marsh's report is comprised between £3,700 and £8,700 per m^2.

- Affordable housing for less than 10 units would be based on contributions which may mean there would be more scope to provide sustainable energy measures.
- Finally, it was assumed that none of the costs of integrating carbon reduction measures could be passed on to the customer through a premium, which could be challenged as customers become increasingly concerned about rising fuel costs.

In summary:

- Even though the analysis shows that carbon reduction measures described above are feasible for developments with a sales value higher than £4,300 per m^2 (flats 2-10) or £4,900 per m^2 (flats 11+) or £5,200 per m^2 (houses), it is probable that developments with lower sales value would also comply with these standards.
- Higher standards than a 44% reduction in DER over TER and 20% renewable energy could be achieved and therefore required by the planning authority for developments with sales value higher than £4,300 per m^2 (flats 2-10) or £4,900 per m^2 (flats 11+) or £5,200 per m^2 (houses).

Offices

Sustainable energy measures to achieve a 20% renewable energy standard are deliverable when the sales value of offices is higher than[4] £4,600 per m^2. This means that in theory not all office developments would be able to achieve this standard. However, this threshold could be lowered to take into account the following elements:

- Conservative construction and CO_2 reduction costs were used (e.g. if a wood-fuel heating system were to be feasible, the cost would be significantly reduced).
- The methodology assumes that the minimum land value acceptable to the landowner (Existing Use Value) does not vary with the sales values. In reality, it is likely that developments achieving a lower sales value will be developed in areas with lower existing use values, resulting in sustainable energy measures being feasible at these lower sales values..
- Finally, it was assumed that none of the costs of integrating carbon reduction measures could be passed on to the customer through a premium, which could be challenged as reduced operational costs are a significant incentive to companies.

Retail

Achieving the 20% renewable energy standard for new retail spaces can be done in a number of ways, albeit at different percentage increases in build cost. The most cost-efficient option to achieve this standard is to integrate a wood-fuel heating system; this would allow CO_2 savings of approximately 34% and would cost approximately 1% increase in build cost. However, this technology would be feasible only for larger sites. It could potentially be combined with residential units in the case of a large development.

An alternative option would be to integrate ground source heat pump and solar PV panels. This would enable the CO_2 emissions to be reduced by approximately 21% and would cost between 11% and 14% increase in build cost.

[4] The range of offices sales value in the London Borough of Richmond is comprised between £2,000 and £9,000 per m^2 and is deducted from data on rent and yield present in Chris Marsh's report.

The most cost-efficient solution would vary depending on the specific situation of the retail space considered. The study suggests however that the 20% standard can be achieved.

Schools

A CO_2 reduction of 10% compared to Building Regulations can be achieved through energy efficiency measures with an estimated 2% increase in build costs. It is also required that all new build schools achieve a 40% reduction of total CO_2 emissions, where feasible. This target can be easily achieved through the use of a wood-fuel heating system, which is likely to be feasible inmost cases. This will ensure that schools take a leadership role in sustainable development and maximise the use of sustainable energy measures for educational and awareness raising purposes.

Works to existing / Refurbishment

No specific standard was defined for refurbishment as it is difficult to predict a single common CO_2 emission level for existing buildings. Generally, refurbishments should comply with the Building Regulations for existing dwellings dealing with the conservation of energy and fuel (AD L1B). This can deliver a reduction of up to 70% of the total CO_2 emissions.

However, refurbishments are expected to install one or more of the renewable energy technologies. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective (e.g. excessive shading on solar panels) or technically unfeasible (e.g. no access for a drilling rig or no roof space).

2 Introduction

The London Borough of Richmond upon Thames has asked CEN and BDP to conduct a study providing evidence, as required under the provisions of Planning Policy Statement 1a (PPS1a), to underpin the definition and justification of CO_2 emissions reduction targets.

CEN and BDP have undertaken a detailed study of the constraints and opportunities which are specific to the Borough, and of the measures and technologies which could be integrated into different types of development.

The results of this study are contained within the following documents:

- A report providing details of the research and analysis conducted;
- A development brief for each development group summarising the target reduction in carbon emissions, options suggesting ways to achieve that target, and financial justification.

The structure of this report is as follows:

Section 3 provides the policy and regulatory background to the study, from the perspective of national, regional and local levels.

Section 4 contains the results of an analysis of Richmond's constraints and opportunities for sustainable energy measures at the Borough wide and individual building level

Section 5 provides a list of development groups (i.e. development types combined with a series of additional criteria) for which sustainable energy options were investigated, based on an analysis of planning permissions.

Section 6 explains the detailed methodology that was followed for each development group to quantify sustainable energy measures and assess their financial viability.

Sections 7 and 8 give an overview of the energy efficiency measures and low and zero carbon technologies that could be integrated in future new build development and refurbishments.

Section 9 investigates the feasibility of sustainable energy measures for each development group, quantifying their costs and related CO2 savings. A financial analysis is also provided.

3 Policy and regulatory drivers

3.1 Planning policy background

The last decade has seen a growing policy thrust towards delivering sustainable development, originating as a key planning objective in the Planning and Compulsory Purchase Act (2004). Since that time specific planning policy has been developed to address the potential causes and consequences of climate change. The Planning White Paper *Planning for a Sustainable Future* (2007) emphasised the importance of planning's role in delivering sustainable development in a changing global context and, in particular, in delivering the infrastructure which provides access for all to transport, energy and water, and underpins sustainable communities. The Department for Communities and Local Government's (DCLG) *Building a Greener Future* (2007) additionally set moves to tighten Building Regulations to reduce carbon emissions from new homes, and to achieve zero carbon in all new homes by 2016.

This section summarises the planning policy at the national, regional and local levels which underpins the need to address climate change and to develop a policy framework for sustainable energy solutions at the Borough level. In summary, recent national and regional planning policy on addressing climate change requires local planning authorities to take a more strategic approach to planning for sustainable energy measures, and encourages local planning authorities to secure highly energy efficient development and supply prior to seeking installation of renewable and local carbon technologies.

3.1.1 National planning policy

The requirement for local authorities to develop policies promoting renewable energy generating resources in new developments came about in Planning Policy Statement (PPS) 22 *Renewable Energy* (DCLG, 2004). The need for target and criteria based policies was established for on-site renewable energy generation, requiring local planning authorities to maximise opportunities for incorporating small scale renewable energy in all new developments, with technologies including solar panels, biomass heating, small scale wind turbines, photovoltaic cells, and combined heat and power systems. PPS22 requires positive policies to be expressed in Local Development Documents to encourage such development (paragraph 18). While PPS22 requires local planning authorities to develop policies which reflect local circumstances, it also states that landscape and nature conservation designations should not alone restrict renewable energy developments.

PPS1 *Delivering Sustainable Development* was issued in 2005 establishing a key requirement for planning and development plans address climate change through promoting energy efficient design and supply and renewable and low carbon schemes as part of future developments. While there is therefore a real emphasis on policies to promote sustainable energy measures, the importance of design that accounts for local character is additionally emphasised by PPS1. There is a requirement for development to be integrated into the existing urban form, natural and built environments, and for policies to be developed which 'respond to their local context and create or reinforce local distinctiveness' (paragraph 36).

A supplement to PPS1 (PPS1a) *Planning and Climate Change* was published in 2007 with a specific focus on planning and climate change. PPS1a seeks to ensure that spatial strategies make the fullest contribution to addressing climate change through integrating climate change considerations into all planning decisions. Local planning authorities are required to develop policies which promote principles of passive design, to employ a strategic approach to identifying existing and planning for new decentralised energy networks, and to identify appropriate locations for renewable energy infrastructure and developments.

An important requirement of PPS1a is the need for policies within Development Plan Documents (DPDs) to expect a proportion of the energy supply for new development must be secured from decentralised and renewable or low carbon sources, and for area based opportunities for such infrastructure to be identified through the plan process. All policies relating to sustainable energy must be underpinned by a robust evidence base and viability assessment, and the purpose of this document is to meet that requirement.

3.1.2 Regional planning policy – The London Plan

The London Plan (Consolidated with Alterations since 2004) was adopted in February 2008 following Examination in Public. One of the key areas in which policies have evolved from the previous version of the London Plan is in Chapter 4A *Climate Change and London's Metabolism*. That chapter now involves new and strengthened policies pushing forward planning as a mechanism to address climate change, emphasising energy efficient design and decentralised energy supply before the installation of renewable energy technologies on new development, and promoting adaptation as well as mitigation in sustainable building design. The key policies that underpin this sustainable energy evidence base are discussed below.

Policy 4A.1 is the headline policy entitled 'Tackling Climate Change' and seeks to ensure that Development Plan Documents produced by London Boroughs require developments to make the fullest contribution to the mitigation and adaptation to climate change and to minimise CO_2 emissions. A hierarchy of measures, from 'be lean' (using less energy), 'be clean' (supply energy efficiently), to 'be green' (use renewable energy), is specified. Policy 4A.2 Mitigating Climate Change requires that minimum reduction targets are achieved for London against a 1990 base of:

- 15% by 2010;
- 20% by 2015;
- 25% by 2020; and
- 30% by 2025.

Seeking to meet the targets set out above for London the plan, under Policy 4A.3 'Sustainable Design and Construction', requires future developments to meet the highest standards of sustainable design, to make the most efficient use of land and existing buildings, and to minimise the need to travel. Developments are required to reduce energy use by employing principles of passive solar design, natural ventilation, and vegetation on buildings, and provide natural heating and cooling (4A.3, 4A.6 'Decentralised Heat, Cooling and Power', 4A.9 'Adaptation', and 4A.10 'Overheating').

Policy 4A.7 'Renewable Energy' requires that all Boroughs adopt an assumption in their Development Plan Documents that all new developments will achieve a reduction in CO_2 emissions of 20% from on site renewable energy generation. This policy places onus on developers to demonstrate that such provision is not feasible, but additionally implies a need for Development Plan Documents to identify development types and areas where specific targets and technologies will be appropriate. Other key elements of that policy are the need for Boroughs to identify sites for zero carbon developments, and promote the use of small scale renewable technologies in street infrastructure.

3.1.3 Local planning policy for London Borough of Richmond upon Thames

The need for sustainable development, and in particular development which incorporates measures for sustainable energy use and generation, is promoted in the London Borough of Richmond upon Thames by both adopted and emerging local planning policies. Such policy is contained in the Adopted Unitary Development Plan (March 2005), associated Planning Policy Guidance (PPG), and in the documents prepared to date as part of the emerging Local Development Framework (LDF).

The LDF Core Strategy is being considered at Public Examination from November 2008 and this research supports the requirements of the Core Strategy (Code level 3 and 20% reduction in CO2 from renewable energy) and will inform the future LDF Development DPD which is under preparation.

In considering sustainable development, there is a clear policy objective for the reuse of existing buildings and land to be maximised in the future, to promote mixed use development, and to ensure that future new development is focused in highly accessible locations where energy and resources can be best preserved. New development is therefore to be focused in existing town centres, and the emerging Core Strategy seeks to promote Richmond as the key location for future high density development, followed by Twickenham and other District Centres.

In relation to sustainable energy, policies in both the UDP and the emerging Core Strategy seek to ensure that the design, orientation, use of materials and operation of developments maximise the potential for energy generation from renewable sources, subject to the impact on amenity and the environment (Policies BLT 30, BLT 31, and CP1). Emerging core policies require a reduction in the Borough's carbon emissions to address climate change through energy efficient design, supply and the installation of renewable energy technologies (Policy CP2). The importance of incorporating energy measures in retrofit schemes is additionally highlighted.

Evidence produced for the LDF has confirmed that the Borough has a special historic and landscape character. Policies within the UDP and emerging Core Strategy seek to protect and enhance the character and local distinctiveness of the Borough through particular designations, which include Conservation Areas, Listed Buildings, Scheduled Ancient Monuments, the River Thames, Metropolitan Open Land, Green Belt, and nature conservation policies. Policies for sustainable energy must take account of these important designations where they will place constraints on the appropriate types of measures in future developments. The particular planning considerations relevant to each designation are detailed in the next section of this report.

3.2 Legislation and sustainable design standards

This section provides a summary of the requirements of the legislation contained in Part L of the Building Regulations that currently establishes the mandatory minimum standards for reducing carbon emissions from all new development. A discussion of the sustainable design standards contained in the Code for Sustainable Homes (CSH) and BRE Environmental Assessment Method (BREEAM) is also presented to demonstrate the national push for the highest standards of sustainable design.

3.2.1 Building Regulations

Part L – Conservation of fuel and power is the section of the Building Regulations that sets the specific mandatory minimum thresholds of reductions in CO_2 emissions that all new and adapted existing buildings must meet. Part L1 deals with dwellings only and Part L2 deals with non – residential forms of development.

The current 2006 Building Regulations Part L requires that CO_2 emissions related to all development (i.e. the DER[5] for dwellings or BER for non-residential) should be equal to the TER[6], which is generally in the region of 20% lower than the 2002 Building Regulations depending on the specific building type. Although there is no confirmed date for the next Building Regulations or details of the potential minimum requirements, it is anticipated that a consultation version will be issued in 2009 and will step up to align with the following targets established by the Department for Communities and Local Government[7]:

- 2010: 25% improvement (relative to 2006 levels), corresponding to Code Level 3
- 2013: 44% improvement (relative to 2006 levels), corresponding to Code Level 4
- 2016: Zero Carbon, corresponding to Code Level 6

It should be noted that the Zero Carbon target for all new homes by 2016 pushes even further than having a 100% improvement of DER over TER where this target additionally incorporates the non building regulated energy demand, related to cooking and appliances, in the total energy consumption. These sources of energy demand are not accounted for in the DER. Such an onerous target will only be achieved through the adoption of renewable energy measures to serve each dwelling.

3.2.2 Code for Sustainable Homes and BREEAM

Where the Building Regulations provide the mandatory minimum requirements for all buildings, the Code for Sustainable Homes (hereafter referred to as the Code) provides national sustainability standards for residential development. Within the standards, homes are rated against criteria within nine different categories. Credits are available against each of the criteria and a Code Level is awarded depending on the total number of credits achieved. While many of the criteria are optional, there are a number against which a score is mandatory for the corresponding Code Level to be achieved.

Category 1 relates specifically to energy and carbon dioxide emissions. Criteria Ene1 provides mandatory minimum requirements in terms of CO_2 emissions reduction, and there is, in addition, criteria Ene7 which provides credits for achieving a reduction in CO_2 as a result of low and zero carbon technologies. Ene1 requires the following percentages of CO_2 reduction to be achieved below Part L of Building Regulations:

- Level 1: 10%
- Level 2: 18%
- Level 3: 25%
- Level 4: 44%
- Level 5: 100%
- Level 6: Zero carbon

[5] Dwelling Emission Rate
[6] Target Emission Rate
[7] Building a Greener Future: Towards Zero Carbon Development – CLG – December 2006

Since April 2008, all new publicly funded housing must be built to a minimum of Code level 3. In 2012, the requirement will step up to Code level 4[8]. The Code is currently voluntary for privately built housing. However, since May 2008 all new homes must be rated against the Code as an integral requirement of the Home Information Pack (HIP). This means that all homes must include a Code certificate within the HIP. Homes not assessed against the Code must include a nil-rated certificate of non-assessment in the HIP.

Category 2 relates specifically to water consumption. Criteria Wat 1 provides mandatory minimum requirements in terms of internal potable water use. Wat1 requires the following water consumption levels per person per day:

- Levels 1 and 2: 120 l/p/day
- Levels 3 and 4: 105 l/p/day
- Levels 5 and 6: 80 l/p/day

There are other mandatory requirements associated to other categories within the Code, namely[9]:

- Materials
- Water surface run-off
- Waste

While the Code applies to residential buildings, standards for new and existing non-residential buildings are provided by the BRE Environmental Assessment Method (BREEAM) to assess their environmental performance. As of August 2008, the BREEAM ratings that can be achieved under BREEAM are Pass, Good, Very Good, Excellent and Outstanding, and there are now mandatory requirements which must be achieved for each of the ratings.

There is no specific legal requirement for non-residential development, including office, retail and schools, to achieve a specific level under BREEAM. However, a BREEAM rating is commonly required by Local Planning Authorities as a means of securing the highest possible standards of sustainable design.

3.3 Scope of the study

The policy and regulatory analysis shows that the integration of sustainable energy measures in new developments is promoted by national and regional government, and by the London Borough of Richmond. Specific national targets for both private and publicly funded residential development will need to be met in the near future and it is vital that the highest possible standards are demanded by emerging planning policy to assist in achieving those targets.

The Local Development Framework, for which this study is completed, aims to set the long term direction for the Borough. It is however difficult to provide robust evidence for CO_2 reduction measures over long time horizons as the low and zero

[8] "For the forthcoming 2008-11 NAHP (National Affordable Housing Programme) we have committed to a minimum of Code level 3(***). We will increase our minimum requirement to Code level 4(****) as part of the 2012 bid process with a view to the achievement of zero carbon/Code level 6(******) by 2015, if the technology needed to achieve cost effectively this is available." (Design and Quality Strategy 2007 – Housing Corporation – 2007)

[9] Details of these requirements are provided in the development briefs for each development group.

carbon technologies evolve rapidly and , economics will vary with high levels of uncertainty.

This study therefore investigates, and provides robust evidence for the possible different sustainable energy measures that can be feasibly integrated into future developments, underpinned by the requirement to meet or exceed the Building Regulations and Housing Corporation targets for 2013 and 2012 respectively[10].

After 2013, it is expected that new developments will have to comply with more stringent targets defined by the Building Regulations (i.e. zero carbon target in 2016). No justification is provided for this target in the study.

In order to provide justification, the following methodology was adopted:

- Development groups were identified
- Appropriate sustainable energy measures were defined for each development group and costs estimated to achieve the relevant target
- Costs were then compared to financial elements of the development, including the residual land value for residential and offices, build cost for schools and retail as well as refurbishment. For residential and offices, this comparison shows the sales values for which the target could be exceeded.
- The potential for decentralised heat networks was investigated

[10] As explained in Section 3.2.2 of this report.

4 Borough wide analysis of Richmond

4.1 Feasibility of renewable energy technologies and decentralised energy supply

4.1.1 Renewable energy technologies

This section presents a summary of the feasibility of using certain renewable energy technologies in the London Borough of Richmond upon Thames. For each type of renewable energy technology, a series of benefits and limitations are presented along with an informed conclusion regarding their suitability in the specific context of the Borough. Product information, as well as environment and design requirements are provided in Section 8 of this report.

<u>Wind power</u>

Stand-alone wind turbines are a good technology to integrate into low density developments which have sufficient areas of open land to ensure that the turbine can be located at the required distance from buildings. A minimum wind speed of 6m/s is necessary in order to obtain a reasonable energy output. Wind speeds in Richmond vary, but typically can be expected to be around 4.7 to 5.1m/s at 10m above ground level, and 5.4 to 5.9m/s at 25m above ground level[11].

This would suggest that whilst the wind speed for wind technologies is not likely to be appropriate across the borough, there may be specific areas where there is sufficient wind speed. This would particularly be true in areas of higher ground and where building density is low with obstruction free orientation towards the prevailing south west wind.

There are a number of further issues associated with wind turbines which would limit the extent of their use in the London Borough of Richmond, including:

- Visual impact on protected open spaces, special historic areas and buildings, and on important views;
- Availability of sufficient space for an exclusion zone;
- Access for maintenance;
- Impact on ecology; and
- Impact on amenity, including noise and flicker.

Given the number of protected areas (including open spaces) and the high density level in Richmond, it is unlikely that many locations will be appropriate for the integration of wind turbines. While landscape designations should not preclude the installation of renewable energy technologies, alternative options for achieving the required on site energy generation levels should be explored, particularly where the site is closely related to Green Belt, Metropolitan Open Land, World Heritage Sites, Conservation Areas, and Historic Parks and Gardens. Schools with a large area of open land should be considered, as wind turbines present a good educational value.

Building-mounted wind turbines are not yet a proven technology. A number of technical problems have been identified by manufacturers and are currently being investigated with the aim of rectifying these issues. This technology is continuing to develop and might therefore be a useful means of securing on site energy generation in the near future. In the meantime, however, building-mounted wind turbines have not been investigated in this study.

[11] Based on average wind speed obtained for the London area, using NOABL database.

<u>Solar technologies</u>

There is sufficient solar gain in the London Borough of Richmond for solar technologies to be feasible and to produce a good energy output. Figure 4.1 below shows the UK solar irradiation, in terms of annual total kWh/m^2.

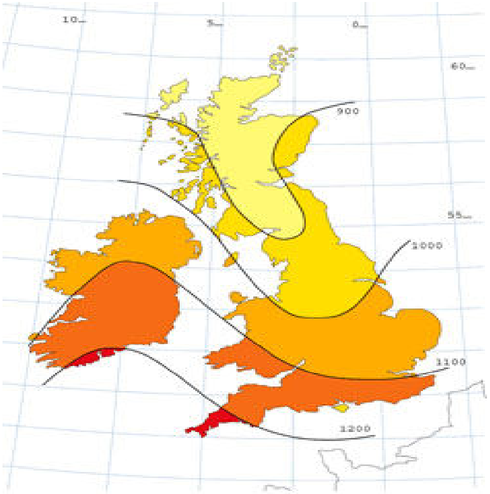

Figure 4.1: Map showing average solar radiation on a 30° incline facing due south
Source: Solar Trade Association

Figure 1 shows that London should benefit from an annual irradiation providing on average of 1,100kWh/m^2, which is sufficient for the efficient operation of solar thermal collectors or solar photovoltaic panels. Solar technologies are advantageous in that they can generally be well integrated into buildings within sensitive areas, such as Conservation Areas, to protect their appearance and setting; both in retrofit or new build. There are, however, limitations in buildings and areas of special historic or townscape value subject to high quality and innovative design techniques.

<u>Ground source heating and cooling</u>

Ground source heating and cooling is a tried, tested and reliable means of providing space heating and cooling for buildings, and is commonly combined with under-floor heating. Such a heat distribution system is efficient due to low flow and return temperatures[12], and offers high levels of comfort for building occupants. Such a technology provides CO_2 emissions reduction, but does require a certain level of electricity consumption to operate the pump. As such, ground source heating and cooling is considered a low carbon technology.

In order to operate effectively, the pump must be linked to pipes which are buried in the appropriate type of soil. The Coefficient of Performance[13] (CoP) of heat pumps depends mainly on the target temperature to be produced by the pump. The higher this target temperature is, the lower the CoP. A target temperature of 35°C as used in underfloor heating would yield a CoP of 4. A target temperature of 65°C would yield a CoP of 2.5. A ground survey should always be conducted to demonstrate that the ground conditions are adequate.

There are no major constraints related to the integration of ground source heat pumps, as pipes are buried underground. Pipes can be installed horizontally, which

[12] Under-floor heating requires a lower temperature to be efficient than conventional distribution systems. It allows for a more efficient operation of the heat pump.
[13] Defines the number of units (in kWh) of usable heat generated by one unit of electricity used to operate the pump

requires sufficient open space, or vertically where the available space is more restricted. The pump can be located in a plant room for large developments or take the space of a standard electrical equipment (such as fridge) for individual systems.

Wood-fuel (biomass) heating

Wood-fuel combustion in modern, efficient and automated systems is considered almost carbon neutral given that only carbon absorbed during the tree's growth is released during combustion, and not dating back millions of years as is the case with fossil fuels.

For wood-fuel heating systems, there are a number of spatial requirements which must be factored into the design process at the earliest possible opportunity. Such requirements include the need for an adequately sized wood-fuel store to ensure that the frequency of fuel deliveries is minimised. Another key requirement is for access to the store for delivery vehicles and for maintenance purposes.

Fuel source
There are two main types of wood fuel which can be used in biomass boilers – wood pellet and wood chip. Both have various associated advantages and disadvantages. However, the main differences are that pellet fuel is a manufactured product, and therefore more expensive, but also has a higher energy density, lower moisture content and more standardised quality than chip. This means that, as a general rule, the potential for pollution as a result of the combustion process is reduced.

Wood chip on the other hand is a far cheaper fuel source but, owing to its bulk, has greater requirements for both deliveries and storage. Therefore, purely for economic reasons, wood chip cannot be transported over long distances. There are also considerable sustainability issues with regard to the availability of a local supply. London has less woodland than other areas within England, and therefore less immediately available wood chip. However, many London Boroughs have considerable green areas, from which green waste is derived, and several suppliers operate on the outskirts of London. The main suppliers which could feasibly supply fuel to the London Borough of Richmond are outlined in the appendix.

There are examples of tree waste from Richmond Borough Council sites being chipped in situ, and dried at Hampton – then reused as mulch (10 tonnes/week). According to a 2007 Bioregional Report, this exceeds the amount of mulch that is required for use by the Council, and therefore presents a potential supply for investigation. Other opportunities, including selling the chip locally, additionally exist. Tree surgeons, for example, operate in the area – one of which is currently selling green waste to Slough Heat and Power. There is therefore the potential to explore establishing a tree station in the London Borough of Richmond, subject to waste management and transport strategies.

As an energy dense and compact fuel, wood pellet is often transported greater distances than wood chip. However, to reduce carbon associated with transport, a local supplier should be prioritised wherever possible. There is only one manufacturer in London, based in Barking and Dagenham (The Renewable Fuel Company). However, other companies operate out of the South-East, and some companies operate nationally. Most wood pellet used in the UK comes from Europe, Ireland or Canada. Several suppliers are included in the appendix.

Constraints
The use of wood-fuel heating generates two major impacts which are: increased level of traffic due to transportation of the fuel, increased air pollution due to emissions of

NOx, SOx and particulates. As stated in Section 4.2.2, there are restrictions in the Borough related to air quality, transport and visual impact, which will require consideration in determining the suitability of such a system for a given site.

- Air quality: All of London is within a Smoke Control Zone[14] where visible smoke must not be emitted (except during start up and shut down periods), and only exempted appliances should be installed. A list of wood-fuel boilers which are exempt from testing protocols is available from the UK Smoke Control Areas website on http://www.uksmokecontrolareas.co.uk/appliances.php?country=e. Air Quality Management Areas (AQMAs) present additional constraints within the Borough, and specific tests or modelling could be required in considering the use of such a technology. High design quality in wood-fuel heating systems can minimise the potential for pollution, such as ensuring that the fuel burns at high temperatures and installing technologies to prevent the escape of particulate matter.

- Transport: Large vehicle movements are limited to certain areas of the Borough, therefore any foreseen increase or significant change in traffic movement for fuel deliveries would be considered as an important planning issue. In considering the use of this technology, the applicant will be required to demonstrate that the transport movements will not have a detrimental impact on local amenity or the operation of the highways network. It must additionally be demonstrated that the cumulative impact with other developments has been thoroughly considered and the number of deliveries minimised through an adequately sized fuel store. Early discussions should be held with the planning and highways departments.

- Visual impact: The use of a biomass boiler will require the installation of a chimney flue, which could have a visual impact in protected areas of Richmond. The design should ensure that this is minimised as far as possible through sensitively siting and integrating the flu with the building fabric where practically possible.

Wood-fuel heating is a highly efficient technology to use when seeking to reduce the CO_2 emissions of a development. However, based on the above constraints, it is suggested that wood-fuel heating should be considered only for major new build sites where the site layout can be designed to secure easy and safe access to the adequately sized wood-fuel store. As such, traffic nuisance and the potential for air quality issues across the Borough will be limited. Wood-fuel heating will therefore not be recommended as a standard technology available for small to medium scales of development (e.g. blocks of 2 to 10 flats) or for refurbishment.

4.1.2 Decentralised energy generation

Decentralised energy generation in comparison to conventional heating is a far more efficient way of providing heat as the overall losses from combustion are lower and, where electricity is supplied, distribution losses are lower when the energy source is localised to the need. If individual heating systems are installed in new dwellings, it is more difficult and expensive to convert these to communal systems at a later date. A decentralised network can provide both heating and cooling. While least preferable in the hierarchy of technology types for such systems, installing communal heating infrastructure provides an opportunity in the future for converting to more efficient systems, such as Combined Heat and Power (CHP).

[14] defined areas subject to Smoke Control Orders made by the Local Authorities under powers of the Clean Air Act

Although current technologies for decentralised heating systems generating electricity are most frequently powered by gas, advances in technology are enabling the emergence of systems powered by renewable fuel sources such as biomass CHP. Systems providing only heat are commonly fuelled by gas, but also use a number of renewable fuel sources, such as biomass or biodiesel. It is considered feasible only to require the installation of decentralised heating systems for high density developments[15]. However, where a decentralised system is in place, future developments within a reasonable proximity should be required to connect to that system. As such, decentralised energy networks will be developed in certain locations within the London Borough of Richmond upon Thames.

Major regeneration projects are particularly appropriate for the integration of a heat and/or power network, but there is none planned in the London Borough of Richmond. However, Richmond has a number of large scale housing developments that are planned in the coming years[16]. Tables included in the Local Housing Availability Assessment (February 2008) give a list of proposal sites and other large sites that are being considered for development. The following large developments could be considered for the integration of a decentralised heat network, given the reasonably high range of units that is planned for each one of them:

- Sainsbury's, located on Manor Road (Richmond): 60-255 units
- Greggs Bakery, located on Gould Road (Twickenham): 75-200 units
- Richmond Station, located on The Quadrant (Richmond): 25-150 units
- Post Office Sorting Office, located on 109 London Road (Twickenham): 30-170 units
- Twickenham Station: to be added later
- Two colleges: to be added later

A heat network would not be financially viable if any of the above developments are to be low density, i.e. if the buildings were mainly houses or small blocks of flats. In those instances it would be more appropriate to instead incorporate communal heating systems, i.e. to have a plant room in each block of flats, rather than connecting the buildings together.

The feasibility of a heat network increases if a non-residential development, such as a school, offices, leisure centre etc, could also be connected to the system,. This would ensure a minimum level of heat required throughout the day, rather than peak heat demands in the morning and evening.

It is expected that a heat network fuelled by biomass, and serving dwellings only, could provide a minimum of 40% CO_2 emissions reduction. This amount could be increased to 50% for a heat network that would also include non-residential schemes.

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[15] A community/district heating system could supply multiple buildings on a site, or if there is only one building on the development it could supply heat and/or electricity communally to all the occupiers of that building. It should be noted that community / district energy schemes are most commercially attractive where densities are in excess of 75 dwellings/hectare or in the case of larger developments (100 homes) over 55 dwellings/hectare. A community heat or electricity scheme would count as a community energy scheme, electricity *and* heat therefore do not need to be provided together.

[16] Local Housing Availability Assessment – LBRuT – February 2008. Available from http://www.richmond.gov.uk/home/environment/planning/planning_guidance_and_policies/local_development_framework/local_development_framework_research/housing_land_supply_in_the_london_borough_of_richmond_upon_thames.htm

As a general rule, all new developments which are close to an existing or planned heat network should be connected to this network, and provision should be made to address the interim period (e.g. a new development finished to be built prior to the heat network will need an interim solution to operate the heating system of the building until the heat network is available – this interim solution will have to imply minor changes once the building can be connected to the heat network).

The following recommendation, based on Policy 4A.6 of the London Plan, is to establish a rule that should be followed for all new large developments in the London Borough of Richmond to ensure that the option of connecting to a decentralised heat network is investigated thoroughly.

Requirements to incorporate a decentralised heat network
A feasibility study for a heat network should be conducted for any large development of more than 100 units with a density above 55 dwellings/hectare and/or incorporating a non-residential element.

The energy should be supplied in the following order of preference:

- Connection to existing CHP/CCHP networks
- New CHP/CCHP networks powered by renewable energy
- CHP/CCHP powered by gas
- Communal heating and cooling powered by renewable energy
- Communal heating and cooling powered by gas

Where there is an existing heat network near to a proposed development, the development (new build or major refurbishment) will be connected unless it can be proved that this is not technically feasible[17].

Where connection to a decentralised heat system is not considered possible, robust evidence of the feasibility assessment must be submitted to the Council. Any arguments on economic grounds must be supported by evidence of the cost of the proposed alternative heating infrastructure, marketing possibilities, and thorough investigation of the use of an Energy Services Company (ESCo).

4.2 Planning constraints

There are a range of national and local designations that have implications for the implementation of sustainable energy measures throughout the London Borough of Richmond upon Thames. Landscapes, habitats, and buildings of special quality are protected by legislative and planning policy designations which place restrictions on the nature of appropriate development. There are additionally policy designations in areas which have been classified as being sensitive to the environmental impact of development on, for example, pollution and the transport infrastructure. While sustainable measures will be promoted in line with national, regional and local planning policy, the specific measures will need to be more carefully considered. Certain technologies will require greater design sensitivity and some will not be appropriate where a development site falls within or near to one of the areas listed below.

[17] There is, at the time of writing this report, no existing heat network identified in the London Borough of Richmond. However, any future heat network should be considered for connection of existing buildings or new developments.

Each planning application must be considered on its own merit, and sufficient information will be required to enable the local planning authority to assess the likely impact on any special designated area relevant to the particular application site.

4.2.1 National and Regional Constraints

World Heritage Site (WHS) and associated buffer zone
The Kew Gardens WHS lies within the London Borough of Richmond upon Thames. The main planning considerations relevant to any site within or near a WHS are the impact upon its setting. In relation to sustainable energy measures, the key consideration will therefore be the visual impact on any landscape and buildings related to the WHS.

Conservation Areas
Planning policy seeks to protect and enhance the character, appearance and setting of Conservation Areas. Sustainable energy measures will need to be considered in relation to their visual impact. Further guidance can be found in section 4 of this report.

Listed Buildings and Scheduled Ancient Monuments
Listed buildings and Scheduled Ancient Monuments (SAMs) such as Hampton Court Place are afforded protection under planning policy and the main planning considerations will be the impact of proposals on the building or structure and its setting. Restrictions are applied to demolition, alterations, extensions and changes of use which may detrimentally affect the physical fabric or setting of these structures. Any sustainable energy measures will be required to fully integrate with the building or structure, and should not be visibly obtrusive in their settings.

Green Chains and Sites of Special Scientific Interest (SSSIs)
Richmond Park is a National Nature Reserve, SSSI and SAC. SSSIs are designated for their special biological or geological interest. Planning policies seek to protect and enhance both SSSIs and Green Chains, and any sustainable energy measures must not have a detrimental impact on the special geology, habitats or species within those areas.

Green Belt
Policy seeks to protect and enhance Green Belt areas, with a presumption against inappropriate development. Development proposals on land in or adjoining the Green Belt must ensure that they will have minimal visual impact and this will be a requirement for sustainable energy measures.

Metropolitan Open Land (MOL)
A key feature of the Borough of Richmond is the presence of Metropolitan Open Land (MOL). Policy seeks to protect and conserve such designated areas by keeping them predominantly in open use, with a presumption against inappropriate development either in or adjacent to these areas. The key consideration for sustainable energy measures is the need to minimise visual impact and to avoid a detrimental impact on the character of the MOL.

Thames Policy Area
Development in the Thames Policy Area is required by planning policy to protect and enhance its special character. High quality and commensurate design, height and siting will be required for sustainable energy measures within these areas.

4.2.2 Local Constraints

Areas and Buildings of Townscape Importance
Planning policy seeks to protect and enhance buildings and areas of townscape merit. Sustainable energy measures must therefore minimise the visual impact on these areas and the physical fabric of buildings.

Other Sites of Nature Importance
Proposals within these areas must preserve and enhance existing habitats and wildlife features, with particular regard to protected species and the river corridor. The design of sustainable energy measures must therefore not impact detrimentally in terms of noise, air pollution, water quality and biodiversity.

Public Open Space
Areas of open land are protected from development, and proposals for sites adjoining these areas must not have a detrimental visual impact on the character of the land.

Local Views
Views to historic and culturally significant areas will be protected and enhanced, including those to or from historic parks and gardens, open spaces, and areas of nature conservation. The design of sustainable energy measures must not have any detrimental impact on such views.

Floodplain and Urban Washlands
Within an area liable to flood sustainable energy measures must ensure that they do not increase impedance of the flow of floodwater and interfere with water courses or flood defence features. Measures to improve a site's capacity to store water will be encouraged.

Transport
Strategic planning policy objectives seek to reduce congestion and pollution and encourage sustainable modes of transport. Heavy lorries and the lorry route network are restricted to the A316, and traffic management measures are sought to control heavy vehicle traffic.

Archaeology
The archaeological heritage of the Borough is protected by planning policy. As such it is important that any sustainable energy measures conserve archaeological resources this must be demonstrated where technologies involving intrusion into the ground are being considered.

Air Quality and Pollution
Planning policy protects the Borough from development that would result in increased air pollution. This is particularly relevant where the entire Borough is designated an Air Quality Management Area (AQMA) and London is covered by a smoke control zone. Sustainable energy measures that would result in an increase in pollution will not be acceptable.

4.3 Conservation areas

The London Borough of Richmond upon Thames contains some 70 Conservation Areas, and their protection and enhancement is clearly a priority of planning policy. This does not however preclude all opportunities for energy and broader sustainability measures; it simply implies a need for locally specific consideration of the characteristics of the Conservation Area and, in particular, identification of areas that will be more sensitive to alterations to the external appearance of a new or existing building. The primary concern will be to ensure that any measures protect the setting of the Conservation Area and, importantly, any listed buildings therein. Sensitive and innovative design measures will be required to provide solutions to overcome the constraints of the Conservation Areas where important opportunity sites are concerned.

Following an amendment to the Town and Country Planning Act (General Permitted Development Order) 1995 (GPDO, 1995) in 2008, the installation of many renewable energy technologies was brought under the definition of permitted development for householders subject to a range of detailed considerations including scale and design. It is however possible for a local authority to apply Article 4 Directions to whole or parts of Conservation Areas to withdraw the permitted development rights meaning that planning permission is required where it would not normally. Richmond Council has issued many such Directions across the Borough to protect important sites within Conservation Areas. Appendix A contains a list of those Article 4 Directions and the addresses to which they are applicable. Where a Direction is applied, there will be greater restriction on the appropriate sustainable energy measures and, in particular, any measures which result in visible alterations to the front elevations, roofs, doors and windows.

Design Considerations for Sustainable Energy Measures

In consideration of the above heritage policies, and more stringent requirements on planning applications as a result of Article 4 Directions, future policy must seek to promote more sensitive and innovative solutions to sustainable energy measures in Conservation Areas.

The key objectives to consider for all statutory heritage designations, including Conservation Areas, are:

- Preserving the appearance of listed buildings;
- Respecting, and where possible enhancing, the locally distinctive context;
- Respecting the settings of listed buildings and Scheduled Ancient Monuments (SAMs);
- Preserving the setting of Historic Parks and Gardens;
- Respecting the open nature of importance spaces and landscapes; and
- Protecting important views and panoramas into, through and out of the Conservation Area.

In relation to the setting of Conservation Areas, the appropriateness of technologies will depend upon the particular site location and the historic sensitivity. Within these areas, design must preserve and enhance character, appearance, setting, layout, cohesion and physical value by retaining buildings and townscape features, and allowing development which removes unsightly elements or enhances the character.

General considerations for determining appropriate technologies include:

- The degree of visibility in the context of a listed building or Scheduled Ancient Monument;
- The extent to which the technology alters the appearance of the main frontage/elevation of important buildings, especially those which are the subject of Article 4 Directions;
- The degree of visibility in the context of an area or building of special interest in either the Conservation Area or a Historic Park and Garden;
- The extent to which the technology is visible from a key vantage point;
- The extent to which the technology will be visible so as to be detrimental to a key view into, through or out of the Conservation Area, or an important panorama.

4.4 Richmond's development objectives

A number of key policy objectives for the London Borough of Richmond upon Thames, as described in Section 3.1.3, in terms of future developments are emerging that have implications for this study. They can be summarised as follows:

- Fundamental objective for the reuse of existing buildings wherever possible throughout the Borough;
- New development, preferable mixed-use, is to be focused in existing town centres with Richmond being promoted as the key location for future high density developments, followed by Twickenham.
- The potential for energy generation from renewable sources, subject to the impact on amenity and the environment, should be maximised in order to reduce the Borough's carbon emissions. Sustainable energy measures should also be incorporated in existing buildings.

These Borough wide policy objectives must be pursued in developing sustainable energy measures for future developments while ensuring that the constraints identified in Section 4.2 above, related to the special historic and landscape character of the Borough, are properly accounted for.

In terms of quantitative objectives for housing, the Local Housing Availability Assessment (Richmond Council - February 2008) shows that the Borough has been allocated a housing target of 2700 units from 2007 to 2017. It is anticipated that these units will come from small sites (approximately 2/3) and large sites of 10 or more units (1/3).

Moreover, Richmond has set the objective in its Core Strategy to comply with Policy 3A.*9 Affordable housing targets* of the London Plan that 50% of units within new housing developments should be affordable.

The analysis of planning permissions (detailed in Section 5.1) shows that the majority of developments are for housing (almost 70%). Richmond's Council is expecting to maintain a similar proportion between development types in order to meet the objectives described above. This means that there is no intention from Richmond Borough Council to encourage certain development types by amending CO_2 reduction targets for these development types in order to reduce their overall development costs.

5 Development groups

In order to define development groups, development types which cover the majority of planning permissions granted by the London Borough of Richmond upon Thames have been identified. Once the development types were identified, other criteria (such as new build, works to existing, conservation areas, etc) have been taken into account and development groups formed.

This section provides details on the planning permission analysis undertaken, as well as a list of development groups to be considered in this study.

5.1 Planning permission analysis

An analysis of the planning permissions granted in the last year has been undertaken. This analysis was based on the following documents provided by Richmond Borough Council:

- Residential Permissions between 01/04/2007 and 31/03/2008
- A1, A2 permissions between 01/04/2007 and 31/03/2008
- A3, A4 permissions between 01/04/2007 and 31/03/2008
- B1, B2 permissions between 01/04/2007 and 31/03/2008
- D1, D2, SG permissions between 01/04/2007 and 31/03/2008

5.1.1 Residential

Planning permissions identified from the document analysis which fall within the residential category (C3 – Dwelling Houses) comprise the following (percentages provided in terms of units and not planning permissions): new build (69%), conversion (19.4%), extension (6.1%) and change of use (5.5%). This is illustrated in Figure 5.1 below. Detail of total planning permissions per area is provided in the appendix.

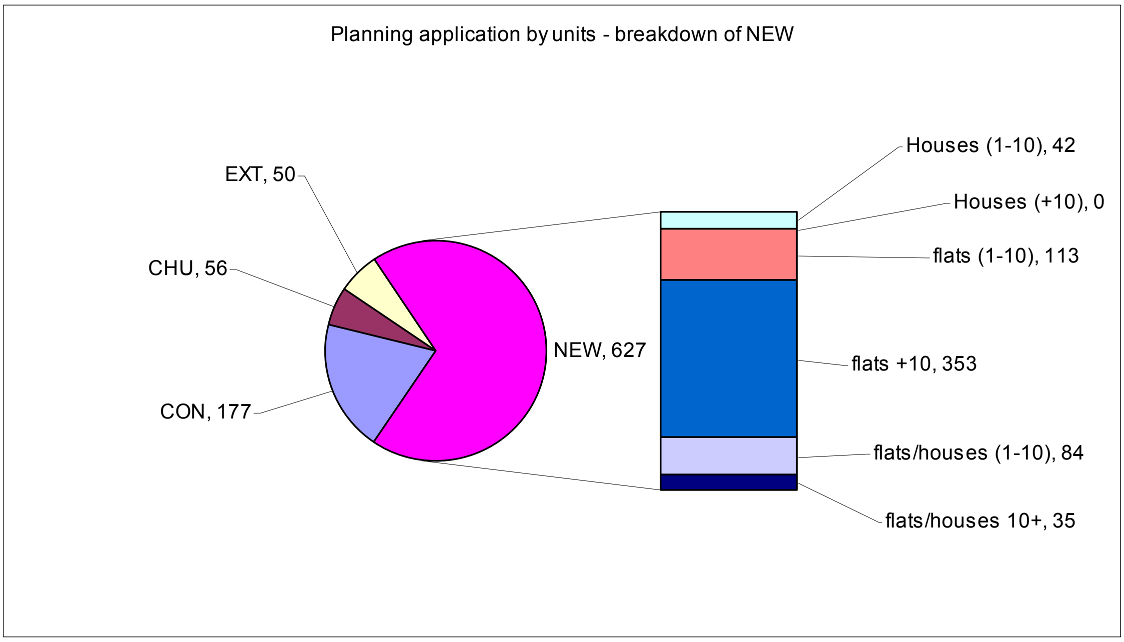

Figure 5.1: Breakdown of planning applications for residential

Approximately 42% of the planning permissions are for new build, with 35% pertaining to conversions. However, new build represents two thirds (69%) of the total when considering units rather than planning permissions, the majority of which (56%) involve blocks of more than 10 flats. Blocks of less than 10 flats are the second largest proportion at 18% of the total new build residential units. Planning permissions involving both flats and houses represented 19% of the total units.

Based on the documents provided, almost 10% of the planning applications are for extensions, which in the great majority consist of the enlargement of an existing building to provide independent flats. These are also therefore considered as new build.

A meeting with the project team[18] confirmed that many of the extensions also involve refurbishment work to individual houses or flats to provide additional space in the basement or in the loft. This type of extension therefore falls in the refurbishment category.

More than 19% of the units are conversions, usually involving the refurbishment of an existing house to form several flats. Conversion will therefore be considered as refurbishment.

Changes of use represent only 5.5% of the total units and were considered as refurbishment.

Finally, even though there were no permissions identified for major refurbishments (e.g. the complete refurbishment of building retaining only the façade), it was suggested to cover this category in the policy where there is the potential for future planning applications and significant CO_2 emissions reduction could be obtained.

➢ The development types retained from the above statistics which were used in the definition of development groups therefore consist of the following:

- Houses / Flats (1 unit) – Extension
- Houses (2+ units) – New build
- Flats (2 to 10 units) – New build (new or extension to existing) + Conversion
- Flats (11+ units) – New build + refurbishment

5.1.2 Non-residential

Detail of total planning permissions per development type is provided in the appendix.

<u>Schools</u>

The analysis of D1 and D2 types of planning applications show a much higher proportion (in terms of square meters) of new build and extensions for schools (77%) than any other category. New build for other categories than schools represent only 10% of the total area. Refurbishment, i.e. change of use and conversions, represent only 13% of the total area.

A meeting with the project team[18] confirmed that only new build should be considered and that, although there could be a distinction between small and large schools, sustainability requirements applying to them should be the same. Therefore, only one category was required: schools (2+ class rooms) / new build.

<u>Offices</u>

[18] Meeting held at Civic Centre on 2nd October 2008.

As with schools, the analysis of B1 and B2 types of planning applications show a much higher proportion (in terms of square meters) of new build and extensions for offices (91%) than any other category. There was only one planning permission granted over the period analysed, for a new build print room facility (type B2).
When looking at the nature of new build planning applications for offices, it appears that many of them involve mixed-use residential, i.e. offices converted into mixed-use residential with major changes, and these are therefore considered to be new build (confirmed by Richmond's project team).

Refurbishment of offices (as change of use or conversions) only represents 5% of total square meters for this category.
Finally, the great majority of permissions are for offices with a surface area smaller than 1,000m^2. However, it is suggested to also consider bigger sites as they can contribute to significant CO_2 emissions reductions.

As a consequence, the categories that were investigated considered new build only and made the distinction between small and large offices as well as included mixed-use residential.

<u>Retail, financial & professional services, restaurants</u>
The analysis of planning permissions for retail (Class A1 to A5) reveals that the most significant proportion of floorspace (in square meters) involves either new build or extensions, at 33% for classes A1 and A2, and 16% for class A3 restaurants. Over the year analysed, planning permissions for new build development was consistently either mixed-use with residential or a combination of retail (A1 and A2) and restaurants/cafes (A3).

Planning permissions for changes of use represent 44% of the total analysed in terms of floorspace, and consistently involved a change within Class A and not, for example, changes from A1-A3 to C3 residential. There were no planning permissions identified for conversions. It was agreed with the project team that change of use will usually not allow improvements to the building fabric as will concern in most of the cases a single unit in a mixed-use residential.

As a result, it was decided that the categories to be investigated should involve new build development only. It is important however to make a distinction between small and large scale developments, and to ensure that mixed-use developments incorporating an element of residential are included.

- The development types from the above analysis that have been selected for use in defining the development groups are as follows:

  - Schools (D1) (2+ class rooms) – New build
  - Offices (B1) (<1,000m^2 – incl. mixed-use) – New build
  - Offices (B1) (≥1,000m^2 – incl. mixed-use) – New build
  - Retail, financial & professional services (A1 and A2) & restaurant (A3) (<1,000m^2 – incl. mixed-use) – New build
  - Retail, financial & professional services (A1 and A2) & restaurant (A3) (≥1,000m^2 – incl. mixed-use) – New build

5.2 Geographical and building type criteria

Different rules for sustainability measures will apply depending on the specific characteristics of a development site. The characteristics which feature in the London Borough of Richmond are listed in Section 4.2. These include, for example: Conservation areas, Metropolitan Open Land, Green Belt, etc.

For the sake of simplicity, and to allow the application of development briefs to a wide range of developments, it was decided to define only the following scenarios in the definition of CO_2 emissions reduction targets:

- Standard building outside any conservation area
- Standard building in a conservation area (follows the General Permitted Development Order (1995))
- Building of townscape merit in a conservation area (subject to an Article 4 Direction)

All other types of developments located in areas subject to sensitive designations, other than those mentioned above, will be considered on a case by case basis by the planning department and therefore fall outside the scope of this study. However, for specific considerations relating to each designation, please refer to the planning constraints section of this report.

5.3 Development groups to consider

Based on analysis set out in 5.1 above, a number of development groups have been formulated for which sustainable energy targets will be defined. These are presented in Table 1 below.

Category	Development types	New build	Works to existing
C3	Houses - Flats (1 unit)	**N/A**	✓
	Flats (2 to 10 units)	✓	✓
	Flats (11+ units)	✓	✓
	Houses	✓	✗
D1	Schools (2+ class rooms)	✓	✗
B1	Offices (<1,000m^2 plus additional uses)	✓	✗
	Offices (≥1,000m^2 plus additional uses)	✓	✗
A1, A2, A3, A4	Retail, fin & prof services & restaurant (<1,000m^2 plus additional uses)	✓	✗
	Retail, fin & prof services & restaurant (≥1,000m^2 plus additional uses)	✓	✗

Table 1: List of development groups

5.4 Development scenarios

A typical scenario has been determined for each development in order to allow for energy efficiency modelling, sizing of renewable energy technologies and estimation of CO_2 emissions reduction.

These scenarios are presented in Table 2, along with the rationale for each case.

Development types	Scenario	Rationale
Flat	Top floor and mid-block 2-bed / 3 persons / 70m^2 10,080m^2/hectare (2-10) 11,760m^2/hectare (11+) bn	1-bed flat 60m^2 [19] + 10m^2 for additional person
House	Semi-detached 3-bed / 4 persons / 90m^2 8,400 m^2/hectare	2-bed semi 76m^2 [19] + 14m^2 for additional person (assuming 9m^2 bedroom + 5m^2 remaining space)
School	3 storey building 6,000m^2	Planning application analysis + CEN experience
Offices	5 storey building 1,090m^2 12,000m^2/hectare	Building size from which meeting a 20% CO_2 with PV panels becomes challenging because of roof space limitation. Also size from which biomass starts to be viable.
Retail, financial & professional services & restaurant	Ground floor retail space in building used for offices	Assumed to be a likely scenario based on the planning applications.

Table 2: Development scenarios investigated

[19] Based on development scenarios retained in Cost Analysis of The Code for Sustainable Homes – Final Report – July 2008 - DCLG

6 Methodology for economic assessment

This section details the methodology that has been adopted to determine the feasibility of sustainable energy targets for different development groups for application in the London Borough of Richmond upon Thames. In order to conduct an economics assessment, the cost of measures and the impact of this cost on the financial elements of a development were assessed. The specific objectives were to:

1) Define and quantify the cost of appropriate CO_2 reduction measures for each development group;
2) Assess the impact of these measures on the residual land value and therefore the viability of the development for residential and offices. For retail and schools, express the cost of these measures as a percentage of build cost, and discuss their impact on the development's viability.

CO_2 reduction measures are defined in terms of improving the energy efficiency of a building through improving insulation and the heating system, and the use of on-site low and zero carbon technologies.

Section 6.1 presents a brief explanation of the concept of residual land value that is used in the financial assessment for residential and offices developments (described in Section 6.3). Section 6.2 describes the methodology followed to determine and estimate the costs of sustainable energy measures. Section 6.3 explains how the impact of these costs on financial elements has been determined.

6.1 Residual land value

A development's value consists of the following five variables:

- Cost of land
- Building costs
- Planning obligations (SPG, Affordable housing provision, renewable energy)
- Interest paid on building and land cost
- Developer's profit margin on costs (land and building)

The objective of the developer is to ensure that the development's value is smaller or equal to its market value.

The maximum price that can be paid to the land owner for his land is defined as the residual land value. It is the result of the following equation:

Completed development value
-
Construction costs, Planning obligations, interest, fees, etc
-
Developer's profit
=
Residual land value

Integrating CO_2 reduction measures will decrease the residual land value owing to their associated additional costs. "The residual land value therefore becomes the critical variable, i.e. if a proposal generates sufficient positive land value, it will be implemented; if not, unless there are alternative funding sources to bridge the 'gap'

(…), the proposal will not go ahead[20]„ . In order for development to proceed, the residual land value must exceed the Existing Use Value (EUV).

Therefore, when considering the extent to which CO_2 reduction measures can be integrated into developments, there is a need to determine the maximum cost of these measures that the landowner can bear before the residual land value reaches the EUV.

This methodology has been used to assess the financial viability of sustainable energy measures for residential and offices developments. See Section 6.3 for more details.

6.2 Methodology to define appropriate measures and quantify CO_2 reduction targets

6.2.1 New build

In order to determine the appropriate sustainable energy measures that should be applied to the different development groups, the methodology described below has been followed:

1. - Calculate predicted energy (electricity and gas) consumption and the related CO_2 emissions for each scenario chosen (e.g. flat 70m^2 middle block) using:
    a. - Residential: data provided by CEN's initial SAP calculations, and estimated electricity consumption for appliances and cooking[21]
    b. - Non-residential: 2006 Building Regulations compliant BRE benchmark data
2. - Define appropriate energy efficiency measures to be integrated into the development with the objective to achieve reasonably high performance (equivalent to former EST Best Practice[22]) and calculate improvement of Dwelling Emissions Rate (or Building Emission Rate in case of non-domestic buildings) over Target Emissions Rate
3. - Assess the technical feasibility of the low and zero carbon technologies that can be deemed suitable for the site
4. - For the feasible technologies, estimate suitable system sizes providing details of the energy produced and CO_2 offset through their application, guideline system costs, and operational information
5. - Calculate the percentage of a development's CO_2 emissions that can be offset through the use of low and zero carbon technologies
6. - Identify design requirements for each of the technologies
7. - Determine the optimum combinations of technologies to achieve the most cost-effective sustainable energy solution for the site (including energy efficiency and renewable energy technologies) that meet the targets defined in Section 6.3.

[20] Chris Marsh, 2007, p.3
[21] SAP is used to calculate the energy required for space and water heating, ventilation, pumps, fans and internal lighting, but not appliances. In this case, data for the electricity requirements for appliances and cooking has been estimated using BRE Code for Sustainable Homes Ene 7 calculator
[22] EST Best Practice has now been replaced by guidance on how to achieve different Code for Sustainable Homes levels.

6.2.2 Works to existing buildings

The CO_2 emission reductions achieved through sustainable energy measures implemented during a refurbishment will vary widely depending on the type of building. A number of measures are deemed to be feasible because they do not require significant changes to the building fabric including, for example, energy efficient lighting. Other measures, such as insulation of the walls and floors, will be more difficult and costly as a retrofit solution. The energy performance obtained will therefore be highly dependent on the initial performance of the building envelope, and on the extent of the refurbishment works that are proposed.

In any case, Building Regulations for refurbishment (Part L1B) must be complied with. Building Regulations give guidance on the level of performance that should be achieved with, for example, an indication of minimum U-values that must be reached. The methodology therefore adopted in this study assumes that the building to be refurbished will comply with the Building Regulations and excludes the associated costs from the overall costs of additional sustainable energy measures.

The methodology described below has therefore been followed, using the same scenarios as those used for the new build development groups:

1. - Apply energy efficiency measures
    a. - <u>Residential</u>: Using the Standard Assessment Procedure (SAP) model completed for the new build assessment, modify certain elements of the building envelope (higher U-value) to reflect the requirements of Building Regulations, and determine the energy requirements in terms of both electricity and gas consumptions
    b. - <u>Non-residential</u>: Estimate energy efficiency measures based on work done for residential and best practice
2. - Assess feasibility of low and zero carbon technologies (e.g. ground-source heating might not be feasible in a retrofit if there is no access to available land)
3. - Estimate suitable system sizes for the feasible technologies taking into account potential limitations due to the already existing design of the building (i.e. the roof space available might limit the amount of solar technologies that could be integrated). Calculate energy produced, CO_2 offset through their application and guideline system costs.
4. - Calculate percentage of buildings' CO_2 emissions that can be offset through the use of low and zero carbon technologies
5. - Determine the best combinations of technologies to achieve the most cost-effective sustainable energy solution for the site (including energy efficiency and renewable energy technologies)
6. - Based on previous results, define a range of CO_2 emissions that can feasibly be achieved for each development group.

6.3 Methodology to define the impact of CO_2 reduction measures on residual land value

6.3.1 Residential

For residential developments, the methodology is based on an analysis already conducted for the London Borough of Richmond[23].

This report presents the residual land value for different residential densities taking into account planning obligations, including the integration of 50% affordable homes in all new developments[24]. The results are shown in Figure 6.1.

Different bands of Existing Use Value have been defined. They correspond to:

- top band: high density, better quality office at £7.2 Millions/hectare
- middle band: lower density & less prime location at £4.8 Millions/hectare
- bottom band: single storey industrial buildings at £2.4 Millions/hectare

In order to be conservative, and given Richmond's Council objective to generally increase development densities, the top band of EUV has been retained for the definition of viable CO_2 reduction measures.

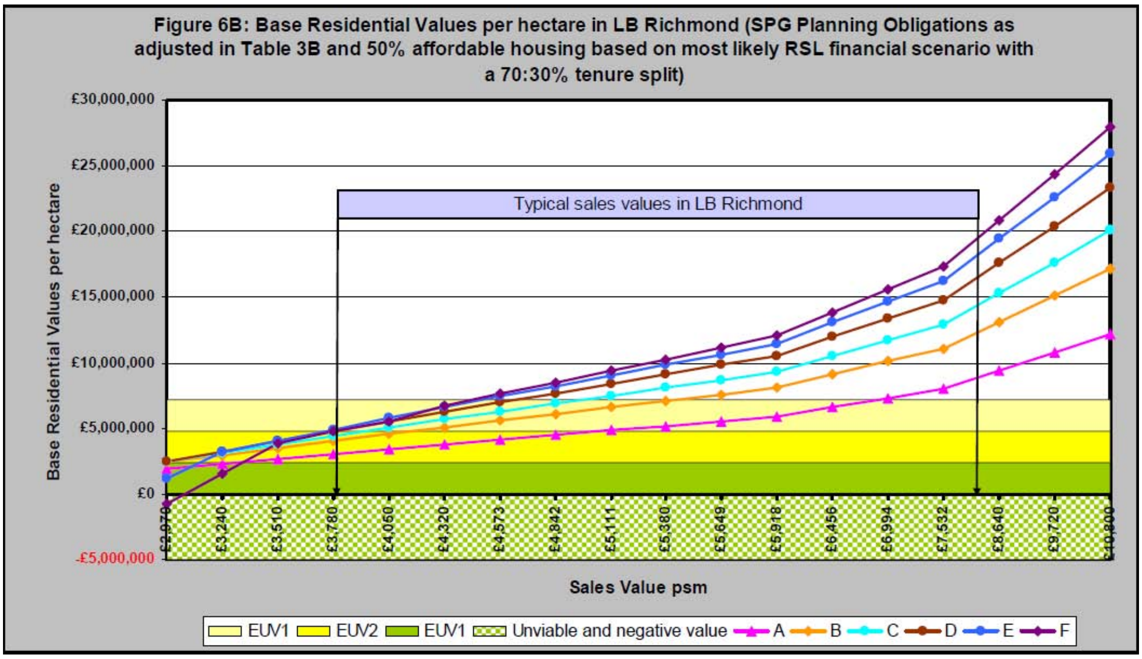

Figure 6.1: Residential values – Results report Chris Marsh

Initially the objective was to determine the difference between the residual land value resulting from the lowest typical sales value in Richmond (£3,780 per m^2) and the highest EUV (£7 Mio per hectare). This difference defines the maximum costs of CO_2

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[23] MARSH, C. *Financial Viability Assessment for affordable housing thresholds and employment redevelopment,* 2007. Available from: http://www.richmond.gov.uk/home/environment/planning/planning_guidance_and_policies/local_development_framework/local_development_framework_research/financial_viability_assessment.htm

[24] corresponds to Richmond's Council development objectives for residential developments of 10 or more units or 0.3 hectares (UDP Policy HSG 6)

reduction measures that can be added, on top of costs for affordable housing and meeting SPG obligations, before the residual land value falls below the existing use value.

Generally, using the results obtained in Chris Marsh's report, it appears that CO_2 reduction measures would decrease the residual land value below the EUV for developments of lower sales values and that only developments of higher sales values would be able to bear the additional cost of sustainability. As shown on Figure 6.1, this was already the case for all the development scenarios when SPG and affordable housing obligations were introduced.

The approach has therefore been to identify the minimum level of CO_2 reduction measures that should be required for residential developments to comply with current and future regional and national policies.

An initial target, corresponding to the minimum mandatory energy requirement to comply with Level 4 of the Code for Sustainable Homes, has been adopted based on the fact that all affordable housing funded by The Housing Corporation will have to achieve this target by 2012. It is also the level that is likely to be required for all housing by the Building Regulations in 2013 to align with government targets. Specifically, this requires a 44% reduction of Dwelling Emission Rate over the Target Emission Rate.

In addition, a 20% reduction in overall CO_2 emissions from renewable energy has also been specified as it implements London Plan policy 4A.7.

As a consequence, the following approach has been adopted:

- Step 1: the residual land value for the relevant density (e.g. 144 units per hectare for the case of a block of 2 to 10 flats) has been taken as a baseline

- Step 2: costs related to the sustainable energy measures necessary to achieve Code for Sustainable Homes Level 4 and to meet the 20% renewable energy target have been added to this baseline (creating a second land value line that is lower than the baseline line)

- Step 3: the intersection point between this second land value line and the top EUV gives the sales value threshold at which sustainability starts to become financially viable. Above this threshold, it would be possible to require more stringent targets. Below this threshold, the targets required are less likely to be achievable in financial terms.

It should be noted that this threshold is defined based on a combination of information provided in Chris Marsh's report and details of the costs of sustainable energy measures provided by CEN. The assumptions made in the report are voluntarily quite conservative, particularly:

- The EUV considered to identify the threshold is linear across the graph, i.e. it assumes that the land value does not vary with the sales value of the development. It could however be argued that, if a development will sell for less, the land value will also be lower For example, in the case of land located further away from station or located in a deprived area.

- The build costs retained for the different density levels are high compared to other data sources

- For a given development density, the corresponding gross/net ratio available in Chris Marsh's report was lower than the ratio that would have been selected from CEN's modelling assumption. For example, a net/gross ratio of 85% had to be retained for developments of 2-10 flats. In reality, this ratio would be higher for this type of development, with a positive impact on the land value.

Different baselines from Figure 6.1 have been used depending on the scenario:
- semi-detached house: line D (8,400m^2/hect)
- block of flats 2-10: line E (10,080m^2/hect)
- block of flats 11+: line F (11,760m^2/hect)

6.3.2 Offices

For offices, i.e. generally B1 and B2, the methodology based on residual land value has been used, following the same approach as the one adopted in Chris Marsh's report. This involves defining the threshold where sustainable energy measures are financially viable as the intersection between land value and EUV. However, new data had to be compiled for sales value and build costs.

The list below provides the different elements required for the assessment and the data source that has been used:

- The EUV is based on Chris Marsh's report
- Sales values calculated using rent/yield information in Section 4.5.2 of Chris Marsh's report

This set of data and assumptions has enabled us to estimate the residual land value for offices, which varies with the sales value.

In relation to residential development and to be conservative, the top band of EUV has been considered for the definition of viable CO_2 reduction measures.

There is no BREEAM target specified for non-residential development. However, a 20% reduction in overall CO_2 emissions from on site renewable energy generation has been specified, reflecting London Plan policy 4A.7, in order to assess its impact on the residual land value.

As a consequence, the same principles as for the residential analysis have been adopted:

- Step 1: the residual land value has been calculated using the components specified above and has been taken as a baseline

- Step 2: costs related to sustainable energy measures necessary to achieve the 20% renewable energy targets have been added to this baseline (creating a second land value line that is lower than the baseline line)

- Step 3: the intersection point between this second land value line and the top EUV gives the sales value threshold where sustainability starts to be financially viable. Above this threshold, it would be possible to require more stringent targets. Below this threshold, the targets required are more financially difficult to implement.

6.3.3 Schools

The methodology for schools developments did not involve use of the concepts of residual land value, calculated based on profit margin and sales value, as this type of development does not follow the same commercial criteria as residential or office developments.

Energy requirements, based on 2006 Building Regulations compliant BRE benchmark data, have been estimated. Low and zero carbon technologies have then been applied to meet a high proportion of the energy requirements (within the limit of heat requirements for technologies generating heat), with the objective of both meeting London Plan Policy 4A.7, establishing schools as forerunners in sustainable development, and maximising the use of sustainable energy measures as educational tools.

6.3.4 Retail

For retail, the methodology did not use the concepts of residual land value coming from Chris Marsh's report as it was unclear whether the same EUV could be also applied to a retail component.

Instead, energy requirements based on 2006 Building Regulations compliant BRE benchmark data have been estimated. Low and zero carbon technologies have then been applied in a similar proportion as for offices, using the percentage increase in build cost as an element of comparison.

6.3.5 Mixed-use residential

For mixed-use developments including either a combination of residential and offices or residential and retail, it was assumed that the targets defined for each development type would be applied to each section of the mixed-use development.

7 Energy efficiency

Energy efficiency is concerned with achieving the same level of comfort with less energy through better insulation and greater efficiency of the heating system. Prior to integrating low and zero carbon technologies, all buildings should be made as energy efficient as possible. Energy efficiency will reduce the overall energy consumption of the buildings, and therefore reduce the CO_2 emissions associated with the overall operation of the building. Implementing such measures at the early design stage will also minimise the residual baseline against which a further 20% reduction in CO_2 emissions is required through the installation of renewable or low carbon technologies, and therefore reduce the total capital outlay required for achieving sustainable energy targets by way of CO_2 reduction targets and renewable energy targets. Furthermore, the cost of implementing energy efficiency measures is usually lower than that of integrating low and zero carbon technologies.

This section provides an overview of energy efficiency principles and measures that can be applied to developments within the London Borough of Richmond upon Thames and which have been used in the modelling exercise of this study.

7.1 Passive design

Passive design can only be considered at the design stage; it provides a one-off opportunity to save energy during the lifetime of a building and generally does not carry a cost implication. In modern housing, up to 20–25% of heating and lighting energy can be saved by the application of passive design principles in the design of development.

There is sufficient scope within the parameters of passive design to secure the creation of interesting and varied layouts and townscape, and to maintain an entirely conventional appearance if required. In the case of offices, schools and other public buildings, features with a passive design function, such as ventilation stacks and atria, can be designed in ways that add interest and character.

The objective of passive design is to maximise the use of energy and light from the sun. Simple design approaches are employed which intentionally enable buildings to function more effectively, minimising the need for mechanical heating and lighting, and provide a comfortable environment for living or working. The following principles of passive design should be applied to a development during the design stages:

- Orientation - The capture of solar gain can be maximised by orientating the main glazed elevation of a building within 30 degrees of due south
- Room layout - Placing rooms used for living and working in the south facing part of the building will reduce reliance on artificial lighting and heating methods
- Avoidance of overshadowing - Careful spacing of buildings should seek to minimize overshadowing of southern elevations, particularly during the winter when the sun is low
- Window sizing and position - In housing, smaller windows should generally be used in north facing elevations to prevent excessive loss of heat
- Natural ventilation - Atria and internal ventilation stacks projecting above the general roof level can be used to vent air as the building warms during the day, with cool air being drawn in through grills in the building façade
- Lighting - In offices the avoidance of deep-plan internal layouts and the use of atria, roof lights and light reflecting surfaces can help reduce the need for artificial lighting
- Thermal buffering - In order to reduce heat losses, unheated spaces such as conservatories, green houses and garages which are attached to the outside of heated rooms can act as thermal buffers

- Landscaping - Landscaping, including the use of earth bunds, is often used as part of an overall passive design approach providing a buffer against prevailing cold winds and shading for summer cooling.
- Living Roofs – The installation of Green or Brown roofs can provide benefits, not only in terms of appearance, biodiversity, and surface water retention, but also has thermal properties.

7.2 Building fabric

Following careful consideration of passive design, the building fabric should be specified to provide minimal heat losses and to reduce internal overheating during the summer months. A well insulated building with minimal air permeability can cost-effectively reduce heat losses from the building by 25% compared to a Building Regulations compliant building as shown by the modelling exercise carried out on flats and houses.

U-values are used to measure the insulation levels of the building fabric. They indicate the thermal transfer through the walls, roof, floor, windows and doors of a building, i.e. the heat loss rate per square meter of insulating element for a given temperature difference between the inside and the outside. A wall with a low U-value will have smaller heat losses than a wall with a larger U-value. Insulation can be improved by increasing the thickness of conventional types of insulation, such as rock wool or glass wool or by using more modern forms of insulation.

Insulation must be coupled with high air-tightness in order to prevent heat escaping through gaps in the building fabric. Building Regulations require an air permeability level below $10m^3/m^2/hr$. However, best practice standards are around $5m^3/m^2/hr$. If the air permeability is below $3m^3/m^2/hr$, it is essential that mechanical ventilation with heat recovery (to capture waste heat from the ventilation) is installed to ensure sufficient ventilation in the building. Alternatively, for buildings with dual aspect, shallow plan buildings cross ventilation could be used.

The use of breathable membranes is also very important to ensure that moisture can exit the building, thereby reducing condensation and damp problems.

Reducing thermal bridging will also reduce heat losses from a building. This can be achieved by using accredited construction details which limit the number of conductive materials connecting the inside of the building to the outside.

For housing, the Energy Saving Trust produce best practice guidance on the U-values required to achieve a building fabric which allows minimal heat losses.

In refurbishments of older buildings, improving the insulation can achieve high carbon dioxide savings. Insulating the loft with a roll of mineral wool will provide the greatest carbon savings with the minimum expenditure. Properties built during the 20th Century often have a cavity wall which can be filled at a very little cost using an insulating foam spray. Properties older than this would require solid wall insulation, which is more expensive.

The table below gives U-values as stated in the Building Regulations and the "backstops values" provided in the Energy Saving Trust's guidance for achieving Code for Sustainable Homes Level 3 (25% reduction of DER over TER) and Levels 5 & 6 (100% reduction and zero carbon home). In practice, using the 25% EST backstop value will result in a DER that is barely inferior to the limiting TER.

Item	U Value [W/m²K]		
	Building Regulations Limiting values	EST 25% backstop	EST 100% and zero carbon solution
Walls	0.35	0.25	0.15
Roof	0.25	0.13	0.13
Floor	0.25	0.2	0.15
Door	2.2	1.5 (glazed) 1.0 (solid)	1.5 (glazed) 1.0 (solid)
Windows	2.2	BFRC rating in band C[25] or better U_{window} Max ≈ 1.8 W/m²K	BFRC rating in band A or better U_{window} Max ≈ 1.4 W/m²K
	Other parameters		
Boiler	86%	Conform to CHeSS HR7 or HC7. As for Building Regulations	Condensing 91% efficiency
Thermal bridging		Energy Saving Trust's Enhanced Construction Details (not yet available as of September 2008)	
Air permeability	10 m3/(hr.m²) @50pa	3	3
Mechanical Ventilation with heat recovery	Natural ventilation	Minimum heat recovery efficiency 85%. Limit on fan energy consumption.	Minimum heat recovery efficiency 85%. Limit on fan energy consumption.

Table 3: U-values and energy efficiency measures

7.3 Other energy efficiency elements

In addition to passive design and building envelope, the energy efficiency of a development can be improved through a number of measures:

- Install a high-efficiency gas boiler (at least 90% efficient), should one still be needed after renewable energy technologies have been integrated
- Install heating controls to include a programmer, a room thermostat and a thermostat on any hot water storage cylinder
- Ensure that rooms with internal or solar heat gains (i.e. bathrooms or rooms with south-facing glazing) have responsive heating controls, such as Thermostatic Radiator Valves (TRVs)
- Ensure that the rooms are equipped with internal fittings for energy efficient lighting

[25] The rating combines the performance of the window in terms of thermal transmittance, air leakage and solar factor (g-value) into a single rating going from G (worse) to A (best)

8 Low and zero carbon technologies

The aim of this section is to provide an overview about the renewable energy technologies which have been considered to achieve CO_2 emissions reduction targets. For each technology, a short description and the design requirements, to be considered by developers when assessing the feasibility of these technologies, are presented.

8.1 Wind turbine

8.1.1 Product information

A wind turbine converts the wind's kinetic energy into mechanical energy and electricity via a generator. There are two main types of wind turbines: horizontal vs. vertical axis turbines. They can be stand-alone or building-mounted wind turbines. The latter are not investigated in this report as field tests are currently being undertaken to fully assess the effectiveness of these turbines.

8.1.2 Environment requirements

The requirements for stand-alone wind turbines are the following:

- Minimum average wind speed of 5 to 6m/s[26]
- Large area of open ground
- No airflow turbulence (e.g. from obstacles such as buildings or trees)

8.2 Solar thermal

8.2.1 Product information

A solar thermal system pre-heats[27] a building's hot water requirements. There are two types of collectors – flat-plate and evacuated tube. Per m^2, flat-plate collectors have a lower output than evacuated tube collectors, but they are the most cost effective and robust collector type. Solar thermal tiles are less efficient than flat-plate collectors per m^2 installed, but can be better integrated with a tiled roof. However, some independent installers have raised doubts regarding the long term longevity of this arrangement because of the high number of "high temperature" connections between all the tiles of the system.

Heat collected in the solar thermal collectors is transferred to water in a thermal store. Solar thermal systems must be sized to the anticipated heat requirement, as excess heat production cannot be exported and may damage the system. Heat absorbed in the solar thermal collectors is transferred to water in a central twin-coil hot water cylinder.

8.2.2 Design requirements

Environment: in order to optimise their efficiency, solar thermal collectors need to be free from overshadowing (trees, roof obstacles and shadows cast by surrounding buildings).

Roof-type: solar thermal collectors should ideally be mounted at tilt angle of 30 to 40 degrees to maximise solar gain throughout the year. In case of a flat roof, solar thermal collectors can be mounted on A-frames. Where a number of collectors mounted on A-frames are installed, care should be taken to ensure one row does not overshadow the row behind.

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[26] London Toolkit

[27] During the summer months, when solar resources are high, the collectors can collect enough heat to provide 100% of the hot water requirements.

Roof orientation: the roof should ideally be south-facing to maximise the efficiency of the panels. Panels mounted east or west at the optimum tilt angle would generate 85% of the output of an optimally-mounted, south-facing panel.

Area required: with the example of a Schuco-Sol, the roof area required would be approximately 2.5m^2 on a pitched roof. On a flat roof, the same model mounted on an A-frame would need approximately 5m^2. On flat roofs, sufficient access space (minimum 0.5m) should be allowed around the rows of collectors for maintenance purposes.

For individual systems, storage space must be available to house hot water tanks within dwellings. For communal systems, a plant room is required.

8.3 Solar photovoltaic (PV)

8.3.1 Product information

PV panels convert light from the sun directly into electricity. Any electricity that is not consumed at the point of generation can be exported to the National Grid. They exist in a variety of formats: tiles, slates, bolt-on modules. As with solar thermal, solar PV tiles can be well integrated into a tiled roof.

8.3.2 Design requirements

Environment: It is imperative that PV panels are free from overshadowing (trees, roof obstacles and shadows cast by surrounding buildings). Due to the way in which they are electrically connected, even if one small area of a panel is overshadowed, the efficiency of the PV array will be significantly reduced.

Roof-type: PV panels should ideally be mounted at tilt angle of 30 to 40 degrees to maximise solar gain throughout the year. In case of a flat roof, PV panels can be mounted on A-frames. Where a number of PV panels mounted on A-frames are installed, care should be taken to ensure one row does not overshadow the row behind.

Roof orientation: the roof should ideally be south-facing to maximise the efficiency of the panels. Panels mounted east or west at the optimum tilt angle would generate 85% of the output of an optimally-mounted, south-facing panel.

Area required: with the example of a Sanyo hybrid panel, the roof area required would be approximately 1.25m^2 on a pitched roof. On a flat roof, the same model would need 3m^2 when mounted using an A-frame.

- PV panels can be mounted in landscape or portrait orientation to maximise the roof space.
- On flat roofs, sufficient access space (minimum 0.5m) should be allowed around the rows of PV panels for maintenance purposes.

8.4 Wood-fuel heating

8.4.1 Product information

Wood-fuel heating provides hot water for domestic use and space heating through the combustion of bi-products of the wood industry. Modern systems are fully automated and highly efficient. Features include automatic ignition, automatic de-ashing, careful control over air injection and recirculation of the flue gases to ensure a complete and clean combustion and continual monitoring of the flue gases and system operation.

There is a range of fuels available, such as logs, wood chip and pellets: the suitability of each fuel is dependent on a number of factors, including available storage space, local fuel supply chains and the heat demand and consumption patterns. The main differences between pellet and chip are that pellet fuel is a manufactured product and therefore more expensive, but also has a higher energy density, lower moisture content and more standardised quality than chip. Chip is much cheaper, but due to its bulk, is harder to deliver and to store.

For centralised systems, boilers are available with an integral hot water energy storage or buffer tank that stores water up to 90º C, enabling the supply of heat to be further decoupled from the combustion of the fuel. All systems will normally require more space than a gas boiler for the same heat load, not only because wood-fuel boilers tend to be larger but also because room for fuel storage is necessary.

8.4.2 Design requirements

Environment: a reliable fuel supply is essential

Space: sufficient space in the plant room for the biomass boiler and auxiliary equipment, e.g. buffer tank, fuel transfer, gas boiler must be ensured. The fuel storage hopper should be located close to the boiler. If there is limited space for a suitably sized plant room to be incorporated into the building, an underground plant room could be considered.

Delivery: Good approach access for fuel delivery vehicle - firstly onto the site (possibly including turning circle), and secondly the direct approach to the fuel store.

Fuel storage: Fuel silos must be kept separate from the boiler for safety reasons and should be watertight and well ventilated. The design of the fuel store must be considered alongside the available equipment of the fuel supplier. Underground stores provide faster delivery times and therefore less noise, disruption and ongoing costs. However, they are more expensive than an above ground store. Surface silos will be more labour intensive to refill but will be cheaper to install initially.
If pellets are blown from the truck into the store, there is no specific requirement in terms of the location of the store i.e. an underground or ground level store would be viable. For wood chips, the lorry needs to be able to tip into the fuel store.

The area required varies with the size of the development.

8.5 Ground source heating and cooling

8.5.1 Product information

Ground source heating is a tried, tested and reliable means of providing space heating to buildings and is most often combined with under-floor heating. Such a heat distribution system is efficient due to low flow and return temperatures, and offers high levels of comfort for building occupants.

A ground source heating system comprises piping buried beneath the ground (horizontally or vertically) and a heat pump to extract the heat (the temperature of the ground remains at a constant 12°C throughout the year).

8.5.2 Design requirements

Environment: Vertical drilling is possible in areas that are free from obstructions. Where possible, borehole drilling on contaminated land should be avoided. A ground survey is required in order for the system to be correctly sized, as the rate of heat transfer will be dependent on soil properties. Laying the pipes horizontally in trenches is cheaper than boring vertical boreholes. However, a large area of open ground is required (there should be a minimum distance of 7m between boreholes).

Ground source cooling is the inverse of the ground source heating system and operates, in effect, like a large refrigerator. One system can be installed to operate as a heating and cooling system. Such a system can increase the Coefficient of Performance of the system, as during the cooling cycle, heat is put back into the ground to be extracted again later during the heating cycle.

Space: In case of a communal system, sufficient space for the pump and thermal store is required. In the case of an individual system, the heat pump would occupy a similar space as a standard gas boiler.
Horizontal pipes can be buried beneath paving and car parks but are generally not laid beneath buildings. However, vertical boreholes could be integrated under a new building (work done at the same time as the foundations).

Heating system: a ground source heating and cooling system operates more efficiently with a low grade heat distribution system, such as under floor heating.

The area required varies with the size of the development.

8.6 Combined cooling heat and power (CCHP)

8.6.1 Product information

CHP is a tried and tested technology and is particularly suitable for large developments with a heat network. A CHP system simultaneously generates heat and electricity. The heat that is produced during electricity generation is recovered, resulting is less energy wastage. It can then be used for space and water heating. Although CHP is not a renewable energy, it is a very efficient technology, reducing carbon emissions related to a site's energy consumption. It can be used for cooling purposes with absorption chillers. The electricity can be exported to the National Grid or sold to residents through a private wire network.

Gas and diesel can be used to run a CHP system. Biomass CHP is available but requires particularly large developments in order to be feasible.

8.6.2 Design requirements

Environment: If fuelled by gas, a connection to gas mains is required.

Plant room: the development would require a plant room (or energy centre in case of a heat network) that is large enough to house a CHP unit and other auxiliary equipment, such as a thermal store and a gas boiler. The plant room construction should take into account noise levels from the CHP unit. The systems incorporate acoustic enclosures and exhaust silencers but manufacturer guidance should be sought for plant room design.

The distribution of electricity to residents would require the installation of a private wire network and individual meters (high capital investment).

The area required varies with the size of the development.

9 Analysis and setting of the CO_2 reduction standards

This section investigates the different combinations of energy efficiency measures and low and zero carbon technologies which are feasible for a given development group. Estimated costs and CO_2 savings are also provided based on systems sized to meet the targets defined in Section 6.3 of this report, i.e. for new build:

- Residential: A 44% reduction in the DER over the TER[28] and a 20% reduction in total CO_2 emissions through the installation of renewable energy technologies on site.
- Non-residential: a 20% reduction in CO_2 emissions through the installation of renewable energy technologies on site, where feasible depending on the development groups.
- Schools: a 40% reduction in CO_2 emissions through the installation of renewable energy technologies on site, where feasible.

The financial impact of achieving these targets is then analysed. For residential and office developments, this is assessed against the residual land value or sales value. For schools and retail developments, the impact is analysed in terms of the percentage increase in build cost.

Specific targets in terms of CO_2 reductions cannot be given for refurbishments. This is due to the complexity of establishing the baseline CO_2 emissions after a refurbishment has taken place, where the Building Regulations for existing dwellings specify different levels of energy efficiency depending on the nature of the refurbishment and the type of building.

The selection of low or zero carbon technologies is site-dependent and will in certain cases be restricted by planning and/or building constraints (e.g. roof areas, surrounding land areas, biomass fuel supply, etc).

9.1 Energy requirements for new dwellings

The energy requirements of a dwelling, as calculated using SAP[29] and the BRE calculator for cooking and appliances, are determined by the following items:

Item	Mainly dependent on
Space heating	• Surface of building elements exposed to the outdoor • U-values of these building elements • Boiler efficiency and controls • Air tightness & thermal bridging • Solar gains
Hot water	• Floor area • Boiler efficiency and controls • insulation of pipes/hot water cylinder

28 This corresponds to the minimum mandatory requirement for meeting the energy requirements of level 4 of the Code for Sustainable Homes

29 Standard Assessment Procedure: implements the National Calculation Model (NCM) that demonstrates compliance with Part L (conservation of fuel and energy) of the Building Regulations.

Item	Mainly dependent on
Lighting & other	• Number of light fittings. The DER calculation assumes a fixed ratio of 25% of dedicated energy saving bulbs even if more is feasible • Number of pumps and fans
Cooking & appliances	• Floor area • Represents a significant proportion of CO_2 emissions for new dwellings (40% to 50%). Not accounted for in the DER, but must be included in calculations determining the percentage of total CO_2 reduction from on-site renewables.

Table 4: Items determining energy requirements according to the SAP and BRE methodology

Hot water, lighting, cooking & appliances are all directly dependent on the net floor area, whereas the space heating requirements depend on the surface of exposed wall of the dwelling. This is why, for example, top end floor flats have a higher Target Emission Rate (TER)[30] than a mid-floor flat, or why small houses have a higher TER than flats.

9.2 Flats 2 – 10

9.2.1 Detailed options

For this dwelling type, four scenarios were studied to derive conclusions on the technical feasibility of energy efficiency measures and renewable energy installations. The following table presents the details of a typical flatted development used in the modelling exercise.

Element	Size	Comment
Net floor area	70 m^2	part of a 3 storey building, <11 units
Roof area available for PV	14 m^2	This represent the area of the pitched side of the roof that is closest to the south orientation, per dwelling
Build cost	£1,722/m^2	Taken from Chris Marsh's report; conservative figure as the BCIS[31] gives an average of £1,175/m2 for 3-5 storeys flatted development. Cyril Sweet's report[32] for the DCLG assumes a figure of £1,342/m2
Density per hectare	144 units 10,080 m^2/hect	Taken from Chris Marsh's report
Net/gross ratio	85%	Taken from Chris Marsh's report

Table 5: Assumptions for new built Flats 2-10

Two scenarios for energy efficiency are presented for a top end-terrace, and two for a mid-block flat of 70m^2 as described in Table 3. The main difference between the two scenarios is a lower air permeability requirement (6 or 4 instead of 3) and a that Mechanical Ventilation with Heat Recovery (MVHR) system was not specified.

30 The TER is a figure describing the maximum annual CO_2 emissions per m^2 of a 2006 Building Regulations compliant dwelling. If the actual Dwelling Emission Rate (DER) is lower than the TER, the dwelling is deemed to comply with Part L of the Building Regulations (conservation of fuel and energy).

31 The Royal Institution of Chartered Surveyors' (RICS) Building Cost Information Service. www.bcis.org.uk

32 Cost Analysis of the Code for Sustainable Homes, Final Report, July 2008, Department for Communities and Local Government

Design values chosen for these two scenarios (EST 25% and 100%) are given in Table 6 below.

Item	U Value [W/m²K]	
	EST 25% backstop	EST 100% and zero carbon solution
Walls	0.25	0.15
Roof	0.13	0.13
Floor	0.2	0.15
Door	1.5 (glazed) / 1.0 (solid)	1.5 (glazed) / 1.0 (solid)
Windows	U_{window} = 1.8 W/m²K	U_{window} = 1.4 W/m²K
	Other parameters	
Boiler	86% efficient	91% efficiency
Thermal bridging	Accredited details	Accredited details
Air permeability	6	4

Table 6: Energy efficiency measures derived from EST publications CE291 & CE292

The yearly energy demand and CO_2 emissions was calculated for each of the four scenarios. Table 7 shows clearly that the space heating demand will change significantly depending on different levels of energy efficiency and the dwelling scenario (top-end versus mid-block flat).

Dwellings	Space Heating [kWh]	Hot water [kWh]	Lighting [kWh]	Cooking & appliances [kWh]	Other [kWh]	Gas [kWh]	Electricity [kWh]	CO_2 total [kg]
Top floor Flat (25%)	3,050	3,029	392	2,479	175	6,080	3,046	2,465
Top floor Flat (100%)	2,280	2,863	392	2,479	175	5,143	3,046	2,283
Mid floor flat (25%)	1,786	3,029	396	2,479	175	4,816	3,049	2,221
Mid floor flat (100%)	1,303	2,863	396	2,479	175	4,166	3,049	2,095

Table 7: Breakdown of annual energy requirements of new build flats

Table 8 details the percentage reduction in DER over TER, which varies from approximately 5% to 20% depending on the proportion of exposed dwelling wall and the level of insulation used.

Dwellings	TER [kg CO_2/m^2]	DER [kg CO_2/m^2]	DER / TER reduction	HLP[33] [W/(m²K)]
Top floor Flat (25%)	23.76	21.95	7.6%	1.31
Top floor Flat (100%)	23.76	19.27	18.9%	1.15
Mid floor flat (25%)	19.15	18.17	5.1%	0.95
Mid floor flat (100%)	19.15	16.32	14.8%	0.84

Table 8: DER/TER achieved in new flats with different levels of energy efficiency

[33] Heat Loss Parameter

Energy efficiency:

The costs of energy efficiency measures were taken from two Cyril Sweet reports[34,35], which analysed the cost impact of implementing different levels of the Code for Sustainable Homes. The increase in build cost (£2,500) used in this report represents the same percentage of build cost assumed in these two publications.

Scenario	Measure	Ene1 reduction	Costs
Cyrill Sweet 60m^2 flat	Improved controls, air tightness and insulation levels	18%	£1,648 - (2%)
Modelled flat 70m^2 (CEN)		15% - 20%	£2,500 - (2%)

Table 9: Energy efficiency costs

Centralised options:

Centralised biomass heating or efficient energy generation (CHP) is unlikely to be viable for this development group owing to the low energy demand, the heat profile, and the disproportionate share in the development's costs that a communal plant room would represent.

Ground source heat pumps (GSHP):

New build flats will require a 3.5kWh pump which will provide space and water heating. This size of pump will usually require one borehole, subject to the geological ground conditions.

The typical DER/TER reduction would be close to 50%, whereas the percentage reduction in overall CO_2 consumption (assuming gas as the other fuel source) would only slightly exceed 10%.

While a GSHP alone would meet the mandatory energy requirements of achieving level 4 of the Code for Sustainable Homes, achieving a 20% overall CO_2 reduction through the installation of renewable energy technologies on site would require the addition of solar technologies to increase the proportion from 10% to 20%. Table 10 provides details of the percentage CO_2 reductions that would result from the installation of GSHP and the associated costs.

Flat	Electricity used [kWh]	Gas saved [kWh]	Ene1 %	Renewable %	Cost [£]	Build cost increase
Top End Flat (25%)	1,809	6,080	49.2%	17%	7,592	5%
Top End Flat (100 %)	1,579	5,143	52.2%	15%	7,592	5%
Mid Flat (25%)	1,534	4,816	45.5%	13%	7,996	5%
Mid Flat (100%)	1,366	4,166	48.0%	11%	7,592	5%

Table 10: Ground Source Heat Pump for new flats

[34] Cost Analysis of the Code for Sustainable Homes, Final Report, July 2008, Department for Communities and Local Government

[35] A cost review of the Code for Sustainable Homes, February 2007, Housing Corporation and English Partnership

The percentage CO_2 reduction decreases when the energy efficiency of this development group is improved. This stems from the fact that less space heating is required while the hot water demand remains identical. Because the Coefficient of Performance (CoP) for hot water is smaller than for space heating, this decreases the CO_2 reduction figure.

Solar thermal:

It is assumed that this development group could accommodate an area of between 2.5m^2 to 4.3m^2 of collectors.

In an ideal configuration (with a south facing roof, of 30 degree pitch and un-shaded), and depending on the level of energy efficiency, the DER/TER reduction will be between 25%-35%. The reduction of overall CO_2 emissions will slightly exceed 10%.

It will therefore be possible to achieve the mandatory Ene1 level of Code Level 3 with a solar thermal installation. However, to achieve a 20% reduction of total CO_2 emissions through the installation of renewable energy technologies on site, the solar thermal installation should be supplemented either with additional PV panels or a GSHP. Table 11 below indicates CO_2 savings and costs associated with solar thermal technology.

Dwelling	System	Energy displaced [kWh/yr]	CO_2 savings [kgCO_2/yr]	Ene1 %	Renew. %	Cost [£]	Build cost increase
Top End Flat (25%)	2 No. Collectors (4.3 m^2)	1,389	269	24%	11%	4,553	3%
Top End Flat (100 %)	2 No. Collectors (4.3 m^2)	1,389	269	35%	12%	4,553	3%
Mid Flat (25%)	2 No. Collectors (4.3 m^2)	1,389	269	25%	12%	4,553	3%
Mid Flat (100%)	2 No. Collectors (4.3 m^2)	1,389	269	35%	13%	4,553	3%

Table 11: Solar thermal for new flats

Solar photovoltaic:

The development modelled for this group is assumed to comprise up to 14m^2 of roof area if dormer windows and chimneys were installed on the roof pitch oriented as far south as possible. Where dormer windows and other features are present on this side of the roof, most appropriate to be used for solar technologies, the available surface area will be less.

A flat roof configuration is often less favourable in terms of panel density, where panels must be installed on A-frames inclined at 15 to 30 degrees, and sufficiently spaced to avoid mutual shading.

Table 12 below shows that the more energy efficient the building is, the fewer panels are required to comply with the mandatory Ene1 target. Installing between 1.1 kWp and 1.5 kWp for each flat will enable both the mandatory energy requirements for level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER) and the 20% reduction in total CO_2 emissions promoted by the London plan (policy 4A.7) to be achieved.

Unit	System	Capacity [kWp]	Energy generated [kWh/yr]	CO_2 savings [$kgCO_2$/yr]	Ene1 %	Renew. %	Cost [£]	Build cost increase
Top End Flat (25%)	7 No panels (9 m^2)	1.47	1174	667	48%	27%	9,114	6%
Top End Flat (100 %)	5 No panels (6.4 m^2)	1.05	838	476	48%	21%	6,510	5%
Mid Flat (25%)	6 No panels (7.7 m^2)	1.26	1006	571	48%	26%	7,812	6%
Mid Flat (100%)	5 No panels (6.4 m^2)	1.05	838	476	50%	23%	6,510	5%

Table 12: Photovoltaic panels for new flats

In cases where the roof is not orientated south, and it is not possible to achieve a pitch of 30° for the panels, the required area panels is likely increased by up to 20% to deliver the same CO_2 savings.

9.2.2 Summary of options

Table 12 below presents a summary of the different options feasible for this development group to achieve the defined targets for CO_2 reductions. The percentages given below assume that the 100% EST backstop values for energy efficiency are used.

Unit	Description	Ene1 %	Renew. %	Individual cost per measure (% build cost)
Baseline	70m^2 flat in apartment block with 85% Net / gross ratio	-	-	£141,810 (70m^2 x £1722m^2 / 0.85)
Energy efficiency	See Table 6	15%-20%	N.A	£2,500 (2%)
PV	5 to 7 No 210W panels (6.4 to 9 m^2 – 1.1 to 1.5 kWp)	48-50%	21% - 27%	£6.5k – £9.1k (5% to 6%)
ST + PV	2 No Collector – 4.3m^2 absorber area + 2 to 4 No 210W panels (2.6 to 5.1 m2 – 0.42 to 0.84 kWp)	47%-49%	20- 26%	£4.5k + £2.6k – £5.2k = £7.1k – £9.7k (5% to 6%)
GSHP + PV	3.5 kW GSHP with underfloor heating + 1 to 2 No 210 W panels (0.21 m2 - 0.42 kWp)	53% - 60%	20%- 23%	£7.6k + £1.3k – £2.6k = £8.9k – £10.2k (6% to 7%)
GSHP + ST	3.5 kW GSHP with underfloor heating + 2 No Collector – 4.3m^2 absorber area	55% - 60%	24% - 28%	£7.6k + £4.5k = 12.1k (9%)

Table 13: Summary of CO_2 reduction options for new flats

9.2.3 Financial analysis

The baseline residential land value, resulting from SPG obligations and a 50% affordable housing requirement, was taken from the 03/2007 financial viability report produced by Chris Marsh for the London Borough of Richmond upon Thames.

The cost of the most expensive option for energy efficiency and renewable energy measures (GSHP + solar thermal @ £14,600 per dwelling) was then subtracted from this baseline figure to produce the graph below. At the other end of the cost spectrum, the energy efficiency and renewable energy measures sufficient to meet the CO_2 reduction and renewable energy target can be achieved at a cost of £9,000 per dwelling where a well suited roof is provided for photovoltaic panels.

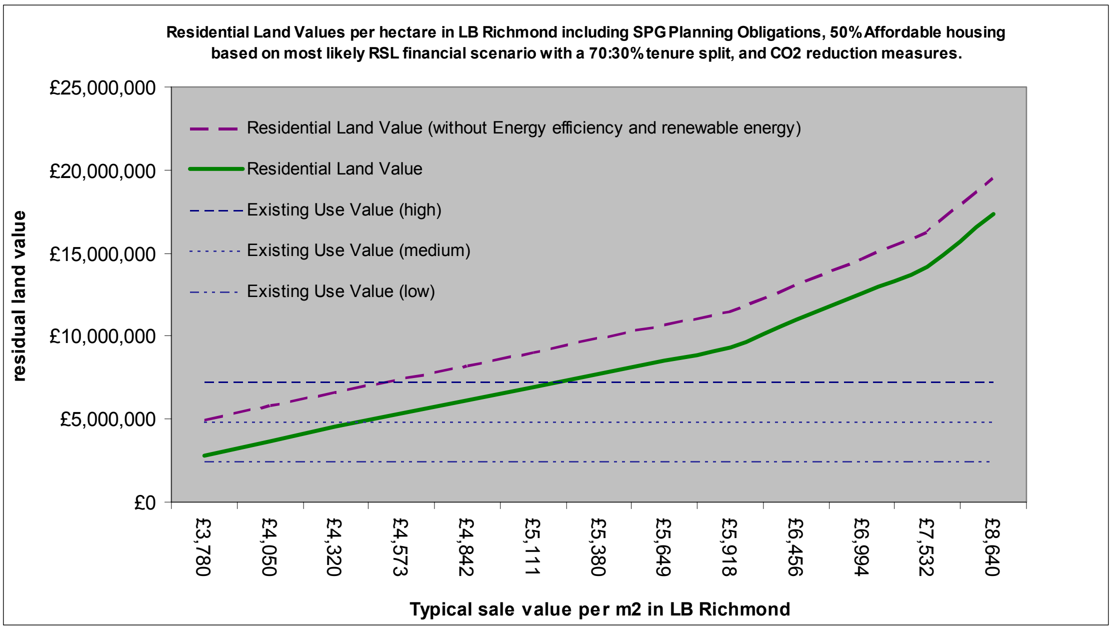

Figure 9.1: Residential land value for 2-10 Flats

The baseline residential land value (excluding energy efficiency and renewable energy measures) exceeded the highest EUV when sales values were above £4,400 per m^2. This pertained to the "rule of thumb[36]" which provides that SPG and affordable housing obligations are increasingly deliverable when the sale value is higher than £4,300 per m^2.

With energy efficiency and renewable energy measures included, the figure increases to £5,200 per m^2.

It should be noted that conservative construction and CO_2 reduction costs were assumed, as described above. This ensures that, in the vast majority of cases, the actual residential land value will be higher than the one displayed on the graph. Anecdotal evidence also suggests that developers may be able to achieve a premium for the developments with high levels of sustainable energy performance, as customers are becoming increasingly aware of environmental issues and concerned about rising fuel costs.

The methodology adopted is considered to be even more conservative through the assumption of a constant and high EUV, irrespective of sales value. In reality it is

[36] Chris Marsh's report

likely that the EUV would decrease as sales value decreases, for example, due to the development occurring in a less prime location.

Finally, the data used includes the costs related to the integration of 50% affordable housing despite the application of this requirement to threshold of 10 or more units. Below 10 units, the requirement will be defined on a case by case basis by the planning officer. This means that, should this planning obligation not be required for this development group, the associated budget could be used to integrate more CO_2 reduction measures. Higher targets than Code 4 and 20% renewable energy could therefore be viably achieved and required by the planning authority.
The dotted line in Figure 9.2 illustrates the residential land value without the 50% affordable housing obligation (but including other SPG obligations), while the solid line represents the residential land value when SPG, energy efficiency and renewable energy costs are accounted for.

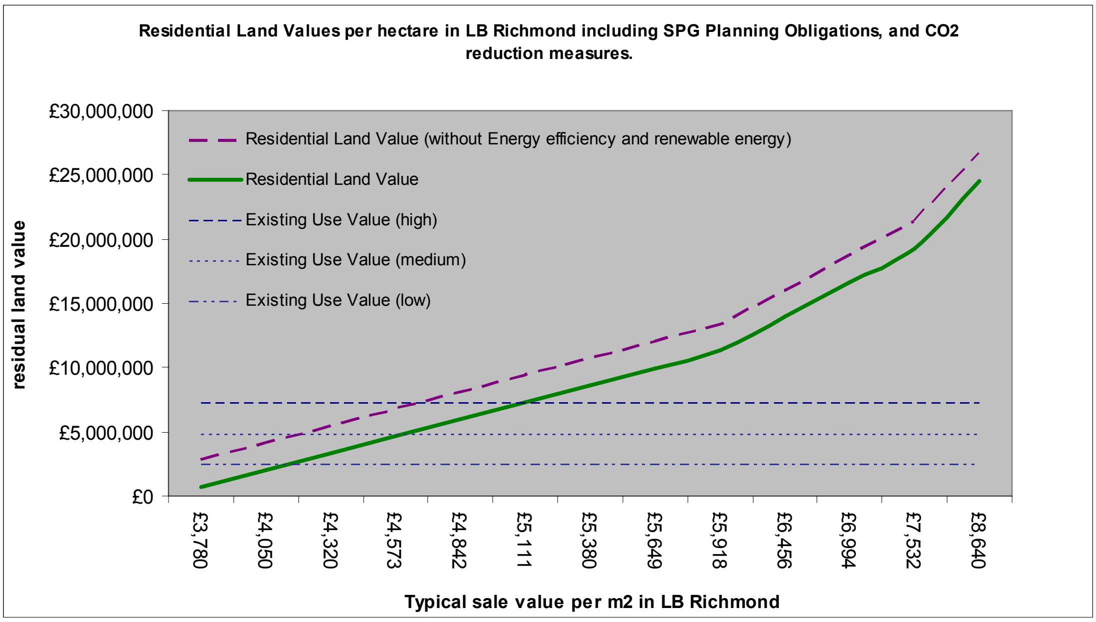

Figure 9.2: Residential land value for 2-10 Flats without affordable housing obligations

9.3 Flats 11+

9.3.1 Detailed options

This higher-density development group is generally characterised by a greater number of storeys. The consequence is a reduction in the area of available roof space per dwelling for the installation of solar technologies, which are the most cost-effective way to meet CO_2 reduction targets (as seen with the previous development type). These buildings are often designed with a flat roof thus implying that the possible number of solar panels is reduced further where they have to be installed in banks that need sufficient separation space to avoid mutual shadowing.

As a result, achieving a 20% reduction in total CO_2 emissions as required by policy 4A.7 of the London Plan may be more challenging, or unfeasible, through the installation of solar technologies alone for a development with more than 20 residential units.

Meeting a 20% reduction in total CO_2 emissions will require either a communal biomass space and water heating system, or a communal ground source heat pump to meet the space heating needs. Both options involve a spatial requirement for a plant room. This is generally not favoured by developers as it reduces the development's market value and introduces management constraints.

Therefore, the scenarios presented here assume a 5 storey, 25-unit apartment block. The energy efficiency of the apartments is the same as described in the 2-10 flat scenarios.

Element	Size	Comment
Net floor area	70 m^2	5 storeys, 25 units
Roof area available for PV	320 m^2	Allowing for (2m) clear spaces on each edge of the flat roof
Build cost	£1829/m^2	Taken from Chris Marsh's report, Conservative figure as the BCIS gives an average of £1553/m^2 for 6+ storeys flatted development. Cyril Sweet's reports for the DCLG assumes a figure of £1342/m^2
Density per hectare	168 units 11,760 m^2/hect	Chris Marsh
Net/gross ratio	82.5%	Chris Marsh

Table 14: Assumptions for new built Flats 11+

The estimated annual energy consumption of this 25 unit residential block is given in Table 15.

Dwellings	Space Heating [kWh]	Hot water [kWh]	Lighting [kWh]	Cooking & appliances [kWh]	Other [kWh]	Gas [kWh]	Electricity [kWh]	CO_2total [kgCO_2]
New build 25 x 70m^2	42,500	71,575	9,800	61,975	4,375	114,075	76,150	54,266

Table 15: Breakdown of annual energy requirements of a block of 25 new build flats

Biomass:

Table 16 below demonstrates that a 50kW biomass boiler could meet at least 70% of the annual space and water heating demand for this development group. This leads to an average reduction of the DER over the TER of 50%, which would exceed the minimum mandatory energy requirements for attaining level 4 of the Code for Sustainable Homes. The overall CO_2 reduction would exceed the 20% required by policy 4A.7 of the London Plan with the potential to achieve some 24.5%.

System	Energy generated	CO_2 savings [kgCO_2]	Average Ene1 percentage	CO_2 reduction from renewable	Extra Cost [£]	Build cost increase
Biomass heating 50 kW	70% of heat demand	13,304	50%	24.5%	£20,000	0.75%

Table 16: Biomass for new flats 11+

The cost presented comprises the biomass boiler and the plant room installation, including the wood fuel storage and transfer system. It does not, however, account for the economic impact of lost space and the cost of pipes linking the plant room and each of the residential units.

Using pellets as a fuel source, which is the wood fuel type with the highest energy density, would require only two deliveries annually to supply the 27 m^3 necessary to fuel the boiler. Wood chip is not recommended for this option as the delivery method requires space that is not generally available in Richmond.

Ground Source Heat pumps:

A 40 kW ground source heat pump could be used to provide space heating for a block within this development group. Hot water should be supplied by a regular gas-fired boiler, where this would require a lower pump efficiency to heat water to 60 deg as opposed to 30 - 45°C for the low grade space heating system (underfloor heating) usually specified with such systems.

Electricty used [kWh]	Gas saved [kWh]	CO_2 savings [$kgCO_2$]	Average Ene1 percentage	CO_2 reduction from renewable	Cost	Build cost increase
10,625	42,500	3,760	26%	7%	£60k - £72k	1.5% - 1.9%

Table 17: GSHP for flats 11+

A communal ground source heat pump will achieve only a 7% reduction in total CO_2 emissions. The average reduction of the DER over the TER is 26%, which slightly exceeds the minimum requirement under Ene1 credit to achieve level 3 of the Code for Sustainable Homes.

If a 20% reduction in total CO_2 is to be achieved, or the minimum energy requirement for meeting level 4 of the Code for Sustainable Homes (a 44% DER/TER reduction), additional renewable energy technologies would be required to be installed.

Solar photovoltaic:

The block modelled for this development group could accommodate solar panels on a 320 m^2 surface. A flat roof was assumed, so the panels would need to be arranged in banks separated by sufficient gaps to avoid mutual shadowing. As a result only 122 m^2 of solar panels could be installed. This corresponds to 20 kWp or 0.8 kWp per flat.

System	Capacity [kWp]	Energy generated [kWh]	CO_2 savings [kg]	Average Ene1 percentage	Renewable %	Cost	Build cost increase
85No. panels (122 m^2)	20.0	15,930	9,048	40%	17%	£101,745	2.6%

Table 18: Photovoltaic panels for new flats 11+

In cases where the roof is not orientated south, and the pitch of the panel not 30°, the surface of the panels would need to be increased by up to 20% to deliver the same CO_2 savings.

If a 20% reduction in total CO_2 reduction is to be achieved, or level 4 of the Code for Sustainable Homes, additional renewable energy technologies must be installed.

Solar thermal:

A communal system sized to meet 55% of the site’s hot water requirement would deliver the savings shown in Table 19 below.

System	Roof area required	CO_2 savings [kg/year]	Average Ene1 percentage	Renewable %	Cost	Build cost increase
34 No collectors ($86\ m^2$)	210 m2	7,640	36%	14%	£57,000	1.5%

Table 19: Solar thermal for new flat 11+

In cases where the roof is not orientated south, and the pitch of the panel not 30°, the surface of the panels would need to be increased by up to 20% to deliver the same CO_2 savings.

This system can be combined with a ground source heat pump to deliver both a DER reduction over the TER which is equal to or exceeds that required to achieve the minimum energy requirement for Level 4 of the Code for Sustainable Homes, and in excess of 20% of overall CO_2 reductions.

9.3.2 Summary of options

Table 20 below presents a summary of the different options feasible for this development group to achieve the CO_2 reduction targets defined previously. The percentages given below assume that the 100% EST backstop values for energy efficiency are used.

unit	Description	Ene1 %	Renew. %	Cost (% build cost)
Baseline	25 x $70m^2$ flat in apartment block with 82.5% Net / gross ratio	-	-	£3,880,700 (25 x $70m^2$ x £$1829m^2$ / 0.825)
Energy efficiency	See Table 6	Av. 16%	N.A	£62,500 (1.6%)
Biomass	50 KW space and water heating boiler Meet 70% of the energy demand 27 m^3 of pellets/year, 2 annual delivery	50%	24%	£20,000 (0.75%)
ST + GSHP	40 kW communal GSHP space heating + 34 No Collector – 86 m^2 absorber area	46%	21%	£57k + £60k – 72k = £117k – £129k (3% to 3.3%)
PV + GSHP	40 kW communal GSHP space heating + 80 No 210W panels (102 m^2 – 17 kWp)	45%	21%	£86k + £60k – 72k = £146k – £158k (3.8% to 4.1%)

Table 20: Summary of options for flat 11+

9.3.3 Financial analysis

By including the most expensive renewable energy scenario (PV + GSHP @ £6,320 per unit) and energy efficiency measures (£2,500 per unit), the total cost would equate to £8,820 per unit.

Figure 9.3 below plots the baseline residential land value resulting from SPG obligations and a 50% affordable housing requirement (taken from the 03/2007 financial viability report produced by Chris Marsh for the LB of Richmond). When the costs of energy efficiency and renewable energy are added, the decrease in residential land value is depicted with the thick solid green line. From this graph, it is evident that the sales value required to generate a residential value in excess of £7.2 Million equates to approximately £4,400 per m^2, increasing to £4,900 per m^2 when energy efficiency and renewable energy are added.

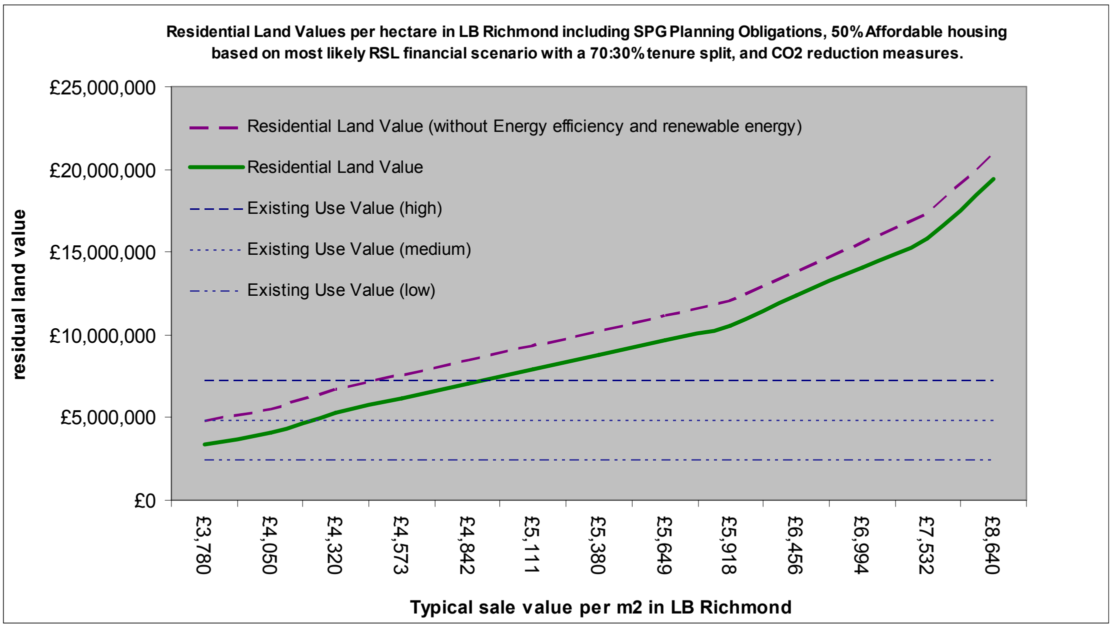

Figure 9.3: Residential Land Value for new Flats 11+

It should be noted that conservative construction and CO_2 reduction costs were assumed, as described above. This ensures that, in the vast majority of cases, the actual residential land value will be higher than the one displayed on the graph. Anecdotal evidence also suggests that developers may be able to achieve a premium for the developments with high levels of sustainable energy performance, as customers become increasingly aware of environmental issues and concerned about rising fuel costs.

The methodology adopted is considered to be even more conservative through the assumption of a constant and high EUV, irrespective of sales value. In reality it is likely that the EUV would decrease as sales value decreases, for example, due to the development occurring in a less prime location.

9.4 Houses

9.4.1 Detailed options

For this development group, a typical 90 m^2 semi-detached 3 bedroom house was modelled in SAP. This was then assessed for two different levels of energy efficiency.

Element	Size	Comment
Net floor area	90 m^2	2 storeys, semi-detached
Roof area available for PV	24 m^2	This represent the area of the pitched side of the roof that is closest to the south orientation
Build cost	£1,614/ m^2	Taken from Chris Marsh's report, Conservative figure as the BCIS gives an average of £1113/ m^2 for "one-off" housing semi-detached. Cyril Sweet's reports for the DCLG assumes a figure of £745/ m^2

Element	Size	Comment
Density per hectare	95 units 8,400 m^2/hect	The cost of CO_2 reduction measures was applied on 95 units per hectare instead of 120, as the modelled semi-detached house has 90 m^2 instead of 70 m^2
Net/gross ratio	87.5%	Chris Marsh's

Table 21: Assumptions for new built Houses

The first level adopts "backstop values" for achieving Code Level 3 Ene1 requirements; whereas the second adopts the limiting values for achieving Ene1 requirements for Code levels 5 & 6, as described in the EST publications CE291 & CE292. The main difference is that the air permeability requirements chosen are less stringent (6 or 4 instead of 3), and a MVHR system was not specified. Design values chosen for the two scenarios (EST 25% and 100%) are given in Table 22 below.

Item	U Value [W/m^{2}K]	
	EST 25% backstop	EST 100% and zero carbon solution
Walls	0.25	0.15
Roof	0.13	0.13
Floor	0.2	0.15
Door	1.5 (glazed) / 1.0 (solid)	1.5 (glazed) / 1.0 (solid)
Windows	U_{window} = 1.8 W/m^{2}K	U_{window} = 1.4 W/m^{2}K
	Other parameters	
Boiler	86% efficient	91% efficiency
Thermal bridging	Accredited details	Accredited details
Air permeability	6	4

Table 22: Energy efficiency measures derived from EST publications CE291 & CE292

The following annual energy demand and CO_2 emissions for the two scenarios as calculated by SAP. Table 23 demonstrates that the space heating demand will change, but that the hot water, lighting and appliances consumption remain almost identical.

Dwellings	Space Heating [kWh]	Hot water [kWh]	Lighting [kWh]	Cooking & appliances [kWh]	Other [kWh]	Gas [kWh]	Electricity [kWh]	CO_2 total [kgCO_2]
semi 90m^2 (25%)	4,154	3,520	544	2,850	175	7,673	3,569	2,995
semi 90m^2 (100%)	3,059	3,326	694	2,850	175	6,385	3,719	2,808

Table 23: Breakdown of annual energy requirements of new houses

Table 24 details the percentage reduction in DER over TER, which vary from 3% to 16% depending on the level of insulation used.

Dwellings	TER [kg CO_2/m^2]	DER [kg CO_2/m^2]	DER / TER reduction	HLP [W/(m^{2}K)]
semi 90m^2 (25%)	22.52	21.83	3.1%	1.39
semi 90m^2 (100%)	22.52	18.83	16.4%	1.20

Table 24: DER/TER achieved in new houses with different levels of energy efficiency

Small-scale flat developments are generally characterised by lower regulated CO_2 emissions per square meter when compared with houses where the exposed surface of wall is smaller in proportion to their volume. This means that the size of a renewable energy installation required to achieve a given target in the case of flats will be smaller. On the other hand, introducing the same level of energy efficiency as in a house will lead to a lower relative reduction in CO_2 emissions.

Energy efficiency:

The costs of energy efficiency measures were taken from two Cyril Sweet reports[37,38], which analysed the cost impact of implementing different levels of the Code for Sustainable Homes. The increase in build cost (£2,500) that will be used in this report represents the same percentage of build cost as in these two publications.

Scenario	Measure	Ene1 reduction	Costs
Cyrill Sweet 76m^2 detached house	Improved controls, air tightness and insulation levels	18%	£1,648 - (2%)
Semi-detached house (90m^2) – 100% EST		16.4%	£3,000 - (2%)

Table 25: Energy efficiency costs

Ground source heat pumps:

The heat loss parameter indicates that a 3.5kWh pump would be suitable, providing both space and water heating. This size of pump will usually require one borehole, subject to the geological ground conditions.

A typical Ene1 DER/TER reduction would be between 45% - 50%, whereas the percentage reduction in overall CO_2 emissions would be some 15% - 20%. This CO_2 reduction would meet the minimum energy requirements for level 4 of the Code for Sustainable Homes (44% reduction of DER over TER), but may fall short of the 20% reduction in total CO_2 emissions through the installation of renewable energy technologies on site required under the London Plan.

Dwellings	Electricty used [kWh]	Gas saved [kWh]	CO_2 savings [kgCO_2]	Ene1 percentage	Renewable %	Cost [£]	Build cost increase
semi 90m^2 (25%)	2,209	7,673	556	46%	19%	7,592	5%
semi 90m^2 (100%)	1,901	6,385	436	51%	16%	7,592	5%

Table 26: GSHP for new houses

Achieving a 20% CO_2 reduction of the total emissions through the use of renewable energy technologies on site would therefore require the addition of either a solar thermal system or of PV panels.

It should be noted that the Ene1 percentage is “artificially” high as the SAP software that must be used assumes that the dwelling would normally be heated with electricity instead of gas. This is an inaccurate representation of reality, but it is the

[37] Cost Analysis of the Code for Sustainable Homes, Final Report, July 2008, Department for Communities and Local Government

[38] A cost review of the Code for Sustainable Homes, February 2007, Housing Corporation and English Partnership

official way of calculating this figure. The percentage of reduction of total CO_2 emissions on the other hand assumes a gas baseline scenario.

Solar thermal:

A 90m^2 house can reasonably accommodate up to 5.0m^2 of collectors. Over-sizing the system by adding more collectors will result in the system overheating in summer and must be avoided.

An ideal configuration (south facing roof, 30° pitch and un-shaded), depending on the level of energy efficiency, will lead to an Ene 1 DER/TER reduction of 15% - 30%. The reduction of overall CO_2 emissions will be close to 10%. For less optimal orientations and tilt angles (which can reduce output by up to 20%) and over shadowing, the surface area of the collector would need to increase accordingly while addressing any risk of overheating.

In most cases, it will therefore be possible to achieve the mandatory Ene1 level of Code Level 3 (25% reduction of DER over TER) with a solar thermal installation, and a 10% reduction in overall CO_2 reduction.

Dwelling	System	Energy displaced [kWh/yr]	CO_2 savings [kg/year]	Ene1 %	Renew. %	Cost	Build cost increase
semi 90m^2 (25%)	2No. Collectors (5.02m^2)	1,465	284	17%	9%	£4,553	3%
semi 90m^2 (100%)	2No. Collectors (5.02m^2)	1,465	284	30%	10%	£4,553	3%

Table 27: Solar thermal for new houses

Achieving higher levels of CO_2 reductions to meet, for example, mandatory energy requirements of Level 4 (44% of DER over TER) of the Code for Sustainable Homes, or a 20% reduction in total CO_2 emissions from the development, would require additional renewable energy technologies to be installed. For houses, a ground source heat pump or photovoltaic panels could be installed to bridge this gap.

Solar photovoltaic:

It is assumed that the dwelling modelled could have up to 24m^2 of roof space if dormer windows and chimneys are installed on the roof pitch towards the north orientation. In the case where dormer windows and other features are present on the side of the roof most appropriate for solar technologies, the available surface area will be reduced.

A flat roof configuration is also often less favourable as the panels have to be installed on A-frames inclined at 15 to 30 degrees, and must be sufficiently spaced to avoid mutual shading.

Table 28 demonstrates that the more energy efficient the building is, the fewer panels are required to comply with the mandatory Ene1 target. Installing between 1.3 kWp and 1.9 kWp on a semi-detached house will meet the mandatory energy requirements for Level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER) and the 20% reduction in total CO_2 emissions required under the London Plan.

unit	System	Capacity [kWp]	Energy generated [kWh]	CO_2 savings [kgCO_2]	Ene1 %	Renewable %	Cost [£]	Build cost increase
semi 90m^2 25% EST	9 No panels (11.5 m^2)	1.89	1,509	857	45%	29%	11,718	7%
semi 90m^2 100% EST	6 No panels (8 m^2)	1.26	1,006	571	45%	20%	7,812	5%

Table 28: Photovoltaic panels for new houses

In cases where the roof is not orientated south, and the pitch of the panel is not 30°, the surface area of panels is likely to need to be increased by up to 20% to deliver the same CO_2 savings.

<u>Centralised options:</u>

For typical developments in Richmond including only houses, a centralised biomass heating or efficient energy generation system (e.g. through CHP) is not considered viable owing to the low demand, heat profile, and the disproportionate share of development costs that such a system would assume.

9.4.2 Summary of options

Table 29 below presents a summary of the different options feasible for a house to achieve the targets defined previously. The percentages given assume that the development implements the 100% EST backstop values for energy efficiency.

unit	System	Ene1 percentage	Renewable %	Cost (% build cost)
Baseline	90m^2 semi detached house with 87.5% Net / gross ratio	-	-	£166,000 (90m^2 x £1614 per m^2 / 0.875)
Energy efficiency	See Table 22	16.4%	N.A	£3,000 (2%)
PV	6 to 9 No 210W panels (8 to 11.5 m^2 – 1.3 to 1.9 kWp)	45%	20% - 29%	£7,8k – £11,7k (5% to 7%)
ST + PV	2 No Collector – 5.02m^2 absorber area + 3 to 6 No 210W panels (4 to 8 m^2 – 0.6 to 1.3 kWp)	45%	20- 29%	£4.5k + £3.9k – £7,8k = £8.4k – £12.3k (5% to 7%)
GSHP + PV	3.5 kW GSHP with underfloor heating + 2 No 210 W panels (2.6 m^2 - 0.42 kWp)	53% - 58%	22%-25%	£7.6k + £2.6k = £10.2k (6%)
GSHP + ST	3.5 kW GSHP with underfloor heating + 2 No Collector – 5.02m^2 absorber area	54% - 59%	26% - 28%	£7.6k + £4.5k = 12.1k (7%)

Table 29: Summary of options for houses

9.4.3 Financial analysis

The baseline residential land value resulting from SPG obligations and a 50% affordable housing requirement was taken from the 03/2007 financial viability report produced by Chris Marsh for the LB of Richmond.

The most expensive option for energy efficiency and renewable energy measures (GSHP + solar thermal @ £15,100 per dwelling) was then subtracted from this baseline figure to produce the graph below. At the other end of the cost spectrum, energy efficiency and renewable energy measure could cost £10,800 per dwelling for a dwelling with a well suited roof for solar technologies.

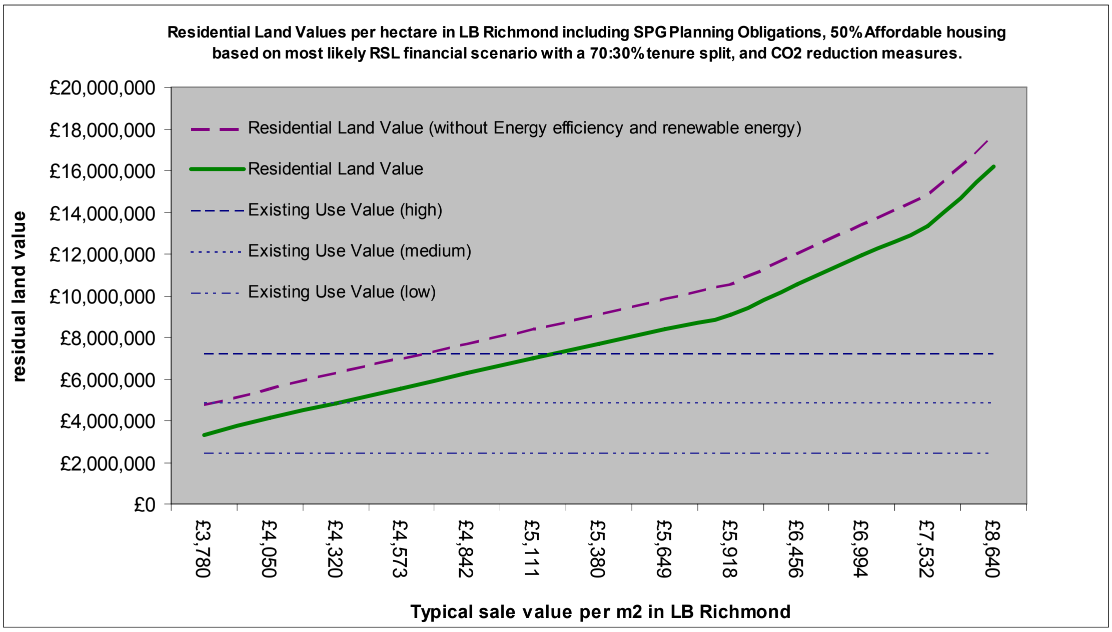

Figure 9.4: Residential value in LB Richmond for houses

The baseline residential land value was above the highest EUV when sale values were above £4,600 per m^2. Including energy efficiency and renewable energy measures would take this figure to £5,200 per m^2.

It should be noted that conservative construction and CO_2 reduction costs were assumed, as described above. This ensures that, in the vast majority of cases, the actual residential land value will be higher than the one displayed on the graph. Anecdotal evidence also suggests that developers may be able to achieve a premium for the developments with high levels of sustainable energy performance, as customers become increasingly aware of environmental issues and concerned about rising fuel costs. Finally with decreasing sale value, which in part indicates a less prime location, the requirement for the residential land value be above the highest EUV may not apply.

9.5 Schools

School developments can range from extensive single-storey primary schools to 3 - 4 storey secondary schools. Based on CEN's experience with schools, and on the analysis of the planning application files made available by the London Borough of Richmond, a 6,000 m^2 3- storey school was used as an example.

Element	Size	Comment
Net floor area	6,000 m^2	3 storey building
Roof area available for PV	1,010 m^2	Pitched roof, 1m "dead zone" on edges
Build cost	£1,520/m^2	BCIS costs

Table 30: schools assumptions for modelling

The energy consumption and CO_2 emissions were taken from benchmark data generated by the BRE for new build schools as presented in Table 31 below.

Dwellings	Space Heating [kWh]	Hot water [kWh]	Lighting [kWh]	Other [kWh]	Gas [kWh]	Electricity [kWh]	CO_2 total [kg]
New build school 6,000m^2	456,194	272,414	72,780	121,320	728,608	194,100	223,350

Table 31: Breakdown of annual energy requirements of a 6000 m^2 school

Energy efficiency

The benchmark data for schools shown in Table 31 reveals that 40% of the CO_2 emissions are generated by space heating, as opposed to 20% - 30% in new dwellings. This means that a similar improvement in energy efficiency in schools as for dwellings will proportionally deliver higher CO_2 savings.

The energy efficiency modelling carried out for semi-detached houses showed that a 25% reduction in the space heating energy demand could be achieved relatively easily at the expense of a 2% increase in build costs. Assuming that the same levels of energy efficiency can be delivered in schools, i.e. a 25% reduction in space heating demand, the overall CO_2 emissions of a school building would be reduced by a further 10%.

For more details, please refer to the part dealing with energy efficiency for offices in Section 9.6.

Biomass:

In most cases, it will be possible to incorporate a large plant room and fuel storage space required for a biomass boiler into school developments. A school's space and water heating demand accounts for 64% of its CO_2 emissions. Therefore a biomass boiler generating 100% of the heat load would result in a 55% reduction in the total CO_2 emissions. The 9% difference is a accounts for the CO_2 emissions that result from the production and transport of biomass fuel.

System	Energy generated	CO_2 reduction from renewable	Extra Cost	Build cost increase
Biomass heating 320 kW	100% of demand	55%	£115,000	1.3%

Table 32: Biomass for schools

The costs are detailed in Table 32 above. The cost associated with a standard gas boiler being replaced by the biomass boiler has been taken into account, but represents only about 15% of the total cost given.

Using wood pellets, which is the wood fuel type with the highest energy density, a monthly delivery of 30m^3 would be required during the winter months. This frequency would drop in the summer months. Using wood chips, which have a lower energy density, a fortnightly delivery of 60m3 will be required in the winter months.

Ground Source Heat pumps:

A 320 kW ground source heat pump could be used to provide the school with space heating. Hot water should be supplied by a regular gas-fired boiler, as the heat pump has a much lower efficiency to heat water to 60 deg as opposed to 30 - 45°C for the low grade space heating system (underfloor heating) usually specified with such systems.

System	Electricity used [kWh]	Gas saved [kWh]	CO_2 savings [$kgCO_2$]	CO_2 reduction from renewable	Cost	Build cost increase
Ground source heat pump 320 kW	99,222	456,194	46,630	21%	£384k - £576k	4.2% - 6.3%

Table 33: GSHP for schools

Solar photovoltaics:

Sizing the installation to achieve a 20% reduction in CO_2 emissions through the installation of renewable energy technologies on site gives the results shown in Table 34 below. The installation will cover slightly more than 50% of the most favourably orientated half of the roof (assumed pitched, three storey building).

System	Capacity [kWp]	Energy generated [kWh]	CO_2 savings [$kgCO_2$]	Renewable %	Cost	Build cost increase
460 No panels (590 m^2)	97	77,130	43,800	20%	£415,380	4.6%

Table 34: Solar PV for schools

Solar thermal:

This technology is generally not recommended for schools unless they include a swimming pool. This is because the school will be closed during the summer months which usually provide the highest solar irradiation. As no hot water would be drawn from the system during this time, the system would overheat, leading to a risk of system damage and possible failure.

Wind turbine:

Wind turbines are not recommended in urban environment because of the adverse effect that surrounding buildings generally have on the wind flow. Furthermore, the turbine needs to be at least 15m from surrounding buildings to avoid issues of noise and flicker, which is rarely possible. Finally, the wind speeds in Richmond generally are not deemed to be sufficient to ensure an effective output is achieved.

In the case of a school with a large play ground, conditions could be such as that the installation of a wind turbine would be feasible and desirable for educational purpose. Table 35 below compares data provided by a manufacturer for his range of wind turbines with rural and suburban scenarios as modelled by SAP. The discrepancy in estimated outputs illustrates the optimistic generation data provided by manufacturers.

System	Diameter (m)	Hub height (m)	Energy generated Manufactured data Ideal site, 5m/s (kWh/year)	SAP estimation Rural Suburban (kWh/year)	Cost	CO_2 savings kg/year and % of total emissions
Proven 2.5 kW	3.5	6.5-11	2,500 – 5,000	2,800 – 900	£15,000 (0.2%)	1180 -380 (0.5% - 0.2%)
Proven 6 kW	5.5	9-15	6,000 – 12,000	7,300 – 2,200	£28,000 (0.3%)	3080 – 930 (1.4% - 0.4%)
Proven 15 kW	9	15	15,000 – 30,000	19,500 – 5,900	£48,000 (0.5%)	8230 – 2490 (3.7% - 1.1%)

Table 35: Wind turbine CO_2 reduction potential for schools

It may be desirable to install one wind turbine near a school for educational reasons, but the installation of more than one turbine may not be suitable. If the intermediate model is selected, which is generally the case for schools; it is likely to reduce the CO_2 reduction by about 1%. This is negligible in comparison of the 20% reduction in CO_2 reduction that needs to be achieved to accord with London plan policy 4A.7.

Other renewable energy sources like PV, Biomass or GSHP are therefore needed to achieve high CO_2 reductions.

9.5.1 Summary of options

Table 36 below presents a summary of the different options feasible for a school to achieve high levels of CO_2 reduction.

Item	System	CO_2 reduction	Cost (% build cost)	comment
Baseline	6,000 m^2 3 storey school	-	£9,120k (6,000m^2 x £1,520)	-
Energy efficiency	See Table 22	10% (from baseline)	£182k (2%)	Assumption. 10% CO_2 reduction NOT to be cumulated with reduction form renewable energy technologies below.
PV	460 No 210W panels (590 m^2 – 97 kWp)	20%	£415k (4.6%)	For a 6,000 m^2 school with pitched roof. Will take about 60% of the most favourably orientated roof space.
GSHP	320 kW GSHP with underfloor heating	21%	£384k - £576k (4.2% to 6.3%)	Will provide only space heating to limit size of the pump and depth of borehole.
Biomass	320 KW biomass boiler	55%	£115k (1.3%)	100% of space and water heating demand.
Wind	Proven 6 kW	1.1 – 3.7%	£48k (0.5%)	High value for education purpose More than one turbine probably not desirable CO_2 reduction range given by a SAP calculation for rural and suburban environment

Table 36: Summary of options for schools

The cost of the renewable energy technologies described here are given both in absolute terms and as a percentage of the built cost of a 6,000 m^2 school development.

Table 36 shows that a CO_2 reduction of 10% compared to Building Regulations can be achieved through energy efficiency measures with an estimated 2% increase in build costs. Even though only one renewable energy solution (wood-fuel heating) achieves higher CO_2 savings than 40%, it is required that this standard (40% reduction of total CO_2 emissions) is achieved where feasible. It is indeed very likely that biomass is feasible in most new build schools.

9.6 Offices

The energy and associated CO_2 emissions of commercial buildings can vary considerably, as described in a 12/2007 report of the UK Green Building Council for the Department of Communities and Local Government[39].

Four different baseline energy emissions are presented in this report to apply to four scenarios provided by the council. These scenarios describe shallow plan side lit buildings, which are believed to be the most representative for offices in the London Borough of Richmond. The modelled buildings are described as "Various fabrics and glazing, rarely full curtain wall glazing. Commonly low-rise 3-6 floors, but can be high rise – used as offices, hospitals, education and numerous uses".

Annual energy and CO_2 emissions for these four examples are given in Table 37 for comparison against CEN's proposed benchmark data for higher quality offices built to 2006 Building Regulations (taken from BRE).

No.	Data	Gas [kWh / m^2]	Non cooling Electrical Energy [kWh / m^2]	Cooling Energy [kWh / m^2]	Total CO_2 emissions [kg / m^2]
0	Higher quality office building	102.4	50.1	10.7	46.0
1	Model 1	16.1	92.2	8.5	45.6
2	Model 2	20.2	53.7	7.9	29.7
3	Model 3	69.5	46.4	0.3	33.1
4	Model 4	43.9	31.6	0	21.8

Table 37: Energy consumption of different office types

This comparison indicates that the proposed benchmark data is at the higher end of this data set, while being consistent with it for the electrical loads and the resulting CO_2 emissions.

Type	Space Heating [kWh/ m^2]	Hot water [kWh/ m^2]	Cooling [kWh/ m^2]	Lighting & Appliances [kWh/ m^2]	Other [kWh/ m^2]	Gas [kWh/m^2]	Electricity [kWh/ m^2]	CO_2 total [kg/ m^2]
Higher quality office building (2006)	94.4	8	10.7	17.1	33.1	102.4	60.8	45.5

Table 38: Benchmark energy data used for offices

Office developments at the threshold between "small" (i.e <1,000m2) and "major" (i.e > 1,000m2) were chosen for the modelling exercise.

[39] Report on carbon reductions in new non-domestic buildings, December 2007, UK Green Building Council, Department for Communities and Local Governments

Element	Size	Comment
Net floor area	1,090m^2	5 storey building (16m x 16m)
Roof area available for PV	200m^2	Flat roof (14m x 14m)
Build cost	£1,678/m^2	BCIS mean for 3-5 storey offices
Density per hectare	12,000m^2 / hect	Assumption (CEN)
Net/gross ratio	85%	Assumption (CEN)

Table 39: offices assumptions for modelling

Energy efficiency:

The benchmark data for offices shown in Table 38 reveals that 40% of the CO_2 emissions of new high quality office developments are generated by space heating, as opposed to 20% - 30% in new dwellings. This means that a similar improvement in energy efficiency will deliver proportionally higher CO_2 savings in office developments when compared with dwellings.

The energy efficiency modelling carried out for semi-detached houses showed that a 25% reduction in the space heating energy demand could be achieved at an expense of only a 2% increase in build costs. Assuming that the same levels of energy efficiency can be delivered, the overall CO_2 emissions of an office building will be reduced by 10%.
The above-mentioned report[40] shows that specifying very high levels of energy efficiency could increase the building costs up to a point where it is no longer viable. A 24% increase in build costs would be required for a 65% - 95% reduction in heating demand.

Solar thermal:

Offices typically do not consume a large amount energy for hot water heating, as shown in Table 38 where CO_2 emissions resulting from hot water heating represent only 3.5%. Considering that a communal solar thermal system usually provides 50% of the water heating demand, the potential CO_2 reductions through the use of solar a thermal system become negligible.

Solar Photovoltaic

New high-rise office developments increasingly incorporate photovoltaic panels on their façades. However, owing to the borough's character, it is considered that this configuration is unlikely to be suitable in most cases. Roof-mounted panels are thus likely to be the preferred option.

The office development described in Table 39 could accommodate sufficient solar panels to reduce its CO_2 emissions by 20%, where an unshaded roof orientation to the south, and a roof availability of 100% are assumed.

System	Capacity [kWp]	Energy generated	CO_2 savings [kg/year]	Renewable %	Cost	Build cost increase
102 No panels (131 m^2)	21.4	17,100	9,715	20%	£123,000	5.7%

Table 40: Photovoltaic panels for new Offices

40 Report on carbon reductions in new non-domestic buildings, December 2007, UK Green Building Council, Department for Communities and Local Governments

If some of the roof space is used by building services, or is shaded by other building, a 20% reduction in overall CO_2 emission will not be possible for this building configuration through photovoltaic panels alone.

Ground Source Heat Pump

Office development could feasibly incorporate a ground source heat pump for both space heating and cooling. The energy consumption for a 1,090m^2 office building as described above is set out in Table 41.

Space Heating [kWh]	Hot water [kWh]	Cooling [kWh]	Lighting & Appliances [kWh]	Other [kWh]	Gas [kWh]	Electricity [kWh]	CO_2 total [kgCO_2]
102,900	8,700	11,600	18,600	36,000	111,600	66,200	49,600

Table 41: Annual energy consumption of a 1,090m^2 new offices

A 60 kW heat pump would provide heating with a COP[41] of 4 and cooling with a COP of 5.5. The savings and costs are described in Table 42.

Electricty used [kWh/year]	Gas saved [kWh/year]	Electricity saved [kWh/year]	CO_2 savings [kg/year]	CO_2 reduction from renewable	Cost	Build cost increase
26,600	102,900	11,600	13,635	27%	£72k - £108k	3.3% - 5.0%

Table 42: Ground source heat pump for new offices

Biomass heating

The smallest biomass heating system is an 8kW pellet stove, which could provide space heating to a small office of around 200 m^2. This would require a wood-fuel storage and a plant room, which would dramatically reduce the office space where offices of this size would normally have wall mounted combination boilers.

On the basis of our benchmark data for offices, and a conservative heat loss of 60 W/m^2, the sizing exercise concludes that 90% of the space heating requirement of a 1,000m^2 office space could be provided by a 40kW boiler. A smaller gas-fired boiler would generally be installed alongside to provide peak heat in times of high demand, or in summer when the demand is low and the biomass boiler is switched off.

System	Energy generated	CO_2 reduction from renewable	Cost	Build cost increase
Biomass heating 40 kW	90% of demand	34%	£16,000	0.8%

Table 43: Biomass for new Offices

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of 12m^3 would be required. Using wood chips, which have a lower energy density, a quarterly delivery of 44m^3 would be required.

41 Coefficient of Performance, the number of heat/cooling unit generated by one unit of electricity used to power the heat pump.

The costs include the biomass boiler and the plant room equipment (wood fuel storage and transfer mechanism, accumulator tank).

Combined Heat and Power (CHP):

CHP is not considered to be a renewable energy technology, where wood fuelled CHP is not yet a proven technology, but is an efficient way to generate on-site heat and electricity. Some building types are more suited than others, particularly the ones which demand a lot of energy or operate around the clock including, for example, leisure centres, hotels, and hospitals.

CEN's CHP models indicate that an office space of minimum 3,500m^2 would be required to reach 4,500 hours of operation, which is considered a minimum for CHP viability. 3,500m^2 of office space represent a 5-6 storey office block.

System	Hours operation	Heat Generated /Total [kWh/year]	Electricity generated/Total [kWh/year]	CO_2 savings [kg/year]	Cost [£]	Build cost increase
XRGI 15 CHP unit in 3,500m^2 office	4,718	142,000 / 358,400	68,000 / 212,800	15.4% 24,603 / 159,331	26,000	0.4%

Table 44: CHP for new offices

9.6.1 Summary of options

Table 45 below presents a summary of the different options feasible for an office to achieve the target defined previously.

unit	System	CO_2 reduction	Cost (% build cost)	comment
Baseline	1090m^2 3-5 storey office with 85% Net / gross ratio	-	£2,152k (1090m^2 x £1678 per m^2 / 0.85)	-
Energy efficiency	See Table 22	10% (from baseline)	£43k (2%)	Assumption. 10% CO_2 reduction NOT to be cumulated with reduction form renewable energy technologies below.
PV	102 No 210W panels (131 m^2 – 21.4 kWp)	20%	£123k (5.7%)	For a 1,090 m^2 office. Believed to be the limit from which a 20% reduction in CO_2 emission will be difficult with PV alone
GSHP	60 kW GSHP with underfloor heating	27%	£72k – £108k (3.3% to 5%)	1,090 m^2 office Can be used for any size
Biomass	40 KW biomass boiler	34%	£16k (0.8%)	1,000 m^2 office Biomass not advised for smaller offices
CHP	XRGI 15 CHP	15%	£26k (1.2%)	3,500 m^2 office. Operation hours not sufficient for CHP viability below this floor area

Table 45: Summary of options for new offices

9.6.2 Financial Analysis

The analysis utilises the rent and yield figures provided in Chris Marsh's 03/2007 report for the London Borough of Richmond. The figures found in the report are shown as a thin blue line in Figure 9.5 below. The impact of a 20% CO_2 reduction target on the land value is indicated by the thick purple curve.

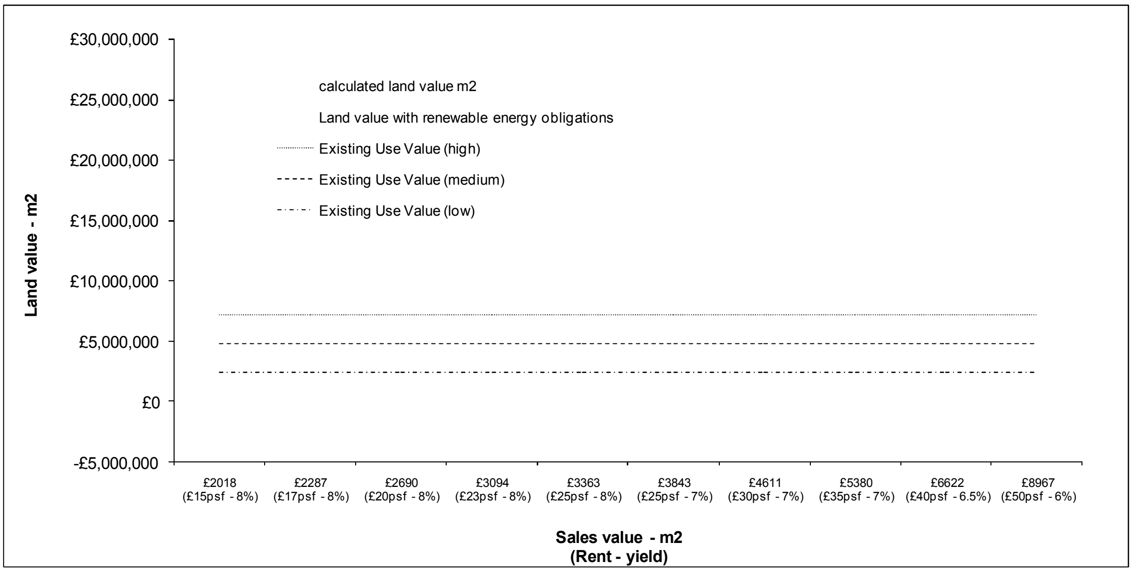

Figure 9.5: Residential value in LB Richmond for Offices

The land value, including the costs of a 20% CO_2 reduction obligation, was calculated by deducting the cost of the most expensive (but also the most likely) renewable energy option, which was found to be photovoltaic panels at £113 per m^2 of floor area. As an indication of the lower range, the costs of a biomass heating system could be as low as £15 per m^2 if no additional cost were incurred by the provision of plant room and storage space.

Offices are expected to reduce their BER by 10% over TER through energy efficiency measures alone. In addition, total CO2 emissions should be reduced by 20% through the use of on-site renewable energy technologies.

9.7 Retail

It is very difficult to generalise about the energy demand of retail developments. One end of the energy consumption spectrum of this development type could be defined as small garment boutiques, using little more energy than required for their space heating and lighting. At the other end of this spectrum, there are large supermarkets with their significant energy needs for cooling and refrigeration.

CEN's benchmark data for retail spaces is shown in Table 46, which compares in the following ways to the energy benchmark data used for offices:

- 1/3 less energy used for space heating;
- same demand for hot water heating and cooling;
- double energy demand for both lighting & appliances and other electrical load;
- annual CO_2 emissions are 40% higher than for offices.

Type	Space Heating [kWh/m^2]	Hot water [kWh/m^2]	Cooling [kWh/m^2]	Lighting & Appliances [kWh/m^2]	Other [kWh/m^2]	Gas [kWh/m^2]	Electricity [kWh/m^2]	CO_2 total [kWh/m^2]
Retail (2006)	63.0	7.7	8.0	40.8	68.3	70.7	117.0	63.1

Table 46: Benchmark energy data used for retail

Retail floor space to the ground floor of a building predominantly in office use, as described in section 9.6 is taken for modelling purpose. Table 47 lists the associated assumptions.

Element	Size	Comment
Net floor area	218 m^2	Ground floor on a 5 storey building (16m x 16m)
Roof area available for PV	49 m^2	Flat roof (14m x 14m) / 5
Build cost	£996/ m^2	BCIS mean for "shops, generally"
Net/gross ratio	85%	Assumption

Table 47: retail assumptions for modelling

<u>Energy efficiency:</u>

The benchmark data for retail spaces set out in Table 47 above shows that 20% of the CO_2 emissions from new retail spaces is generated by space heating, about half of that for schools and offices. Most of the CO_2 emissions of this building type are created by the significant electrical loads, which produce about 20% to 30% more CO_2 emissions per m^2 than new dwellings.

The energy efficiency modelling carried out for semi-detached houses showed that a 25% reduction in the space heating energy demand could be achieved at the expense of only a 2% increase in build costs. Assuming that the same levels of energy efficiency improvement can be delivered, the overall CO_2 emissions of the building will be reduced by only 5%.

Therefore it would be recommended for any energy efficiency standards to be limited to an improvement of 5% in order to avoid a significant increase in build cost.

<u>Solar thermal:</u>

The data shown in Table 46 indicates that a small proportion of energy consumed is for water heating, representing only 2.4% of the total in this case. Considering that a communal solar thermal system usually provides 50% of the water heating demand, the potential CO_2 reductions through the use of solar a thermal system is considered to be negligible.

Solar Photovoltaic

The retail space described in Table 47 would likely have available one fifth of the total roof area if it is divided equally between the five floors. Up to 20 PV panels could be installed on this roof area.

System	Capacity [kWp]	Energy generated [kWh/year]	CO_2 savings [kgCO_2/year]	Renewable %	Cost	Build cost increase
20 No panels (25.6 m^2)	4.2	3,350	13,800	14%	£24,000	5.7%

Table 48: Photovoltaic panels for retail space

In this case, the number of panels that can be installed on the available roof space is considered insufficient. In practice, if the retail space does not have a lot of refrigeration needs, the percentage reduction in CO_2 emissions is likely to be above 20%.

On the other hand if there are sizeable refrigeration needs, as modelled by our benchmark data, the retail space is more likely to take a supermarket-type configuration, which means that more roof area is likely to be available (lower building height), hence allowing the 20% target to be met.

Ground Source Heat Pump

A ground source heat pump could provide the retail use with space heating and cooling. A 218 m^2 retail space, as described above, would have the following energy consumption.

Space Heating [kWh/year]	Hot water [kWh/year]	Cooling [kWh/year]	Lighting & Appliances [kWh/year]	Other [kWh/year]	Gas [kWh/year]	Electricity [kWh/ m^2]	CO_2 total [kWh/year]
13,700	1,700	1,750	8,900	15,000	15,400	25,650	13,800

Table 49: Energy consumption of a 218 m^2 retail

A 13 kW heat pump would provide heating with a COP[42] of 4 and cooling with a COP of 5.5. The savings and costs are described in the table below.

Electricty used [kWh/year]	Gas saved [kWh/year]	Electricity saved [kWh/year]	CO_2 savings [kg CO_2/year]	CO_2 reduction from renewable	Cost	Build cost increase
3,620	13,700	1,750	1,870	14%	£16k - £23k	6% - 9%

Table 50: Ground source heat pump for new retail space

In this case, the ground source heat pump would provide a 14% reduction in CO_2 emissions from the installation of renewable energy technologies on site. Again, if the “other” electric power consumption needs were to be less important due to a less important need of refrigeration, a 20% reduction in CO_2 could be achieved.

Alternatively, a 10 No. panel PV system could be added to the GSHP and installed on the roof to meet an overall 20% reduction in CO_2.

[42] Coefficient of Performance, the number of heat/cooling unit generated by one unit of electricity used to power the heat pump.

Biomass heating

The smallest biomass heating system is an 8kW pellet stove, which could provide space heating to a small retail space of around 300 m^2. This would require a wood-fuel storage and a plant room, which would dramatically reduce the retail space because retail spaces of this size would normally have wall mounted combi boilers.

In CEN's experience, considering a biomass boiler with a rating starting at 40 kW seems appropriate for this type of application. On the basis of our benchmark data for retail space, the sizing exercise concludes that 90% of the space heating requirement of a 1,500 m^2 retail space could be provided by a 40kW boiler. An additional gas-fired boiler would generally be installed alongside to provide peak heat in times of high demand, or in summer when the demand is low and the biomass boiler is switched off.

System	Energy generated	CO_2 reduction from renewable	Cost	Build cost increase
Biomass heating 40 kW	90% of demand	16.4%	£16,000	1%

Table 51: Biomass for a 1,500 m^2 new retail space

In this case, it would not be possible to reach a 20% reduction in CO_2 through biomass heating alone, even though this target is easily met with other development types. The reason is that the electrical consumption of retail spaces is the highest of all development type. Such consumption cannot be displaced by biomass heating where it reduces only CO_2 emissions relating to space and water heating.

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of 13m3 would be required. Using wood chips, which have a lower energy density, a quarterly delivery of 48m3 will be required.

The cost figure include the biomass boiler and the plant room equipment (wood fuel storage and transfer mechanism, accumulator tank)

Combined Heat and Power (CHP):

CHP is not considered to be a renewable energy technology, where wood fuelled CHP is not yet a proven technology, but is an efficient way to generate on-site heat and electricity. Some building types are more suited than others, particularly the ones which demand a lot of energy or operate around the clock including, for example, leisure centres, hotels, and hospitals.

CEN's CHP models indicate that a retail space of minimum 3,000 m^2 would be required to reach 4,500 hours of operation, which is considered a minimum for CHP viability.

System	Hours operation	Heat Generated/Total [kWh/year]	Electricity generated/Total [kWh/year]	CO_2 savings [$kgCO_2$/year]	Cost [£]	Build cost increase
XRGI 15 CHP unit in 3,000 m^2 retail	4,707	141,000 / 212,100	69,000 / 563,100	9% 24,970 / 278,776	26,000	1%

Table 52: CHP for a 3,000 m^2 new retail space

9.7.1 Summary of options

The percentages in CO_2 reduction given below for each renewable energy technology do not assume prior energy efficiency measures. If energy efficiency measures are implemented, the size (and associated cost) of the renewable energy installations could be reduced, while still providing the percentage in CO_2 reduction given in Table 53 below.

unit	System	CO_2 reduction	Cost (% build cost)	comment
Baseline	218 m^2 ground floor retail space with 85% Net / gross ratio	-	£255k (218 m^2 x £996 per m^2 / 0.85)	Percentage increase in built cost for biomass and CHP are based on the smallest floor area of retail space needed to make theses technologies viable
Energy efficiency	See Table 22	5% (from baseline)	£5,1k (2%)	Assumption. 5% CO_2 reduction NOT to be cumulated with reduction form renewable energy technologies below.
PV	20 No panels (25.6 m^2 – 4.2 kWp)	14%	£24k (5.7%)	For a 218 m^2 retail space. If refrigeration needs smaller, a 20% reduction in CO_2 feasible
GSHP + PV	13 kW GSHP with underfloor heating + 10 No 210W panels (13 m^2 – 2.1 kWp)	21%	£29k - £36k (11%-14%)	218 m^2 retail space Can be used for any size
Biomass	40 KW biomass boiler	34%	£16k (1%)	1500 m^2 retail space Biomass not advised for smaller retail space
CHP	XRGI 15 CHP	9%	£26k (1%)	3,000 m^2 retail space. Operation hours not sufficient for CHP viability below this floor area

Table 53: Summary of options for new retail spaces

The cost of the renewable energy technologies described above are given both in absolute terms and as a percentage of the built cost of a 218 m^2 retail space. Because of the potential high electricity use of this development type, generating 40% more CO_2 emissions than in offices, and of a low build cost given by the RICS' Building Cost Information Service (£996 per m^2 Vs. £1,678 per m^2 for offices), the percentage increase in build cost are higher than for Offices.

For this reason, it is required that 20% reduction of total CO_2 emissions is reduced through the use of on-site renewable energy technologies, where feasible.

9.8 Works to existing / Refurbishment

9.8.1 Works to existing - House / Flat

Existing dwellings generally emit significantly more CO_2 than dwellings which comply with the latest Building Regulations. While CO_2 emissions of a new building can readily be predicted by using the SAP calculation methodology, it is difficult to predict a single common CO_2 emission level for existing buildings. This stems from the variation of construction methodology since the Victorian period, which results in large variations of the u-values of thermal elements and dwelling air tightness.

Another difficulty is that the requirements for Building Regulations vary depending on the particular situation of the refurbishment project. This is compounded by the fact that there are a number of clauses which allow particular requirements to be waived (due to technical or commercial reasons). In the majority of cases in the London Borough of Richmond, the works to existing in single houses or flats consist of a rear extension or loft extension.

It is therefore not practical to define a single target percentage of CO_2 reduction from energy efficiency measures or renewable energy that should be applied to schemes involving the refurbishment of a house or a flat. It is instead proposed to follow the Building Regulations for existing dwellings and to require the installation of some form of renewable energy where feasible. The systems which are likely to be feasible are solar photovoltaic and solar thermal, as well as ground source heat pumps. The cost of these systems will vary from £4,000 to £8,000.

The cost and suitability of renewable energy technologies must be considered on a case by case basis. Existing roof features, for example, may cast adverse shadows on solar panels thus rendering them ineffective. Another example would be the need to insulate a dwelling to a reasonable level and to switch to a low grade heating system for the efficient operation of a ground source heat pump if these works were not already planned.

<u>Energy Efficiency</u>

This section provides an example of the potential in CO_2 reduction when a pre-1900 house is entirely refurbished to comply with all the energy efficiency measures described in the approved documents L1B for renovated and replacement elements.

Item	U Value [W/m^{2}K]	
	pre 1900 house	renovated and replacement elements as in L1B
Walls	2.1	0.35
Roof	2.3	0.16 / 0.20 (pitched / flat)
Floor	1.2	0.25
Door	3.0	2.0
Windows	4.8	2.0
	Other parameters	
Boiler	72% efficient	91% efficiency
Thermal bridging	-	-
Air permeability	15	10

Table 54: U-values and other energy efficiency standards in pre-1900 and renovated houses

In the best case scenario, where a pre-1900 house is entirely refurbished to comply with the insulation levels and other energy efficiency measures described in the approved documents L1B, the reduction of the Dwelling Emission Rate could be reduced by up to 70% from its pre-1900 baseline. The resulting DER would be around 20% above the Target Emission Rate applying to a new house built to today's mandatory standards.

In the case of the construction of a rear extension, the works will have to comply with the approved documents L1B. This will increase the net CO_2 emissions of the dwelling, even though the thermal performances of the extension will have much higher insulation levels than the rest of the building.

Renewable Energy Technology Feasibility

Three options are presented with indicative CO_2 savings, costs and basic feasibility requirements. CO_2 savings are given as an absolute number as the baseline CO_2 emissions of the building can vary widely depending on its age and the scope of the refurbishment.

1) Solar thermal option:

A solar thermal system should comply with the following basic requirements:

- 1-1.5 m^2 of absorber area per person. Oversizing a solar thermal system will affect its lifespan.
- Roof should be west to east (through south) facing to maximize solar yields.
- No or limited shading from other buildings, threes and features of the building.

Table 55 provides the costs and CO_2 savings of a solar thermal system for a 3-4 people dwelling:

System	Area of roof required	CO_2 savings	Costs
2 No Collector	5.4 m^2	284 kg CO_2 / year	£4,500

Table 55: cost and CO2 savings of solar thermal in refurbishments

2) Solar PV option:

A solar photovoltaic system should comply with the following basic requirements.

- The roof should be west to east (through south) facing to maximize solar yields.
- No or limited shading from other buildings, threes and features of the building.
- PV panels can be replaced by PV tiles (equivalent yield per surface area and a similar cost)

Table 56 gives the costs and CO_2 savings of a typical domestic solar photovoltaic system:

System	Area of roof required	CO_2 savings	Costs
4 No 210W panels (0.84 kWp)	5.5 m^2	381 kgCO_2 / year	£5,200

Table 56: cost and CO_2 savings of PV in refurbishments

3) GSHP option:

Assumes that the building's envelope can be refurbished to a level close to the current Building Regulations and that an under-floor/low heat heating system will be installed.

- A well insulated building will keep the costs of this option reasonable as it will limit the size of the pump and the depth of the boreholes necessary.
- Under-floor / low heat heating system is necessary to improve the coefficient of performance of the pump, therefore maximizing the CO_2 savings.
- An open area must be available for drilling a borehole. Access of drilling rig must be possible. A ground survey must confirm the possibility to drill (e.g: appropriate soil, no services, etc) and the suitability of the ground conditions.

Table 57 gives the costs and CO_2 savings that a GSHP heating system can deliver:

System	Area of roof required	CO2 savings	Costs
5 kWp heat pump	1 borehole 60-120m	754 kgCO_2 / year	£8,000

Table 57: cost and CO2 savings of GSHP in refurbishments

9.8.2 Refurbishments in Flats 2-10

As this scenario is similar to refurbishments in houses in many respects, only the specific parts that differ are discussed in this section.

Renewable Energy Technology Feasibility

Three options are presented with indicative CO_2 savings, costs and basic feasibility requirements. CO_2 savings are given as an absolute number as the baseline CO_2 emissions of the building can vary widely depending on its age and the scope of the refurbishment.

1) Solar thermal option:

In this case, the size of each solar thermal system supplying hot water to each flat would need to be reduced from the system size of 5 m^2 recommended for houses.

System	Area of roof required	CO_2 savings	Costs
2 No Collector	4.3 m^2	269 kg CO_2 / year	£4,553

Table 58: cost and CO2 savings of solar thermal in refurbishments for each flat

2) GSHP option:

The ground source heat pump is likely to be the same model as recommended in refurbishment for houses. If the refurbishment is carried out with a very high level of energy efficiency, the size of the pump may be decreased to 3.5 kW.

9.8.3 Refurbishments in Flats 11+

In this case, the only difference with the discussion previously presented in refurbishment in houses and in flats 1-10, is that a communal plant room may become available for a biomass boiler.

Biomass

Referring to the discussion on biomass size found in section 9.3.1, a 40 kW biomass boiler is considered as the smallest economically viable option.

If a block of 12 flats were entirely refurbished to the standards set out in the Building Regulations' approved documents L1B for existing dwellings (see Table 54), a 40 kW biomass boiler could provide a 28% reduction in CO2 emissions for this block of apartments. The 12 units represent the minimum number of units for which this solution is considered technically feasible. In practice, it may be desirable to request biomass heating only in larger developments where there is a need to minimise the impact of fuel deliveries and emissions on the air quality.

System	Energy generated	CO_2 reduction from renewable	Cost
Biomass heating 40 kW	60% of demand	28%	£16,000

Table 59: Biomass for a block of 12 flats of 70 m^2 each

The costs presented are for the biomass boiler and the plant room installation, including the wood fuel storage and transfer system. They do not however account for the economic impact of lost space and the cost of the pipes linking the plant room to the residential units.

Using wood pellets, which is the wood fuel type with the highest energy density, only 2 annual deliveries would be necessary to deliver the 18 m^3 necessary to fuel the boiler. Wood chips are not recommended for this option as delivery method requires space that is not generally available for this type of development.

9.8.4 Conclusion

No specific target in terms of CO_2 reduction can be provided for this type of development. This stems from the complexity of establishing the baseline CO_2 emissions after a refurbishment. However, the Council should require the following steps to be undertaken.

As a first step, refurbishments should comply with the Building Regulations for existing dwellings dealing with the conservation of energy and fuel (AD L1B). As illustrated by the example above, this can deliver a reduction of up to 70% of the total CO_2 emissions.

Secondly, refurbishments are expected to install one or more of the renewable energy technologies described above. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective, for example where the efficacy would be reduced by excessive shading on solar panels, or technically unfeasible, for example where there is no access for a drilling rig or no roof space.

10 Implications of CO_2 reduction standards on the Code for Sustainable Homes

For residential developments, achieving a 44% CO_2 reduction of the DER over the TER means that Level 4 of the Code for Sustainable Homes could be achieved. However, this would require developers to also meet mandatory requirements for each dwelling in other categories than energy and CO_2 emissions.

The Code sets mandatory targets for the following categories: potable water consumption, Materials, Water surface run-off and Waste. The mandatory levels corresponding to Level 4 are specified below:

Water
Potable water consumption at a maximum of 105 litres/person/day

Materials
At least three of the following five key elements achieve a relevant Green Guide rating from the 2008 version of The Green Guide of A+ to D:

- Roof
- External Walls
- Internal Walls (including separating walls)
- Upper and Ground Floors (including separating floors)
- Windows

Water surface run-off

- Ensure that the peak rate of runoff into watercourses is no greater for the developed site than it was for the pre-development site.
- Ensure that the additional predicted volume of rainwater discharge caused by the new development, for a 1 in 100 year event of 6 hour duration including an allowance for climate change (PPS25, 2006), should be reduced using infiltration and/or made available for use in the dwelling as a replacement for potable water use in non-potable applications such as WC flushing or washing machine operation.

Waste
The space allocated for waste storage should be able to accommodate containers with at least the minimum volume recommended by British Standard 5906 (British Standards, 2005) based on a maximum collection frequency of once per week. This is 100 litres volume for a single bedroom dwelling, with a further 70 litres volume for each additional bedroom.

The other categories of the Code have no mandatory level required and these are:

- Pollution
- Health and well-being
- Management
- Ecology

Overall, achieving Code Level 4 requires that a minimum of 68 points is obtained, across all the categories.

For full details on technical guidance, please visit http://www.planningportal.gov.uk/england/professionals/en/1115316369681.html

11 Appendix

11.1 Wood-fuel suppliers

Wood chip

TV Bioenergy
TV Bioenergy is a woodfuel supply company based in the Thames Valley region. They currently supply in excess of 20,000 tonnes of woodfuel per annum to Slough Heat and Power and a further 2,000 tonnes per annum to small- medium wood fuel boilers. Their wood fuel is sourced from a wide range of resources within the Thames Valley region, Hampshire and Surrey. They have links with a wide range of arborists, foresters, woodland owners and estates many of whom they already have a working relationship. In addition, they have a contract to purchase short rotation coppice from the local producer group, TV Bioenergy Coppice.

LC Energy
LC Energy runs a commercial wood chip hub on Albury Estate near Guildford in Surrey. This produces up to 3000 tonnes of premium wood chip each year from local woodlands through planned and sustainable harvesting programmes. Other wood fuel hubs will be set up as required to meet local demand across South East of England.

LC Energy are partners with Surrey Hills Woodfuel Association (who can provide pellets).

South-East Wood Fuel
South East Wood Fuels is a company working to supply reliable standards based woodfuel for, public and commercial heating installations across the South East and London.
Formed in 2004, they represent a broad network of woodfuel suppliers from independent forestry contractors through to industrial waste recyclers. South East Wood Fuels Ltd is a coordinator of a current network of over 75 wood fuel producers spread across the south east and London with collective sustainable reserves of approximately 140,000 tonnes of woodchip per year.

Croydon Tree Station
BioRegional, Croydon Council and City Suburban Tree Surgeons have established a TreeStation to produce 10,000 tonnes a year of wood chip fuel from tree surgery arisings. The Croydon TreeStation is one of the first sites in the UK where arboricultural arisings are being processed into fuel suitable for use in smaller wood chip boilers. The TreeStation is a work in progress; much still remains to be done to develop chip drying methods, identify wood chip delivery systems for places with restricted access and to further develop the market. The Croydon TreeStation is an important first step for BioRegional which will inform our work to further develop wood chip supplies across London and elsewhere. Most material ends up in Slough Heat and Power.

Richmond Council
It is understood that all tree waste from council sites is chipped in location, and dried at Hampton – then reused as mulch (10 tonnes/week). According to a 2007 Bioregional Report, this is more mulch than required by the council – therefore the council is considering other opportunities including selling the chip locally. Additional tree surgeons operate in the area – one of which is selling to Slough Heat and Power – and Bioregional report that there is good potential to establish a tree station in Richmond.

Wood Pellet

There is currently only one large-scale pellet-producer in the UK - Balcas of Enniskillen, Northern Ireland. Balcas are also developing an even larger plant at Invergordon in Scotland. Balcas's pellets are produced from Forestry Stewardship Council (FSC) certified material. Most pellet within the UK comes from Europe, Ireland or Canada. Several suppliers are noted below.

Manco Energy
Manco Energy Ltd is a Green Energy Supply & Management company, formed to meet the growing demands in the market place for environmentally friendly energy supplying both fuel and highly efficient boilers to convert the fuel to heat. It is understood that Manco import most of their fuel.

Forever Fuels -
Forever Fuels, part of the Summerleaze group of innovative energy companies, - provides a secure, reliable, competitive, quality-controlled supply of wood pellets to - British customers. It is understood that Forever Fuels import most of their fuel. -

The renewable fuel company -
Company was recently established and is situated in Barking close to most transport - amenities. The company produces wood pellets from clean sawdust and aims to - source all raw material from around London. -

Harvest Wood Fuels
Company does not actually sell its own pellets yet as they're still testing the quality of the pellets their own machine produces). They have a vehicle that will deliver up to 18 tonnes of pellets up to 25m.

11.2 Planning permissions data

List of planning permissions from Richmond, analysed from 01/04/2007 and 31/03/2008, and categorised into conversion, extension, change of use and new build.

Residential

	CON		EXT		CHU		NEW	
	Units	Appl	Units	Appl	Units	Appl	Units	Appl
Bar	6	3	2	1	5	3	0	0
East Sheen	17	7	6	3	11	4	37	6
Fulwell, hampton hill	15	3	12	2	4	2	45	3
Heathfield	17	7	0	0	0	0	11	4
Hampton North	4	2	0	1	0	0	50	5
Ham, Petersham, Richmond riverside	0	0	8	2	2	2	9	7
Hampton	2	1	2	1	2	1	33	6
Hampton Wick	8	3	0	0	0	0	263	12
Kew	4	2	0	0	1	1	21	8
Mortlake, barness common	4	2	0	0	1	1	7	3
North Richmond	16	6	4	1	1	1	21	2
South Twickenham	9	3	3	1	1	1	9	4
South Richmond	10	4	0	0	2	2	4	3
St Margarets	22	9	0	0	1	1	9	2
Teddington	11	2	8	3	1	1	30	4
Twickenham riverside	6	3	1	1	19	4	14	5
West twickenham	8	4	1	2	2	1	6	3
Whitton Ward	18	8	3	1	3	2	58	6
Total	**177**	**69**	**50**	**19**	**56**	**27**	**627**	**83**

Non –residential institutions, Assembly and Leisure

D1, D2, SG permissions between 01/04/2007 and 31/03/2008

D1	additional class room	school	EXT	73	EXT - schools	5	3686
D1	children centre extension to school	school	EXT	385	EXT - other	2	830
D1	change of use children day care nursery	school	CHU	369	CHU - schools	1	369
D1	reception block school rebuild	school	NEW	290	CHU - other	11	1622
D1	change of use nursery to familly centre/residential	other	CHU	108	NEW - schools	3	10365
D1	new nursery and children centre	other	NEW	400	NEW - other	3	971
D1	children centre, nursery	other	NEW	270	CON - schools	1	470
D1	conversion head teacher flat to classroom	school	CON	470	CON - other	0	0
D1	schhol multi gym & art/design music room	school	EXT	1289			
D1	4 storey school	school	NEW	9995			
D1	reception class room build	school	NEW	80			
D2	rear extension for tumble run	other	EXT	60			
D1	change of use extension cat clinic	other	CHU	64			
D1	ground/first floor extension school	school	EXT	1742			
D1	parish centre rear of church	other	EXT	770	***proportion based on square meter***		
						New + extension	Conversion + Change of use
D1	familly contact and assessment	other	NEW	301			
D1	change of use from office to dental practice	other	CHU	101	D1 (schools)	77%	5%
D1	change of use office to pilates appartus	other	CHU	110	D1 (others)	10%	9%
D1	change of use play centre to nursery	other	CHU	390		87%	13%
D1	change of use accupunture	other	CHU	16			
D1	change of use office to clinic	other	CHU	41			
D1	change of use offices to physiotherapy	other	CHU	161			
D1	change of use from office to dental practice	other	CHU	390			
D1	change of use flat to nursery	other	CHU	220			
D1	extension to existing school new classroom and flat	school	EXT	197			
D1	change of use retail to chiropody clinic	other	CHU	21			

Business and General industry

B1, B2 permissions between 01/04/2007 and 31/03/2008

B1	change of use garage to office	CHU	34	EXT	4	446
B1	change of use offices to retail	CHU	33	CHU	4	250
B1	two storey extension	EXT	98	NEW	13	5016
B1	office space within residential building	NEW	195	CON	2	76
B1	residential building with unknown B1 application	NEW	102	New - B2		240
B1	rear extension	EXT	152			6028
B1	change of use offices to live work	CHU	107			
B1	conversion/extension office / residential	NEW	335	***proportion based on square meter***		
					New + extension	Conversion + Change of use
B1	mixed use development including B1 offices	NEW	891			
B1	redevelopmet to provide A1/A2 and B1	NEW	121	B1	91%	5%
B1	conversion residential building, keep office/reception	CON	28	B2	4%	0%
B1	new building offices and residential	NEW	1009			
B1	conversion studio flat to offices	CON	48			
B1	demolition new build including offices	NEW	144			
B1	new building offices and residential	NEW	165			
B1	new live/work unit	NEW	80			
B1	erection of a B1 office building	NEW	1933			
B1	office infill	NEW	20			
B1	live work unit	NEW	21			
B1	extension of storeys	EXT	120			
B2	new building for print room facility	NEW	240			
B1	change of use live/work unit	CHU	76			
B1	rear extension	EXT	76			

Shops, Financial & Professional services, Restaurants and Cafes, Drinking establishments, Hot food takeaways

A1,A2,A3,A4 permissions beteewn 01/04/2007 and 31/03/2008

A1	change of use unify retail space	CHU	108	EXT - A1	5	1060
A1	offices to retail	CHU	93	CHU - A1	8	1145
A1	change of use retail to wine and seafood bar	CHU	28	NEW - A1	2	617
A1	change of use	CHU	16	CON - A1	0	0
A1	change of use to allow mixed use A1 and D1	CHU	76	EXT - A2	0	0
A1	change of use	CHU	452	CHU - A2	5	337
A1	change of use	CHU	104	NEW - A2	1	165
A1	change of use	CHU	268	CON - A2	0	0

A1	rear extension to reatil unit	EXT	80
A1	rear extension	EXT	22
A1	extension retail	EXT	91
A1	rear extension	EXT	167
A1	extension retail	EXT	700
A1	redevelopment petrol station with A1 and A3 retail	NEW	371
A1	redevelopment / extension of bakery to provide A1/A3 + flats	NEW	246
A2	use friontage as office	CHU	24
A2	change of use retail to financial	CHU	122
A2	reduction in retail unit	CHU	66
A2	change of use	CHU	53
A2	no description	N.A	188
A2	new building with retail and flats	NEW	165
A2	Change of use	CHU	72
A3	rear extension	CHU	40
A3	change of use offices to restaurant	CHU	110
A3	change of use residential to restaurant	CHU	271
A3	change of use reatail to wine and sea food bar	CHU	18
A3	change of use	CHU	17
A3	rear extension	EXT	72
A3	redevelopment petrol station with A1 and A3 retail	NEW	269
A3	redevelopment / extension of bakery to provide A1/A3 + flats	NEW	201
A3	mixed development new build	NEW	260
A3	change of use	CHU	65
A3	change of use tp coffe shop	CHU	103
A3	change of use	CHU	50
A3	change of use	CHU	50
A3	change of use	CHU	15
A4	pub refurbishment and new residential building	NEW	142

EXT - A3	1	72
CHU - A3	10	739
NEW - A3	3	730
CON - A3	0	0
EXT - A4	0	0
CHU - A4	0	0
NEW - A4	1	142
CON - A4	0	0

proportion based on square meter

	New + extension	Conversion + Change of use
A1	33%	23%
A2	3%	7%
A3	16%	15%
A4	3%	0%
	56%	44%