LONDON BOROUGH OF EALING

Towards zero carbon development in Ealing

ENERGY EVIDENCE BASE

September 2010

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1 Executive Summary

The combined effect of new legislation and guidance over the past few years has resulted in local authorities now having a central role to play in delivering sustainable development. Tackling climate change has become a key Government priority for the planning system with an increasing focus on climate change mitigation and adaptation in national planning policy. Local planning authorities, specifically, have a direct responsibility for mitigating and adapting to climate change. Planning policy is a significant tool for the implementation of carbon reduction measures at a local level and spatial planning will be key to delivering low carbon growth which is resilient to a changing climate. Planning can contribute to climate change objectives through various means including, although not limited to the following:

- Through influencing energy use and carbon emissions from new developments.
- Through waste planning – Identifying sites for waste processing and management in order to divert waste from landfill.
- Through transport planning in terms of promoting sustainable patterns of development, which seek to maximise opportunities to travel by sustainable modes.

The aim of the study is to assist in the development of achievable local policies that seek to positively encourage and promote reduced carbon emissions from the built environment. The study seeks to support the outcomes identified in the supplement to Planning Policy Statement (PPS) 1 which 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 including a viability assessment, and the purpose of this document is to meet this requirement.

Tackling climate change is a significant priority for the London Borough of Ealing and this is reflected in the Council's manifesto:

1.4 "Clear requirements that all major developments should be carbon neutral using the Eco homes and BREEAM "very good" benchmarks and on a scale that does not place undue pressure on available infrastructure (schools, health services, roads, etc)".

1.5 "Tighter planning rules to combat climate change through better insulation, use of renewable energy and recycling facilities".

The methodology employed in undertaking this study was as follows:

- Understanding the development characteristics of the Borough. This initial task involved identifying the development groups common and representative in the Boroughs development profile, which were to be subject to further testing to identify optimum solutions for CO_2 emissions reduction.

- Analyse the technologies' feasibility based on the geographical and planning constraints that exist in the Borough. This involved a general assessment of the feasibility of individual technologies based on the geography of the borough as well as planning designations in the borough which may affect the suitability/application of specific measures.

- Appropriate sustainable energy measures, following the principles of the Energy Hierarchy, were defined for each development group and costs estimated to achieve the set targets.

- Testing the following CO_2 emission reductions targets for new developments in respect of both their technical feasibility and financial viability.
    - 5% reduction in total CO_2 emissions
    - 10% reduction in total CO_2 emissions
    - 20% reduction in total CO_2 emissions
    - 40% reduction in total CO_2 emissions
    - 60% reduction in total CO_2 emissions
    - 100% reduction in total CO_2 emissions

- Developing policy advice and guidance for dealing with refurbishments, including extensions/conversions as distinct from new build

- Costs were then compared to financial elements of the development. It is envisaged that the costs will be also compared with the residual land value when affordable housing viability study will be complete.

The potential for establishing and developing decentralised heat networks within the borough has also been investigated as a separate exercise to this study. Further information regarding the identified opportunity areas for the establishment of district heating can be found in the Heat Mapping Study[1] which is the second element of the evidence base.

<u>Opportunities and constraints in Ealing</u>

A feasibility analysis of the most commonly used low and zero carbon technologies have been carried out. This analysis concluded that most of these technologies are feasible in the Borough, albeit with the following constraints:

- Wind turbines: this technology was assessed for all development groups as wind speed across the borough are considered satisfactory for their operation at around 4.7 to 5.1m/s at 10m above ground level, 5.5 to 5.7m/s at 25m above ground level and 6 to 6.3m/s at 45m above ground level. The Council is generally supportive of their installation subject to compliance with Ealing's noise and visual amenity policies. It was recognised however that some areas of the borough will be more sensitive to their installation, including in conservation areas. Moreover, additional consideration will need to be given where installations are proposed in areas of the borough in close proximity to Heathrow and Northolt airports. The south west of the borough is particularly sensitive to such proposals. In this regard it will be necessary to ensure that the installation does not adversely affect air traffic or radar systems.

- Solar technologies are expected to be feasible in the majority of the cases, although their use might be restricted on certain buildings or in sensitive areas.

- There is no limitation to the use of ground source heating and cooling, apart from access to drilling and subject to ground survey.

- Biomass heating: although there are many factors to consider in their installation, their application is appropriate for all development groups subject to demonstrating compliance with Ealing's air quality policies.

[1] London Heat Map Study For London Borough of Ealing carried out by Ramboll

An overview of the energy efficiency measures and low and zero carbon technologies is provided in section 4 of this report.

Policy Context

In order to develop the policies that will address climate change in Ealing's Development Strategy, several current and future policies will need to be considered.

- Use the spatial planning framework to drive reductions in CO_2 emissions from the built environment
- Set minimum and best practice advisory standards on the percentage reduction in CO_2 emissions from energy used in new development to come from energy efficiency measures, combined heat and power including decentralised energy and low or zero carbon energy sources
- Ensure through policy that opportunities for energy efficiency measures, renewable/zero and low carbon technologies and supporting infrastructure including decentralised energy supply infrastructure are maximised
- Be focussed on site-specific opportunities such as expansion of decentralised energy networks
- Ensure through guidance and advice that refurbishments, including extensions, conversions and change of use will maximise the use of energy efficiency measures and low and zero carbon technologies.
- Policy targets should reflect the zero carbon trajectory due to come into force during the lifetime of the core strategy
- Ensure guidance and criteria to manage the application of energy measures in areas particularly sensitive to such measures – i.e. nature conservation sites and listed buildings, in or adjoining conservation areas.
- Ensure guidance around the use of conditions including securing connections to district heating networks and managing phased developments to be build over longer time horizons
- Zero carbon requires the consideration of both regulated and unregulated energy use
- Ealing has already committed itself to tackle climate change through sustainability design and construction and borough-wide CO_2 reduction targets. To help achieve these targets requires the development of robust climate change policies

Development Scenarios Being Tested

The development scenarios tested in this report have been identified through an analysis of permissions data for the previous 08/09 monitoring year (taken from the AMR Report 2008/09). This analysis has allowed us to identify typical development types and sizes considered to be representative of the development profile of the borough. For each development scenario a real life case study where consent had been granted was identified for further testing. For ease of analysis only new builds were selected as case studies. It should be noted however that the analysis of the permissions data did in fact highlight the relatively large number of applications for change of use/refurbishment.

The following table summarises the twelve development scenarios.

Development Types	Scenarios

Development Types	Scenarios
Flats (1-5)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50m^2, /60 m^2/70 m^2 Total area 296 m^2
Flats (6-10)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50 m^2 /60 m^2/70 m^2 Total area 593 m^2
Flats (10-50)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50 m^2 /60 m^2/70 m^2 Total area 2,963 m^2
Flats (51+)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50 m^2 /60 m^2/70 m^2 Total area 5,926 m^2
Houses	Detached 3-bed / 4 persons/ 87 m^2
	Semi- Detached Detached 3-bed / 4 persons/ 87 m^2
	Mid-Terrace 2 bed / 3 persons/ 70 m^2
	End -Terrace 2 bed / 3 persons/ 70 m^2
Office	7 storey building 9,577 m^2
Warehouse	2 storey building 3,369 m^2
Schools	3 storey building 4,178 m^2
Hotel	5 storey 1,855 m^2
Supermarket	2 storey building 12,631 m^2
Restaurant	1 storey building 104 m^2

Technical Feasibility Results

The following table shows the optimum carbon emission reductions in terms of a) energy efficiency measures (EEM), b) low carbon technologies – CHP (combined heat and power) and c) renewable energy sources, based on their technical feasibility and cost effectiveness for each of the twelve development types. The targets shown in the third column of the table below have been assessed individually against the Building Regulations baseline while the overall targets indicated in the fourth column show the overall CO_2 emission reduction targets achieved through the combination of the optimum energy efficiency measures with the optimum low and zero carbon technologies following the Energy Hierarchy. These targets have been calculated based on the whole energy demand, including both regulated and non-regulated.

It is important to note that although some technologies when assessed individually against the Building Regulations 2006 baseline were feasible offering significant emission savings, it proved that when assessing them in combination with the optimum energy efficiency measures they were not, e.g. CHP. It should also be noted that the combination of measures is a major factor which can impact on the efficiency of the systems and the emission savings achieved. For those development groups where biomass heating has been recommended after CHP, it is assumed that it will act as back-up/top-up boiler and not as the leading technology. It is generally accepted that CHP is not suitable to be combined with biomass heating as both technologies produce the same elements of energy, heat and hot water, while solar PV is more likely to be combined with CHP systems as it tops up the electricity produced by the system.

The development groups tested are differentiated based on their use, their size and in some instances location. Based on the case studies tested it is evident that all development groups can achieve more than 15% reduction in CO_2 from energy efficiency measures, with the exception of the warehouse development. In the case of warehouse developments, carbon emission savings can be more effectively (in terms of cost) delivered through the use of renewable technologies as opposed to energy efficiency measures. CHP is recommended only for developments with a constant demand for heat and electricity throughout the year. With the exception of retail and offices a reduction of at least 20% in CO_2 (based on regulated and unregulated energy use) can be achieved through renewable technologies.

For those developments where the overall CO_2 emission targets did not exceed the minimum carbon emission savings established in Policy 5.2 of the Draft Replacement London Plan, the Council will encourage applicants to demonstrate that they have fully considered measures to satisfy the London Plan policy.

Class Use	Development Group	Energy Hierarchy	Individual CO_2 Targets - Both Regulated & Non-regulated**	Overall CO_2 Target- Both Regulated & Non-Regulated
A1/A2/A3-5	Retail	EEM	15%	15%*
		CHP	10%	
		RES	10%	
B1/B2	Office	EEM	18%	25%
		CHP	24%	
		RES	13%	
B8	Warehouse	EEM	8%	16%
		CHP	not feasible	
		RES	17%	
C1/C2	Hotel	EEM	15%	56%
		CHP	35%	
		RES	57%	
D1/D2	School	EEM	16%	15%
		CHP	not feasible	
		RES	23%	
C3	Residential Block 1-5 units	EEM	24%	32%
		CHP	not feasible	
		RES	34%	
C3	Residential	EEM	27%	32%

Class Use	Development Group	Energy Hierarchy	Individual CO_2 Targets - Both Regulated & Non-regulated**	Overall CO_2 Target- Both Regulated & Non-Regulated
	Block 6-10 units	CHP	not feasible	
		RES	34%	
C3	Residential Block 11-50 units	EEM	27%	64%
		CHP	41%	
		RES	34%	
C3	Residential Block 51+ units	EEM	27%	48%
		CHP	31%	
		RES	34%	
C3	Houses	EEM	26%	26%
		CHP	not feasible	
		RES	27%	

* Approximate average target from both supermarket and restaurant
** Percentages are based on both regulated and unregulated energy use and have been calculated based on the original baseline (Building Regulations 2006). These have been calculated separately for each measure and related back to the original baseline. In practice, however, through the application the percentage contribution for each measure would be calculated at each stage following a revision of baseline, according with the methodology outlined in Appendix D of the supplementary Planning Guidance on Sustainable Design and Construction.

Technical and Cost Analysis Conclusions

The results from the feasibility and cost analysis have been reviewed to draw out key findings to inform the development of policies in the emerging DPD's. A summary of the key areas considered and their policy implications are given below;

- Technical Overview

Findings for new builds – Residential & Commercial

The key finding from the technical analysis is that achievement of 30%, 45% and, in many cases, 50-60% overall CO_2 reduction targets are technically feasible for all of the new build development types tested with the exception of retail, warehouse and school developments.

The findings also showed that even for minor residential applications, the application of energy efficiency measures and the incorporation of low and/or zero carbon technologies can deliver significant CO_2 emissions savings.

With regards to commercial schemes smaller than 1,000m^2 (i.e. minor developments), the Council requires applicants to comply with 2010 Building Regulations for new buildings and as an addition it will encourage them to achieve emission savings from energy efficiency measures in line with the optimum percentage targets in table 8.1. The Council will also require all developments to demonstrate full consideration of CHP and renewable energy sources where the incorporation of these technologies prove to be feasible and viable.

Findings for refurbishment/change of use/conversions/extensions – Residential & Commercial

For the purpose of this report, where reference is made to refurbishment this is understood to involve either a change of use between use classes, or a conversion (i.e. a sub-division in the number of units), both requiring planning consent. Unless proposed either as part of a change of use or conversion application, refurbishment per se is not covered as this does not constitute development. Unlike for new builds the findings of the analysis have indicated that it is difficult to define CO_2 targets for change of use/conversion applications because of the diversity of building stock/type/age/condition etc.

Generally, refurbishments comprising change of use and conversions of up to 4 residential units or below $1000m^2$ of commercial space should comply with the Building Regulations (ADL2A+B). For example, the outcomes from the residential scenarios indicated that a reduction of up to 70% of the total CO_2 emissions can be delivered through better insulation and higher efficient systems.

Applications involving refurbishments will also be positively encouraged to demonstrate full consideration of CHP and renewable energy sources, and incorporate these technologies where proven to be feasible and viable.

Whilst much of the analysis has focused on major applications, both new build and refurbishments, the Council has also recognised the significance of minor residential extensions in contributing to CO_2 emission reductions. This is seen as particularly significant given the proportion of all applications which minor extensions constitutes. For this reason it is proposed that the Council apply an 'Uttlesford' type condition which requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested, although this will be determined on a case by case basis) are earmarked for energy efficiency measures, beyond current building regulations. The suggested percentage will be determined on a case by case basis but it is not generally expected to increase up to the period till 2013. After the end of this period the Council will revisit and potentially increase the target according to the standards and requirements of that time.

Nonetheless most extensions will also be expected to comply with 2010 Building Regulations dealing with the conservation of energy and fuel. For minor commercial developments smaller than $1000m^2$ (including extensions), the Council will require applicants to comply with 2010 Building Regulations (ADL2A). In addition applicants are required to achieve energy efficiency and as an addition demonstrate full consideration of CHP and renewable energy sources and incorporation of those technologies proved to be feasible and viable.

Findings of the analysis for developments in sensitive areas

Where the existing property is of historic or heritage value, it is essential to consult with the Council's Conservation Officers and where needed English Heritage, as to the best way to incorporate energy efficiency measures, and other low carbon technologies into the building in a sympathetic way which will not cause long-term damage to its fabric and structure. As for all existing stock, given the diversity of building stock/type etc, it is difficult to define CO_2 emission saving targets. The application of such measures must therefore be considered on a case by case basis.

- Cost Overview

The overall conclusion drawn from the viability assessment is that the most cost-effective route to achieving the CO_2 reductions is through using best practice energy efficiency measures, biomass and air source heat pumps (ASHP). ASHP proved to be feasible and the most cost effective option for individual residential houses, whilst biomass delivered a 32% reduction in CO_2 particularly in residential blocks. However the cost analysis showed negative yearly net savings through biomass heating due to high biomass fuel prices. This will likely be addressed through the growing demand in the market for this technology. In the scenario where biomass heating is removed as an option due to the above constraint, the increase in overall cost is not too substantial.

- Technical and financial viability of CHP

The analysis showed that combined heat and power is feasible only to those development groups with a substantial baseload heat demand. Residential houses, small residential developments, warehouses and education facilities did not prove to have the right energy profile for CHP to run constantly throughout the year. The significant emission savings achievable however make this technology competitive with renewables in terms of cost per tonne of carbon saved.

- Solar Technologies

Whilst solar thermal and PV are popular solutions, surprisingly they were not found to be particularly cost effective for any of the development groups tested. Both technologies though are considered to be particularly appropriate for renovations and retrofitting.

- Heat Pumps

Heat pumps and particularly ASHP are likely to be the preferred route for achieving the carbon saving targets for individual or small groups of dwelling achieving targets of approximately 26% (both regulated and non-regulated).

- Biomass

A range of 10% to 23% carbon emission savings can be feasibly achieved for most of the commercial development groups. In particular, it is ideally suited to hotel developments where biomass achieves emissions savings of up to 57%. With regards to residential developments, the use of biomass for providing heating and domestic hot water reduced the CO_2 emissions by 34%.

The findings and outcomes of the analysis also indicated that biomass is more likely to be retrofitted in residential properties than commercial developments although this will depend on the type of refurbishment.

- Wind turbines

Wind technology is generally not considered ideal in an urban environment due to lower wind speeds. However where it can demonstrated that adequate savings can be achieved through their application, their use will be supported. Their application will also be subject to compliance with the Council's noise policies. Special consideration may also be required in areas near to Heathrow airport.

Future Changes in Market Conditions and Policy

The Ealing Development Strategy will cover a 15 year period up to 2026 during which time it is reasonably expected that there will be a number of changes in market conditions and the political and regulatory framework.

Whilst such changes make it difficult to accurately predict the cost effectiveness of technologies over this period, it is expected that through a combination of increased usage and financial incentives that costs will be further driven down, ultimately increasing their uptake.

Policy Recommendations

Based on the findings and outcomes of this study, the following recommendations are proposed in the development of policies on climate change and sustainable construction within Ealing's emerging Development Plan Documents, and particularly the Development Management DPD:

- In order to provide the basis and context for more detailed policies on CO_2 reduction and sustainable design and construction, it is proposed that there is an overriding objective in the Development Strategy promoting climate change mitigation and adaptation. In addition it is recommended that the strategy adopts the overall carbon emissions target saving target (60% till 2025) as proposed in the Draft Replacement London Plan (policy 5.1), and the minimum carbon emission savings for major developments as established in Policy 5.2.

- With regard to the emerging Development Management DPD, it is recommended that this document endorse all of the policies in the draft London Plan with regard to energy and climate change mitigation/adaptation. In fact the emerging draft of this document repeats the planning decisions component of the draft London Plan. Whilst it is considered that the policies in the draft London Plan are fairly comprehensive, the findings of this study have identified scope to go further in terms of target setting. In this regard there are a number of policy areas which could be supplemented with local policy. For example, whilst the Council endorses and seeks to adopt the requirements set out in policy 5.2B of the replacement London Plan, it does however recognise that the scope of this policy is limited in that it would only be triggered by major development, i.e. residential schemes of 10 or more units and commercial schemes of ~~a~~ 1,000 sq. m. or more. Moreover the targets relate to regulated energy demand only. It is therefore recommended to set minimum standards for minor residential developments involving the creation of 1 or more units (through new build). For minor commercial schemes, i.e. developments constituting less than a 1000 sq. m. (including extensions up to this size), it is proposed that policies are set to require applicants to comply with 2010 Building Regulations (ADL2A). In addition applicants are required to achieve energy efficiency savings (beyond building regs) as established in table 8.1, and to demonstrate full consideration of the use of CHP and renewable energy technologies, and incorporate these where feasible and viable.

- For all major developments it is also proposed that preferred best practice targets for each use class, are established, which are further broken down in terms of savings achieved from a) energy efficiency measures, b) combined heat and power, c) on-site renewables. These are designed to ensure general adherence to the Mayor's Energy Hierarchy. Whilst these are intended to be advisory, applicants will nonetheless need to demonstrate that they have fully considered measures to satisfy these higher exemplary standards. The targets will apply until the end of 2012, at which time they will be reviewed and revised. It should be noted that these targets should be calculated on the basis of the total energy demand (both regulated and unregulated), as distinct from the London Plan targets which are measured in terms of regulated demand only. These targets may also provide a useful guide for some minor developments too, although some flexibility will need to be adopted in their application. These targets have been set through modelling the potential performance of new builds, and some flexibility will need to be applied in relation to refurbishment schemes (i.e. change of use/conversions), as it is likely to be more challenging and costly to apply such measures to existing buildings as distinct from new build.

- Refurbishments will be expected to install one or more of the low and zero carbon technologies. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective. This is intended to recognise the unique challenges that exist in respect of employing such measures in existing buildings. This is proposed to be achieved either by requiring an energy or sustainability statement with the planning application which will specify how the developer intends to reduce the CO_2 emissions of the building through the use of the Energy Hierarchy or by requiring a 'very good' standard under BRE's EcoHomes for refurbishment standard. The establishment of such policy advice and criteria will supplement the policies of the consultation London Plan and especially policy 5.4 Retrofitting.

- With regards to minor applications involving extensions to single family dwellinghouses, which constitute a considerable proportion of all planning applications, it is proposed to apply an 'Uttlesford' type condition. In effect this condition requires applicants to demonstrate that a certain percentage of the development costs (eg 10% is suggested although this will be determined on a case by case basis), is earmarked for energy efficiency measures.

- That the policy is framed according to the following;
    - Refers to a reduction in CO_2 emissions, not energy consumption
    - The reduction is applied to total CO_2 emissions from energy use (regulated and un-regulated)
    - The baseline position is Building Regulations Part L 2006

- Levels of achievement on the Code for Sustainable Homes and BREEAM
  Note: The targets set in Policy 5.2 will be considered as the minimum standards in terms of the Code but the Council will expect developers to comply with the best practice standards shown in table 8.1

- An energy assessment is required from the developers of major applications to demonstrate how the CO_2 emissions reductions have been achieved

- All developers will be required to investigate the potential to connect to an existing heat network, to make provision to connect to a future network, to commit to discuss connection if they are approached by a DE service provider in the future, or even establish new networks. Developers should use either the London Heat Map tool or the London Heat Map Study for the London Borough of Ealing. The Council will require developers to prioritise connection to existing or planned decentralised energy networks where feasible.

2 Introduction

PPS 1a requires all LDF documents to be underpinned and informed by a sound and robust evidence base. This study forms one of a series of evidence base documents produced, or currently underway, to support the emerging LDF documents. This particular evidence base document seeks to satisfy the provisions of PPS1a, the supplement to PPS 1, which requires local authorities to set carbon emission reduction targets in their LDF documents, which are underpinned by an assessment of local feasibility and viability. This study represents the findings of this assessment and is structured as follows.

Chapter 3 describes the policy and regulatory drivers to this study, at a national, regional and local level.

Chapter 4 provides a general overview of the measures in line with the Mayor's Energy hierarchy which could be integrated into future new build developments and refurbishments.

Chapter 5 at a borough wide level describes an analysis of the feasibility of technologies based on general geographical/planning constraints that exist in the borough.

Chapter 6 outlines the methodology used to assess the economic viability of measures.

Chapter 7 defines development groups in the borough which are considered to be representative of both existing and future development in Ealing, and contains the results of the analysis of the different energy measures applied to these development groups, in terms of their physical feasibility and economic viability.

Chapter 8 based on the findings of the earlier chapters, identifies the optimum targets for carbon emission savings, for each building type and where appropriate by area. Further recommendations regarding policy content for the different emerging LDF documents is also provided.

3 Policy and regulatory drivers

The combined effect of new legislation and guidance over the past few years has resulted in local authorities now having a central role to play in delivering sustainable development. Local planning authorities, specifically, have a direct responsibility for mitigating and adapting to climate change. Planning policy can be a significant tool for the implementation of carbon reduction measures at a local level and spatial planning will be key to delivering low carbon growth which is resilient to a changing climate.

This section of the report summarises the planning policy at the national, regional and local level underpinning the need to address climate change and to develop a policy framework for sustainable energy solutions at the Borough level. Through this section it will also be possible to identify existing or proposed targets, which will either be set at a national or regional level and will set the baseline target, from which local targets will be set.

3.1 National Policy/Legislation

The following key policy documents and legislation set the national context for local authority action:

3.1.1 Planning Act (2008)

The **Planning Act** *(2008)* requires that action on climate change must be included in Development Plans. It makes provision for a Community Infrastructure Levy (CIL) which could support climate change infrastructure, such as district heating networks.

Planning and Energy Act

The emerging Planning and Energy Act would enable local planning authorities to set requirements for energy use and energy efficiency in development plans, including:

- development in their area to comply with energy efficiency standards that exceed the energy requirements of building regulations;
- a proportion of energy used in development in their area to be energy from renewable sources in the locality of the development;
- a proportion of energy used in development in their area to be low carbon energy from sources in the locality of the development; and
- whole unit performance improvements as part of applications for building extensions.

3.1.2 PPS 1 & PPS1a

Planning Policy Statement (PPS) 1, Planning for Sustainable Development *(2005)* and its supplement titled 'Planning and Climate Change' *(2006)* provide the key planning policy drivers at a national level for addressing sustainable design and climate change. It puts climate change mitigation and adaptation at the heart of spatial planning and requires local authorities to generate local targets in support of regional and national climate change targets.

Paragraph 18 of PPS1a states that Planning Authorities should consider the opportunities for the core strategy to add to the policies and proposals in the RSS, such as where local circumstances would allow further progress to be made to achieving the Key Planning Objectives set out in this PPS.

Paragraph 19 of PPS 1a also states that in developing their core strategy and supporting local development documents, planning authorities should provide a framework that promotes and encourages renewable and low carbon energy generation.

Furthermore paragraph 26 states that Planning Authorities should have an evidence-based understanding of the local feasibility and potential for renewable and low-carbon technologies, including microgeneration, to supply new development in their area.

Drawing from this evidence-base, and ensuring consistency with housing and economic objectives, planning authorities should:

(i) set out a target percentage of the energy to be used in new development to come from decentralised and renewable or low-carbon energy sources where it is viable. The target should avoid prescription on technologies and be flexible in how carbon savings from local energy supplies are to be secured;

(ii) where there are particular and demonstrable opportunities for greater use of decentralised and renewable or low-carbon energy than the target percentage, bring forward development areas or site-specific targets to secure this potential; and, in bringing forward targets,

(iii) set out the type and size of development to which the target will be applied; and

(iv) ensure there is a clear rationale for the target and it is properly tested.

Para 31 - There will be situations where it could be appropriate for planning authorities to anticipate levels of building sustainability in advance of those set out nationally. When proposing any local requirements for sustainable buildings planning authorities must be able to demonstrate clearly the local circumstances that warrant and allow this.

When proposing any local requirement for sustainable buildings planning authorities should:

- focus on development areas or site-specific opportunities;
- specify the requirement in terms of achievement of nationally described sustainable buildings standards, for example in the case of housing by expecting identified housing proposals to be delivered at a specific level of the Code for Sustainable Homes;
- ensure the requirement is consistent with their policies on decentralised energy; and
- not require local approaches for a building's environmental performance on matters relating to construction techniques, building fabrics, products, fittings or finishes, or for measuring a building's performance unless for reasons of landscape or townscape.

Para 33 - Any policy relating to local requirements for decentralised energy supply to new development or for sustainable buildings should be set out in a DPD, not a supplementary planning document, so as to ensure examination by an independent Inspector. In doing so, planning authorities should:

- ensure what is proposed is evidence-based and viable, having regard to the overall costs of bringing sites to the market (including the costs of any necessary supporting infrastructure) and the need to avoid any adverse impact on the development needs of communities;
- in the case of housing development and when setting development area or site-specific expectations, demonstrate that the proposed approach is consistent with securing the expected supply and pace of housing development shown in the housing trajectory required by PPS3, and does not inhibit the provision of affordable housing; and
- set out how they intend to advise potential developers on the implementation of the local requirements, and how these will be monitored and enforced.

3.1.3 Planning Policy Statement 22

PPS 22 - Renewable Energy *(2004)* states that local authorities should have an evidence-based understanding of local feasibility and potential for renewable and low carbon technologies to supply new developments in their area. This study contributes directly to that requirement.

National Planning Policy PPS22 views the use of renewable energy in a very positive light and states that planning bodies should be actively promoting the use of renewables. The policy sets out that Local Planning Authorities may include policies in their local development documents that require a percentage of the energy in commercial, residential or industrial developments to come from on-site renewable energy generation where viable and without placing an undue burden for developers.

Para 8 - Local planning authorities may include policies in local development documents that require a percentage of the energy to be used in new residential, commercial or industrial developments to come from on-site renewable energy developments. Such policies:

(i) should ensure that requirement to generate on-site renewable energy is only applied to developments where the installation of renewable energy generation equipment is viable given the type of development proposed, its location, and design;

(ii) should not be framed in such a way as to place an undue burden on developers, for example, by specifying that all energy to be used in a development should come from on-site renewable generation.

3.1.4 Renewable Targets & Obligation Certificates

The UK's current target is that 15.4% of the UK's electricity supply will come from renewable resources by 2016. To achieve this target, the government has introduced a mix of regulation, policy and fiscal measures.

The Renewable Obligation (RO) requires all energy suppliers to source a percentage of electricity from renewable sources each year. The obligation is increased incrementally in April each year and is currently at 10%[2].

Renewable Obligation Certificates are issued for each MWh of electricity produced from certified renewable sources, and electricity suppliers must submit the appropriate amount of ROCs each year or face a financial penalty. Suppliers are therefore keen to purchase ROCs, producing a potential income for developments that have obtained ROCs through generating electricity from renewable sources.

3.1.5 Building Regulations Part L 2006 & 2010

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.

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[2] Statutory instrument 2010 No.1107 The Renewables obligation (Amendment) order 2010

The current 2006 Building Regulations Part L requires that CO2 emissions related to all development (i.e. the DER for dwellings or BER for non-residential) should be equal to the TER, which is generally in the region of 20% lower than the 2002 Building Regulations depending on the specific building type.

Over the last few months Government have published consultations on changes to Parts L and F of the Building Regulations as well as the Standard Assessment Procedure (SAP2009) used to demonstrate compliance with Part L. These proposals, due to come into force in October 2010; form the first step on the legislative trajectory to 'zero carbon'. The changes will have significant and wide ranging impacts on the construction industry.

The key issues to note at this stage are;

- Achieving 25% reduction in CO2 emissions compared to Part L 2006
- Updated CO_2 emission factors for different fuel types
- Removal of import-export differential for on-site generated electricity
- Varying the Target Emissions Rate (TER) by fuel type
- Increased requirements for submission of design stage information to Building Control Body
- Inclusion of fixed air conditioning in dwelling calculations
- Changes to boundary conditions and assumptions e.g. removal of restriction on low energy lighting and requirement for secondary heating
- Calculating the TER: Flat or Aggregate approach

Building a Greener Future Policy Statement *(2007)* sets out the Government's intention to tighten buildings regulations to ensure that, all new homes built in the UK would emit no net carbon.

Building Regulations Part L – Conservation of Fuel and Power –

- sets out new CO2 emission targets,
- encourages the use of renewable energy sources,
- 20% improvement in CO2 emissions for dwellings
- 23.5% improvement in CO2 emissions for naturally ventilated non-dwellings
- 28% improvement in CO2 emissions for air-conditioned or mechanically ventilated non-dwellings

The UK Green Building Council (UK-GBC) - Zero Carbon Task Group Report – Current timeline to Zero Carbon

SDLT Relief	Statutory Instunment 2007 No 3437 HM Treasury Dec 2007	**2007-2012** Period of Stamp Duty Land Tax, Relief for New Zero Carbon Homes 1st October 2007 - September 2012						
English Partnerships	English Partnerships Quality Standards Nov 2007	**2008** Require: CSH Level 3	**2010** Proposed Requirements CSH Level 4	**2013** Proposed Requirement CSH Level 6				
Social Housing Grant	Housing Corporation Design and Quality Strategy April 2007	**2008** **2008/9 - 2010-11** Funding stream: requires CSH Level 3	**2011** **2011/12 - 2013/14** funding stream:likely to require CSH Level 4		**2014+** From 2014/15 funding stream: likely to require CSH level 6			
Buildng Regs. Dwellings	Builing a Greener Future Policy Statement CLG July 2007	**2010** Proposed Carbon improvement: 25% from 2006 BR baseline		**2013** Proposed Carbon improvement: 44% from 2006 BR baseline		**2016** Proposed Zero Carbon homes (ncluding appliance energy use)		
Buildng Regs. Non - Dwellings	Budget 2008 Report HM Treasury Mar 2008					**2016** Proposed Zero Carbon new school/college buildings	**2018** Proposed zero arbon new public sector builings	**2019** Proposed zero carbon newnon-domestic dwellings

'Building a Greener Future' (2007) sets out a programme for the progressive tightening of Building Regulations to require major reductions in carbon emissions from new homes to get to zero carbon by 2016.

3.1.6 Code for Sustainable Homes

The Code for Sustainable Homes (the Code) is an environmental assessment method managed by BRE Global for rating and evaluating the performance of new homes. It is a national standard assessment tool for use in the design and construction of new homes with a view to encouraging continuous improvement in sustainable home building and is based on EcoHomes© scheme.

The Code was launched in December 2006, became operational in April 2007 in England, and having a Code rating for new build homes mandatory, from 1st May 2008. This mandatory requirement came into effect for all developments where a local authority received the building notice, initial notice or full plans application after 1st May 2008. Developments where a local authority had received these stages on or before 30 April 2008 are exempt. Whilst all new homes must have a certificate, to confirm their rating, or in the case of no rating a nil compliance certificate, privately funded residential schemes are not required to achieve a specific rating level.

Since May 2008, all new publicly funded housing must be built to a minimum of Code level 3. During 2010, the requirement is planned to step up to Code Level 4; however, a specific date has not been publicly known yet. It is important to mention that through PPS: Planning and Climate Change – Supplement to PPS1 (CLG, 2007) local authorities are allowed to request higher levels of Code than are required through the Buildings Regulations.

The Code for Sustainable Homes sets standards for energy efficiency and carbon savings beyond those currently required by Building Regulations using a series of Code levels from 1 to 6. The Code differentiates between 'regulated' emissions which are associated with the building itself, such as heating, water and lighting, and those 'non-regulated' emissions which involve substantial off-site energy generation, for example, appliances, cooking or industrial equipment.

As part of the code, homes are rated against criteria within nine different categories including energy and CO2 emissions, water, materials, surface water run-off, waste, pollution, health and wellbeing, management and ecology. Credits are available against each of the criteria and a Code Level is awarded depending on the total number of credits achieved. Whilst many of the criteria are optional, there are a number against which a minimum 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 CO2 emission reduction, and there is, in addition criteria Ene7 which provides credits for achieving a reduction in CO2 as a result of low and zero carbon technologies. Ene1 requires the following percentages of CO2 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

There are however intermediate levels of the Code which are not mandatory but could still be achieved, eg ≥31%, ≥37%,≥52%, ≥60%, ≥69%, ≥79%, ≥89% improvement of DER over TER.

The deadlines for zero carbon development, set out in Building a Greener Future (consultation document), are:

- all dwellings to reach Code level 3 by 2010
- all dwellings to reach Code level 4 by 2013
- all dwellings to reach zero carbon regulated emissions by 2016; and
- all non-domestic buildings should reach zero carbon, including non-regulated emissions, by 2019 (this deadline is currently out to consultation).

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.

Code Level	Percentage carbon emission reduction beyond Part L	Year of implementation - Mandatory Target for private housing	Year of implementation - Mandatory Target for publicly funded housing
1	10%	-	-
2	18%	-	-
3	25%	2010	Current target
4	44%	2012	2010
5	100%	2014	2012
6	Zero carbon regulated energy and occupant energy	2016	2014

Table 3.1: Code for Sustainable Homes level requirement for carbon emission reduction beyond Part L of the Building Regulations[3]

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

[3] CLG, Code for Sustainable Homes: Technical guide (May 2009 Version 2) <www.planningportal.gov.uk/>

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

- Materials
- Water surface runoff
- Waste

The Code assessments are normally carried out in two stages:

• Design Stage (DS), leading to an Interim certificate. This interim certificate is provided for information only and cannot be used to represent the performance of a completed dwelling.
• Post Construction Stage (PCS), leading to a Final certificate. This final certificate is carried out after construction and completion and represents the final Code Certificate given to each dwelling.

3.1.7 Other/BREEAM

Whilst 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 no mandatory requirements which must be achieved for each of the ratings.

There is no specific legal requirement for non-residential development, including office, and retail to achieve a specific level under BREEAM but the Government's target is to make schools zero carbon by 2016 which coincides with the date which all new residential properties are required to be zero carbon.

Generally, a BREEAM rating is commonly required by Local Planning Authorities as a means of securing the highest possible standards of sustainable design.

The Building Research Establishment manages a number of assessment tools for benchmarking design quality. These include BREEAM EcoHomes, BREEAM EcoHomesXB for existing buildings, BREEAM Industrial and other Buildings. Each assesses the environmental performance of a building. There is no direct translation between BREEAM and Code for Sustainable Homes - particularly as BREEAM is a constantly evolving benchmarking tool which ensures the rating remains relevant depending on technology advances and viability. So a Very Good rating in 2009 will be higher than the same award in 2006. The Code levels therefore represent a more measurable and quantified standard and are used as the primary standard for the purposes of measuring performance improvement in this evidence base. The relationship between the Code levels and carbon reduction targets is more direct. For example, if one assumed every building in the Borough was built to 2008 Building Regulations and every existing building in the borough was improved to Code level 3 standards it would record a 25% total reduction in the carbon emitted by the built environment.

3.2 Regional Policy

3.2.1 London Plan

The London Plan (consolidated with alterations since 2004) *(published 2008)* requires all new buildings to be as energy efficient as possible, explore opportunities for renewable energy generation and other low carbon technologies, and makes use of decentralised energy systems. A percentage target of 20% carbon emission savings is also established for on-site renewables. All Local Development Frameworks (LDFs) are required to identify and safeguard existing heat and cooling networks and maximise the opportunities for providing new networks. Boroughs should ensure that all new development is designed to connect to the heating and cooling network. The London Plan adopts a hierarchical approach to investment into carbon emissions reductions. Reductions should firstly be sought through energy efficiency, followed by cleaner energy provision, with renewable provision as a national priority. This report tests whether the hierarchy offers the most cost-effective solution to achieving carbon savings, for individual development types. In addition, this hierarchy has the benefit of being mutually supportive, so that more energy efficient buildings require less energy from renewable sources.

Since the publication of the consolidated London Plan in 2008, the new mayor for London has published a **Draft Replacement London Plan** (October 2009). The draft Plan includes a dedicated chapter on addressing climate change and highlights the importance of both mitigation and adaptation. Overarching growth policies highlight the importance of establishing a common set of policies and procedures "to ensure that there is, so far as possible, a 'level playing field' particularly adjacent to London's boundaries. This will help to meet housing, energy and sustainability targets." The importance of developing opportunities for decentralised energy networks and ensuring high quality design in Outer London boroughs is also highlighted. The important role of large scale residential development in providing energy infrastructure is identified (Policy 3.7). A series of mitigation policies are including, establishing a 60% carbon emissions reduction target and the role of development in achieving such reductions. It is anticipated that the revised London Plan will be adopted towards the end of 2010, beginning of 2011, at which time it will formally replace the current London Plan (consolidated with alterations since 2008).

Draft policy 5.2 re-enforces the energy hierarchy as the overarching framework for achieving carbon emission reductions as follows:
1 Be lean: use less energy
2 Be clean: supply energy efficiently
3 Be green: use renewable energy

This policy also reflects the zero carbon trajectory, and requires the following carbon emission reduction improvements beyond 2006 Building Regulations Part L, for all new major developments:

Residential buildings:
• 2010 – 2013: 44 per cent
• 2013 – 2016: 55 per cent
• 2016 – 2031: Zero carbon

Non-domestic buildings:
• 2010 – 2013: 44 per cent
• 2013 – 2016: 55 per cent
• 2016 – 2019: As per building regulations requirements
• 2019 – 2031: Zero carbon

Major development in this context refers to residential developments comprising 10 or more dwellings, and commercial development with a 1000 sq. m. plus of gross floor area.

The policy also establishes the requirement for planning applications for major developments to be supplemented with a detailed energy assessment. This policy also seeks to secure in the first instance that carbon dioxide reduction targets are met on site. However, "where it is clearly demonstrated that the specific targets cannot be fully achieved on site, any shortfall may be provided offsite or through a cash in lieu contribution to the relevant borough to be ring fenced to secure delivery of carbon dioxide savings elsewhere."

Further mitigation policies set out the following:

• **Policy 5.4** supports reducing the environmental impact of existing urban areas, in particular reducing their carbon emissions and resource use. Opportunities to reduce carbon emissions from the existing building stock should be identified by London Boroughs.
• **Policy 5.5** "prioritises the development of decentralised heating and cooling networks at the development and area wide level, as well as larger scale heat transmission networks." The policy requires boroughs to "develop policies and proposals to identify and establish decentralised energy network opportunities."
• **Policy 5.6** seeks to ensure CHP facilities are connected to wider networks to establish decentralised systems. "Major development proposals should select energy systems in accordance with the following hierarchy: 1 Connection to existing heating or cooling networks; 2 Site wide CHP network; 3 Communal heating and cooling."
• **Policy 5.7** encourages the development of renewable energy within boroughs. Boroughs should "identify broad areas where specific renewable energy technologies, including large scale systems and the large scale deployment of small scale systems, are appropriate." The policy includes "a presumption that all major development proposals will seek to reduce carbon dioxide emissions by at least 20 per cent through the use of on site renewable energy generation wherever feasible. Development proposals should seek to utilise renewable energy technologies such as: biomass heating; cooling and electricity; renewable energy from waste; photovoltaics; solar water heating; wind and heat pumps."
• **Policy 5.8** supports and encourages more widespread use of innovative energy technologies such as electric and hydrogen fuel cell vehicles, hydrogen supply and distribution infrastructure, and advanced conversion technologies such as anaerobic digestion, gasification and pyrolysis for the treatment of waste.

3.2.2 GLA SPG – Sustainable Design and Construction

This SPG does not set policy but has weight as a formal supplement to the London Plan. The SPG sets essential standards as listed below:

- The requirement to carry out an energy demand assessment as part of the planning application;
- Design measures to maximise energy efficiency;
- Outdoor lighting or other electrically powered street furniture should be energy efficient and minimise light pollution;
- Carbon emissions from the total energy needs of the development should be reduced by at least 10% by the on-site generation of renewable energy;
- Major commercial and residential developments to demonstrate that consideration has been given to the preferred ranking method for heating and where necessary, cooling systems.

3.2.3 The Mayor's Energy Strategy

The Mayor's Energy Strategy – Green light to clean power (February 2004) aims to improve London's environment, reduce the capital's contribution to climate change, tackle fuel poverty and promote economic development. In order to do this, massive investment in improving energy efficiency in homes is required.

The Strategy's specific objectives are:

- to reduce London's contribution to climate change by minimising emissions of carbon dioxide from all sectors (commercial, domestic, industrial and transport) through energy efficiency, combined heat and power, renewable energy and hydrogen
- to help to eradicate fuel poverty, by giving Londoners, particularly the most vulnerable groups, access to affordable warmth

- to contribute to London's economy by increasing job opportunities and innovation in delivering sustainable energy, and improving London's housing and other building stock.

A number of policies have been established by the Mayor in order to deliver these objectives, which follow three principal approaches:- setting challenging yet, achievable targets; using the Mayor's powers and the activities of the GLA group; and working in partnership to deliver change.

3.3 Local Policy

The need for sustainable development, and in particular development which incorporates measures for sustainable energy use and generation, is promoted in the borough by both adopted and emerging local planning policies. In this regard existing policies are included in the adopted Unitary Development, and new policies are being developed as part of the emerging LDF, which supplement the draft policies in the replacement London Plan.

3.3.1 Climate Change Strategy

The Climate Change Strategy for Ealing has been developed by the Environment and Climate Change Board and demonstrates the Local Strategic Partnership's commitment to reducing the borough's contribution to climate change over the three-year period 2008-2011.

The overarching aim of the strategy is to reduce Ealing's contribution to climate change by reducing per capita carbon dioxide emissions in the borough by 10% by 2010/11 from a 2005 baseline. An updated version of the Strategy is under development with aim to reduce the borough's CO_2 emissions by 30% by 2013%.

Tackling climate change has become a key Government priority for the planning system with an increasing focus on climate change mitigation and adaptation in national planning policy. Local planning authorities, specifically, have a direct responsibility for mitigating and adapting to climate change. Planning policy is a significant tool for the implementation of carbon reduction measures at a local level and spatial planning will be key to delivering low carbon growth which is resilient to a changing climate.

3.3.2 National Indicators 185/186 (NI185/186)[4]

On the 11th October 2007 the Secretary of State for Communities and Local Government announced a new set of 198 national indicators for English local authorities and local authority partnerships. The set underpins the new performance framework for local government and meets the Government's commitment, as set out in the local Government White Paper Strong and Prosperous Communities, to introduce a clear set of national outcomes and a single set of national indicators by which to measure them.

Several of these indicators are directly related to climate change with National Indicators 185 and 186 associated with the management of carbon emissions.

The public sector is in a leading position to demonstrate CO2 emission reductions through their activities and behaviour as an example of best practise to residents and local businesses. By calculating their own emissions and making in-house reductions, in addition to increasing

[4] National Indicators for Local Authorities and Local Authority Partnerships, Handbook of Definitions, Annex 4: Local Economy and Environmental Sustainability

awareness and supporting local businesses and residents, carbon emissions can be reduced across each local authority area and therefore across the country as a whole, meeting the government's climate change targets. In addition, through their powers and responsibilities (planning, housing, local transport and powers to promote well-being) and by working with their Local Strategic Partnership they can have significant influence over emissions in their local areas.

NI 185 – Percentage CO_2 reduction from LA operations
Under National Indicator NI 185, local authorities are required to calculate the carbon emissions of their buildings and services on a yearly basis and report the results to DEFRA and to encourage them to demonstrate leadership on tackling climate change.

NI 186 – Per Capita CO_2 emissions in the local area
Under National Indicator NI 186, local authorities are encouraged to raise awareness and support carbon emission reduction strategies for the local area. Centrally produced carbon emissions figures will be published on an annual basis, providing end user emissions for each local authority area – based on the energy consumption from the business and public sector and residential housing, along with fuel purchase data demonstrating road transport use, within the boundaries of the local area.

3.3.3 Decentralised Energy Masterplanning

The London Development Agency (LDA) has developed an Energy Master Plan for London. This is in the form of the London Heat Map (LHM), which can be found at http://www.londonheatmap.org.uk/. The LHM provides a web-based GIS resource containing high level data on decentralised energy (DE) across London. The Decentralised Energy Masterplanning (DEMaP) programme is hosted by the LDA and is regularly updated with information from boroughs and developers.

As part of the DEMaP programme, a suite of 'service packages' have been identified setting out the steps necessary to support boroughs to deliver a DE project, from concept, through to implementation. One of these service packages is Heat Mapping, which involves the detailed mapping of decentralised energy data for the borough. This Heat Map will help the borough to identify opportunities for DE in their area and will form part of an evidence base for policies on DE. This support package, which Ealing are currently signed up for, forms part of a broader programme designed to put London on a trajectory towards the target of supplying 25% of its energy from decentralised energy sources by 2025. This discrete project will complement the energy evidence base study.

In broad terms, Decentralised Energy means local or sub-regional supply of heat and electricity. The focus of the support package will be the identification and development of low carbon heat network opportunities and local, low carbon supply opportunities (including gas-fired CHP, biomass, and advanced energy from waste technologies). By 'Masterplanning', we mean spatial and strategic planning that identifies and develops opportunities for decentralised energy and the associated technical, financial and legal considerations that provide the basis for project delivery.

The LHM contains a combination of actual and estimated heat energy consumption data for all buildings in London. As part of the DEMaP programme the Council worked with consultants to develop a heat map for the borough with actual energy consumption data. This actual data will substitute respective estimated data for the borough on the LHM.

Whilst there are no existing district heating networks within Ealing, there are individual communal heating systems across the borough. Several of these communal systems use Combined Heat and Power plant and feed electricity into the local grid and will be the subject of a detailed feasibility study to identify potential opportunities for development or connections and in later stages expansion of the network(s).

It is intended that the findings of this masterplanning exercise will feed directly into the emerging Local Development Framework[5] documents. In particular the Strategy and Sites Development Plan Documents will identify area(s)/site(s) with specific DE opportunities in the borough. This masterplanning exercise will allow us to identify the right location(s) for the establishment of DE network(s) based on the existing and proposed mix of uses within an area, and the physical feasibility of setting up such a network. It is envisaged that this will be aligned with the growth areas planned within the Strategy document. It is hoped that this will provide the certainty needed to attract investment in DE proposals within the borough. This will also be supplemented by the Infrastructure Delivery Plan, which will establish the delivery mechanisms (including ongoing funding/maintenance) for DE proposals within the borough over the LDF plan period (i.e. up to 2026). Moreover the Development Management DPD will establish policies for the assessment of DE proposals, and set criteria to ensure that new development links into established networks.

Having recently completed phase 1 of the DeMAP project, Ealing are receiving further support in phase 2 of the programme with final arrangements still to be determined. The main scope, however, of the second phase is the identification of funding opportunities for carrying out a detailed district heating feasibility study for one of the areas that have already been identified having potential for the creation of such networks.

3.4 Scope of the work

The policy and regulatory framework, reviewed in Section 3, shows that the incorporation of sustainable energy measures in new and adapted existing buildings is promoted by national and regional government and by the London Borough of Ealing. Tackling climate change is a significant priority for the London Borough of Ealing and this is also reflected in the Council's new administration's manifesto as follows:

1.4 "Clear requirements that all major developments should be carbon neutral using the Eco homes and BREEAM "very good" benchmarks and on a scale that does not place undue pressure on available infrastructure (schools, health services, roads, etc)".

1.5 "Tighter planning rules to combat climate change through better insulation, use of renewable energy and recycling facilities".

In developing its policies in the emerging Local Development Framework, the Council will seek to ensure that these are underpinned by a robust and sound evidence base. In line with national, regional and local objectives, climate change policies developed in the emerging LDF should seek to promote sustainable energy use through the design and construction of new dwellings and the refurbishment of the existing stock and in doing so contribute to the reduction of carbon emissions originating from the built environment. The evidence base work will in particular inform the setting of targets and policies in respect of CO_2 emission reductions to be delivered through new and existing development proposals. To ensure that these targets are deliverable, they will be tested for their feasibility and viability.

Given the long term nature of the LDF covering a 15 year period until 2026, it will be difficult to predict with any certainty the achievability of targets, particularly where these incrementally

[5] Link to LDF Documents
http://www.ealing.gov.uk/services/environment/planning/planning_policy/local_development_framework/consultation/

increase over the plan period, given the changing nature of low carbon technologies, and the changing framework of fiscal incentives.

This study therefore investigates, and provides robust evidence for the possible different sustainable energy measures that can be feasibly integrated into existing and future developments, reinforced by the requirement to meet or exceed the Building Regulations, the Housing Corporation targets as explained in Sections 3.1.6 and 3.1.7 and the replacement London Plan.

In order to provide justification, the following methodology was adopted, in line with the requirements of PPS1a:

- Understand the development characteristics of the Borough. The initial task involved identifying the development groups common or representative in the Borough, which were to be subject to further testing to identify optimum solutions for CO_2 emissions reduction.

- Analyse the technologies' feasibility based on the geographical and planning constraints that exist in the Borough. This involved a general assessment of the feasibility of individual technologies based on the geography of the borough as well as planning designations in the borough which may affect the suitability/application of specific measures.

- Appropriate sustainable energy measures, following the principles of the Energy Hierarchy, were defined for each development group and costs estimated to achieve the relevant target.

- Test the following CO_2 emission reductions targets from new developments firstly from a technical feasibility perspective and then a financial viability perspective.
    - 5% reduction in total CO_2 emissions
    - 10% reduction in total CO_2 emissions
    - 20% reduction in total CO_2 emissions
    - 40% reduction in total CO_2 emissions
    - 60% reduction in total CO_2 emissions
    - 100% reduction in total CO_2 emissions

- Costs were then compared to financial elements of the development. It is envisaged that the costs will be also compared with the residual land value soon after the housing affordability viability study is complete.

- The potential for establishing and developing decentralised heat networks has been also investigated but it is not part of this study. Further information regarding the identified opportunity areas for the establishment of district heating can be found in the Heat Mapping Study[6] which is part two of the evidence base.

[6] London Heat Map Study For London Borough of Ealing carried out by Ramboll

4 The Measures

The following chapter provides a general overview of low carbon measures which could be integrated into future new build developments and refurbishments within Ealing. These measures are considered and grouped according to the Mayor's Energy Hierarchy.

The Energy Hierarchy originates from the Mayor's Energy Strategy, and is established as policies in the consolidated London Plan (policy 4A.1 Tackling Climate Change) and draft replacement London Plan (policy 5.2 Minimising carbon dioxide emissions).

In line with the Energy Hierarchy the London Plan adopts a hierarchical approach to investment in carbon emissions reductions. Reductions should firstly be sought through energy efficiency, followed by cleaner energy provision, and then through the use of renewable technologies. It is generally understood that the hierarchy offers the most cost effective route to achieving carbon savings. In addition, this hierarchy has the benefit of being mutually supportive, so that more energy efficient buildings require less energy from renewable sources. In this regard the design of a building should therefore allow for the maximum use of low carbon techniques such as optimising u-values and natural ventilation. Increasing the energy efficiency of a building in the first instance reduces its overall energy requirement and so makes it easier for a greater proportion of its energy demand to be met by on-site low and zero carbon technologies. This hypothesis will however be tested for each development group.

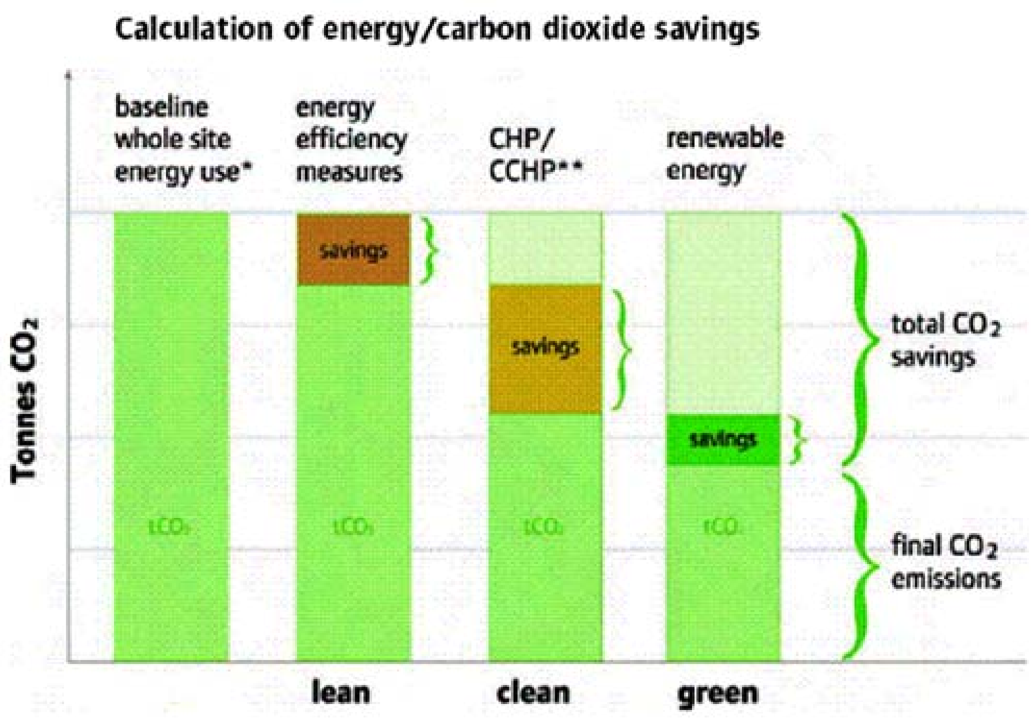


Figure 4.1 – The Energy Hierarchy

In testing the individual measures for all each development type, the accredited Standard Assessment Procedure (SAP) 2005 version 9.81/9.82 and National Calculation Methodology (iSBEM) version 3.4.a design softwares were employed.

The associated CO2 emission factors used within this report to determine carbon emissions and savings have been taken from the Building Regulations Approved Document L (Table 4.1).

Fuel	kg CO_2/kWh
Natural Gas	0.194
Biomass	0.025
Grid Supplied Electricity	0.422
Grid Displaced Electricity	0.568

Table 4.1 - Emission factors by fuel source (DCLG 2006)

The targets for CO_2 reductions from new developments were tested firstly from a technical feasibility perspective and then in terms of their financial viability. The following targets were tested:

- 5% reduction in total CO_2 emissions
- 10% reduction in total CO_2 emissions
- 20% reduction in total CO_2 emissions
- 40% reduction in total CO_2 emissions
- 60% reduction in total CO_2 emissions
- 100% reduction in total CO_2 emissions

The above targets were applied to each development group, in order to gain an understanding of what is achievable. Whilst the development groups identified largely related to major development, consideration was also given to what may be achievable in the case of minor developments, i.e. residential schemes of 9 or less dwellings, or non-residential schemes of less than 1000 sq. m.

4.1 Lean - Energy efficiency

Being lean is the first tier of the hierarchy, and seeks to minimise the energy requirements through better insulation and a more efficient heating system. As the first priority in the hierarchy energy efficiency measures should be incorporated prior to consideration of renewable or low carbon technologies.

The picture below illustrates typical heat loss in a residential property. Achieving optimum use of energy throughout a building's life requires both passive design to reduce the need for energy associated with controlling the environment and efficient controls to assist the occupant in their use of energy.

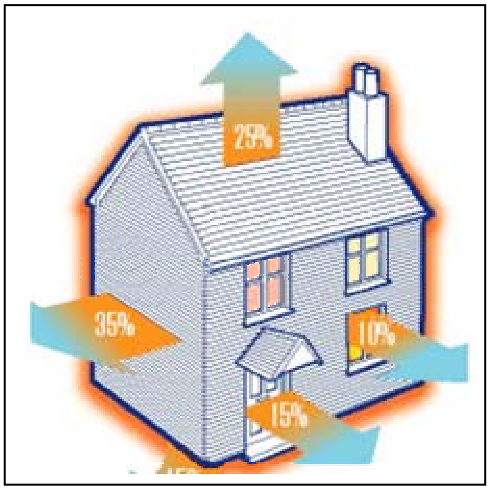


Figure 4.2 – Common heat losses
Source: Saveenergy.org

Energy efficient design is often the simplest and least costly measure to employ. Furthermore, any reduction achieved through energy efficient design will also reduce the level of savings which need to come from the often more expensive renewable/low carbon technologies.

This section provides an overview of the improvements that can be made to the building fabric in developments, together with their associated costs for the London Borough of Ealing. This is part of the exercise to understand the practical changes and examine what is feasible for each development tested. The example buildings used for this modelling exercise have all gone through the planning process and have been recommended for approval or are already approved.

4.1.1 Passive design (PSD)

Passive design is an important element of a sustainable building and it can be considered only at the design stage. The main objective of the passive design principles is to maximise comfort for people's living and working environment while minimising energy use. This means maximising the use of free, natural sources of energy, such as the sun and the wind, to provide heating, cooling, ventilation and lighting. A holistic approach is essential when passive design is considered as all aspects of a building design are interlinked.

Until recently the application of passive design principles was only implemented in residential buildings. However, the growing consciousness over energy conservation has made these principles to be now widely adopted not only in new developments such as schools, offices etc but also in existing buildings in an effort to reduce their monthly energy bills.

The main features of a passive design do not generally have any cost implications and this is due to an effective use of the most common building's features. Other passive design features can have an additional cost but provides the building with significant benefits such as reduce further the heating, cooling and lighting and on-going costs such as energy bills.

The following principles of passive design[7] that do not have cost implications and should be applied to a development during the design stages are the following:

a) Orientation to the sun to provide natural heating and daylighting. The orientation of a building has a significant impact on the amount of passive solar gain available. To maximise solar gain buildings should be generally orientated with the longest face within 30 degrees of south. South easterly orientation is generally preferable to south westerly as this maximises early morning gains and reduces the likelihood of overheating in the afternoons. Using dense materials in construction will enable the building to absorb heat during the day and release it slowly at night.
b) Room layout – Placing rooms used for living and working in the south facing part of the building, and locating storage, kitchens, bathrooms, toilets, stairways and the main entrance on the north side will make most effective use of solar heat and light and will reduce the need for artificial lighting or space heating.
c) Avoidance the overshadowing - Careful spacing of buildings should seek to minimise overshadowing of southern elevations, particularly during the winter when the sun is low. On sloping and wooded sites careful consideration must be given to siting to maximise solar access.
d) Window sizing and position - In housing, smaller windows should generally be used in north facing elevations. On the south elevation whilst larger windows increase solar gain this has to be weighed against greater heat losses in the winter and a risk of overheating

[7] Planning for Renewable Energy – A companion guide to Planning Policy Statement 22 (PPS22)

in the summer. Sloping roof lights facing the sun will increase the solar radiation received. There are more benefits to be gained from reducing the size and number of north facing windows than by increasing south facing ones.

e) Natural ventilation - This is particularly relevant to offices, schools and other public buildings. 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. This approach obviates the need for air conditioning (which can be up to four times more energy intensive than providing heating), and makes for a more healthy and pleasant building environment.

f) 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.

g) Landscaping - Landscaping, including the use of earth bunds, is often used as part of an overall PSD approach providing a buffer against prevailing cold winds and shading for summer cooling.

h) Conservatories and Atria – Carefully designed conservatories and atria can contribute to the management of solar heat and ventilation. To avoid problems of excessive heat gains and losses they should be designed and used as intermediate spaces located between the building and the external environment. Conservatories and atria can be designed to assist natural ventilation in the summer by drawing warm air upward to roof vents. They can also be used as heat collectors during the spring and autumn. The net thermal benefits of conservatories will however be lost if they are heated for use during the winter.

i) 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, the temperature of the unheated space being warmer than that outside.

j) Living Roofs - The installation of Green or Brown roofs can provide benefits, in terms of appearance, biodiversity, and surface water retention.

Features that might place an additional cost can include:

1. Increase the insulation thickness
2. Use of internal walls with high thermal mass
3. Application solar water heating
4. Use of heat recovery devices
5. Application of solar photovoltaic panels and other on-site power generation.

4.1.2 Materials

Building Regulations set the minimum thermal performance standards for a building. Improvements to the material selection and construction methods above minimum standards can significantly reduce the heating and cooling requirements of a building, but there is an optimum position between providing too much insulation and the building overheating in summer, and not enough insulation with perhaps higher heating requirements.

Materials with high thermal densities are able to store thermal energy and this ability to act as a "heat sink" can help to reduce peak heating in winter and high occupancy temperatures in summer. Lightweight, low thermal density materials do not have the same thermal response characteristics but their use can assist off-site fabrication and improve both build quality and construction time.

Heat escapes through all sorts of places in your home. Reducing how much heat escapes can make a significant difference to how much it costs to heat your home.

The changes examined in this modelling exercise focus on improvements to the insulation properties, i.e. the U-values, of the various building elements with the aim of reducing carbon emissions and assessing the feasibility in both residential and non-residential properties. In addition to reducing U-values, the thermal performance can also be improved by a reduction of thermal bridging (loss of heat through the building fabric by conduction), which can be achieved by using accredited construction details which limit the number of conductive materials connecting the inside of the building to the outside. The other opportunity is improving buildings' air-tightness – the reduction of heat loss because of buildings' 'leakiness'. This is also mitigated through better design detailing.

As most of the development types that will be checked in this study are new build, it was reasonable to assume cavity walls, loft insulation, double glazing, insulated floors, insulated doors, high efficient gas heating systems, new appliances etc. In refurbishments, however, of older buildings, improving the insulation can achieve high carbon savings.

For houses built until the 1930's[8] the main from of construction was solid walls with typical U-Value of 2.1 W/m2K, uninsulated solid floors, 100mm of loft insulation with U-Value of 0.4 W/m2K, partially double glazing with average U-Value of 3.5 W/m2K. These U-values have been applied after slight improvements in the building's elements throughout the years. External or internal wall insulation with thickness around 50mm to 150mm can be applied to this house type and reduce the U-Value to 0.30 W/m2K which is what is required by the 2006 Building Regulations Part L. External insulation requires a planning permission compared to internal insulation as it changes the appearance of the building. This is particularly relevant in conservation areas where restrictions applied to what measures can be applied. In terms of the total cost of the insulation for solid walls, the external insulation might cost around £10,500 to £14,500 including installation while the internal is in the range of £5,500 to £8,500[9] including installation. Extra loft insulation up to 250-300mm and floor insulation up to about 75mm in thickness, double glazing, drought proofing, low energy lighting and well insulated hot water cylinder can significantly decrease the heat losses through the building and increase the energy and carbon savings.

For houses built around 1970's[8] the main form of construction was cavity walls with U-Value of 1.4 W/m2K (65mm unfilled cavity) or U-Value of 0.42 W/m2K for filled cavity. These types of walls are amongst the easiest to refurbish in an energy efficient way as the cavity can be filled with insulation. Typical other construction elements include some loft insulation around 25mm, partially double-glazed windows with drought proofing. Likely improvements can include extra loft insulation up to 250-300mm, well-insulated hot water cylinder, floor insulation, low energy lighting, more efficient appliances and heating systems with improved controls.

Generally for refurbishments the requirement will be to achieve the limiting U-Values required by the 2006 Building Regulations Part L. However, with the new Building Regulations that will come in force in October 2010, the required limiting U-Values will be slightly improved.

Further reductions are achieved by increasing the efficiency of heating, ventilation, cooling and lighting systems and by supply of required energy from low carbon or renewable sources (see further on for more details).

The improvements considered in this chapter are based on the Energy Saving Trust's (EST) energy efficiency standards of 'Good', 'Best' and 'Advanced' (Table 4.2) and are limited to

[8] Source: EST – Domestic energy primer –an introduction to energy efficiency in existing houses (GPG 171) and Refurbishing dwellings – a summary of best practice (CE189).
[9] Prices taken from Energy Saving Trust, Home improvements and products, Solid-wall-insulation

improvements to the building fabric. Current 2006 Building Regulations U-Values are used for establishing the baseline. It is important to note that these scenarios were tested in order to find out what can be practically done in the near and long future. It is rather expected that a combination of different U-Values belonging to the different energy efficiency scenarios will be recommended by applicants.

The predicted CO_2 emissions from the dwelling/building (the Dwelling and Building carbon dioxide Emission Rate, DER and BER, respectively) should be no worse than the Target carbon dioxide Emission Rate (TER) as calculated for building regulations compliance.

Table 4.2 shows the details of the different energy efficiency scenarios.

Building Element	Building Regulations Part L 2006 Limiting U-Values Standards	EST Good Fabric Standards	EST Best Fabric Standards	EST Advanced Fabric Standards
Cavity Walls	**0.35 W/m2K**	**0.3W/m2K**	**0.25W/m2K**	**0.15W/m2K**
-Insulated Panel Thickness	~60mm	~70mm	~80mm	>80mm
Floors	**0.25W/m2K**	**0.22W/m2K**	**0.2W/m2K**	**0.15W/m2K**
-Insulated Panel Thickness*	~75mm	~90mm	~110mm	2no x 80mm
-Insulated Panel Thickness**	~50mm	~60mm	~70mm	~100mm
Roofs	**0.25W/m2K**	**0.16W/m2K**	**0.13W/m2K**	**0.15W/m2K**
-Insulated Panel Thickness*	80-90mm	100mm	100mm	100mm
-Insulated Panel Thickness**	85mm	135mm	85mm+90mm	145mm
Windows, roof windows, rooflights and curtain walling	**2.2W/m2K**	**D*/2.2W/m2K**	**C*/1.6W/m2K**	**0.8W/m2K**
-Insulated Panel Thickness	double glazing	double glazing	double glazing	triple glazing
Doors	**2.2W/m2K**	**2.2W/m2K**	**1 or 1.5 (if glazed)W/m2K**	**0.8W/m2K**
-Insulated Panel Thickness	n/a yet	n/a yet	n/a yet	n/a yet
-Indicative price (£/m2)	n/a yet	n/a yet	n/a yet	n/a yet
Other Parameters				
Air permeability (m3/m2/hr@50Pa)	10.0	5.00	3.00	1.00

Floors
*between timber floor joists
**under a concrete slab

Roofs
*Pitched roof loft flat insulating from the inside
** Flat roof insulating into a stripped-down concrete,steel or timber

Table 4.2 EST Energy Standards 2006 U-values (W/m2K), energy efficiency measures and indicative insulation thickness
***BFRC Rating band**
**The Advanced Standard has similar requirements to the Passivhaus standard
Source: Kingspan Insulation Limited, Rehau Limited

4.1.3 Glazing

The combination of frame material, number and thickness of glazing panels, the air gap, and the method of separating the panes produces the area weighted U-value of a window unit.

The current UK Building Regulations area weighted average requirement for is 2.2W/m2K which was used for establishing the baseline. As afore-mentioned, EST's Fabric Standards have been used to achieve the tested U-Values for all the development groups.

Double glazed windows have been used for both commercial and residential and commercial groups for the baseline; good and best fabric standards while triple glazed windows have been used for the advanced fabric standards. For the commercial buildings, SBEM allows the option of manually changing the glazing transmission factor which was assumed 0.8 for the baseline, good and best fabric standards, 0.65 for advanced fabric standards for south-east, south and east orientations and 1 for all the other orientations.

For the purposes of this study, two BFRC model windows, side hung next to fixed 1230 x 1480 mm white S706 casement and Geneo tilt and turn, have been assumed for the residential and commercial development groups.

Examples of the average weighted U-Value are set out in table 4.3 below.

Area weighted average	**2.2 W/m2K window**	**2.0 W/m2K window**	**1.8W/m2K window**
No of panes	Double glazed	Double glazed	Double glazed
Gap space	12mm	12mm	16mm
Gap fill	Air	Air	Air
Frame Material	Wood or PVC	Wood or PVC	Wood or PVC
Coating	Low e coating 0.15	Low e coating 0.05	Low e coating 0.05

Table 4.3 – Typical U-values for windows

The British Fenestration Rating Council has produced its own efficiency label that can help determine how well a product will perform as a function of:

- Helping conservation of heat within the building in the winter (U Value);
- Avoidance of solar gains in summer (g value); and
- Keeping out the wind and resisting condensation (L50 value).

Table 5 presents the BFRC rating which provides a rating on the basis of heat loss per square meter of glass per annum.

BFRC rating scale	BFRC rating (kWh/m^2/yr)
A	O or greater
B	-10 to < 0
C	-20 to < -10
D	-30 to < -20
E	-50 to < -30
F	-70 to < -50
G	Lees than 70

Table 4.4– BFRC Window rating scale

The rating is based on the following formula:

$$BFRC\ Score = 218.6 \times g - 68.5\ (U + L50)$$

g is typically 0.7 to 0.3, *U* is typically 1.0 to 4.2 and *L50* is typically 0.0 to 0.04
Scores are typically in the range of -200 to +10

4.1.4 Air Permeability

A significant proportion of heating energy is lost through air leakage from buildings (infiltration or air permeability). Typically this occurs where there is poor sealing at joins or at penetrations in the building. The building regulations recognise this in setting acceptable standards for air permeability. The regulation standard is 10m3/m2 at 50Pa. However, best practice standards are around 5m3/m2/hr. If the air permeability is below 3m3/m2/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.

For this study, air permeability was based on the Energy Saving Trust's (EST) energy efficiency standards of 'Good', 'Best' and 'Advanced' (Table 4.2). Current 2006 Building Regulations U-Values are used for establishing the baseline.

4.1.5 Shading

As buildings become more thermally efficient and air tight, the possibility of seasonal overheating increases. Integrating shading into the development can lower the risks of summer overheating and reduce the need for mechanical cooling. The use of natural and structural shading is an efficient method in reducing the possibility of overheating in summer, without restricting natural daylight.

Shading for a building can be in the form of external features, external louvrers, balconies and overhangs, or stepped elevations. Internal blinds can also assist to a lesser effect.

Movable solar protection shading was applied to most of the commercial buildings while balconies have been used as shading provision for the residential properties.

4.1.6 Lighting

Internal and external lighting schemes optimise daylight wherever possible and achieve the recommended lighting levels as recommended by SLL Lighting Guide 10[10]. Lighting controls need to be carefully selected to ensure security is not affected and minimise nuisance to occupants, whilst ensuring that lights are not left on for long periods in areas with transient occupancy. Motion sensor and photoelectric controls will be specified for different areas as appropriate. Moreover, lighting controls need to be sensitive to the occupant e.g. passive controls should only be installed in transient areas and lighting level controls only installed in areas where there is sufficient natural light.

Well-designed lighting schemes should:

- Use passive lighting controls to vary lighting levels according to occupational needs and availability of natural light;
- Match lighting levels to the task and/or use of the area;
- Ensure that only the most efficient luminaries, control gear and lamps can be used. Lighting provided within the commercial areas of the development groups should exceed the Building Regulation reasonable provision level of 45 luminaire-lumens/circuit Watt. New thin T5 fluorescent lamps achieve efficacies of between 80 and 105 lm/W, compact fluorescent lights

[10] SLL Lighting Guide 10: Daylighting and window design

can also provide efficiencies in the range 50-85 lm/W and should be installed with dedicated fittings where appropriate.
- Solar powered lighting should be considered in external areas where it is appropriate and not detrimental to the security of buildings or people.
- Enclosed areas with little or no natural light should consider the use of solar tubes that can also provide ventilation.

Different energy efficient lighting and controls have been used for both commercial and residential buildings for the different standards tested in this study.
More specifically for the residential buildings the following assumptions have been made:

- Baseline - 30% of low energy lighting (LEL)
- Good Fabric Standards – 50% of low energy lighting (LEL)
- Best Fabric Standards – 70% of low energy lighting (LEL)
- Advanced Fabric Standards – 100% of low energy lighting (LEL)

Prices will depend on the wattage, manufacturer and the retailer but a typical price for a 18W compact fluorescent lamp can be around £3.70[11]. Additional costs of the dedicated low energy fitting is in the order of £6-£12 excluding installation costs. Therefore the cost of installing the low energy fittings for the baseline is approximately £19, while for the good, best and advanced fabric standards the total approximate cost is £27, £35 and £46, respectively.

For the commercial development groups tested in this study the following assumptions have been made:

- Baseline - Compact fluorescent lamps (CFL) have been used without any controls
- Good Fabric Standards - Compact fluorescent lamps (CFL) have been used with controls in areas such as WC's, cleaner's rooms, plant rooms, lockers, substations etc.
- Best Fabric Standards - T8 (25 mm diameter) triphosphor coated fluorescent tube, high frequency ballast has replaced most of the compact fluorescent bulbs used in the good fabric standards in order to demonstrate the incremental increase in carbon savings. Occupancy sensing and stand-alone sensors have also been used for both lighting options.
- Advanced Fabric Standards - T5 (25 mm diameter) triphosphor coated fluorescent tube, high frequency ballast has been mainly used for main areas in all commercial buildings. However, T8 (25 mm diameter) triphosphor coated fluorescent tube, high frequency ballast and compact fluorescent bulbs were also used for areas with no constant occupancy. Occupancy sensing and stand-alone sensors have also been used for both lighting options as well.

4.1.7 Living Roofs and Walls

Living roofs in a broad term include green roofs, roof terraces and roof gardens. The term includes roofs and structures that may be accessible by workers or residents, and that may be intensively or extensively vegetated. Living roofs comprise two main types – green roofs and recreational roofs.

- Green roofs range from intensively vegetated (intensive) to extensively vegetated (extensive).
- Recreational living roofs provide amenity benefit.

Living roofs have many benefits including adapting and mitigating the climate change effects, improve the thermal performance of the building and reduce carbon dioxide emissions, reduce the urban heat island effect[12], enhance amenity value, conserving and improving biodiversity and

[11] Source: EST, CE61 – Energy Efficient Lighting – Guidance for installers and specifiers
[12] Urban Heat Island Effect (UHIE) is the increased temperature of a built-up area compared to its rural surroundings.

improve storm water attenuation. In the summer a green roof can typically retain between 70-80 per cent of rainfall run-off.

There is a perception that a building cannot have both green roofs and solar photovoltaic panels. Substantial evidence from Germany has proven that when both technologies are combined the green roof saves energy during the summertime while increase the efficiently efficiency of PV by reducing fluctuation of temperatures at roof level and by maintaining a more efficient microclimate around the PV Panels. The green roof serves as a natural cooling mechanism, thereby maintaining the panels' efficiency. By reducing the temperatures around the PV and by helping reduce the need for air conditioning in spaces beneath the green roof, the combination of the technologies should be as one of positive interaction and not one of competition in terms of use of roof space.

Living walls is an alternative to green roofs when the latter is difficult to achieve. They are generally made up of climbing plants and are constructed so as to provide for vegetation actually planted into the structure of the wall itself or some form of additional structure attached to the wall on which climbing plants are supported. They have the same benefits to green roofs and as additional they can improve the noise attenuation properties, the air quality and the visual amenity.

The cost of the green roof will vary depending on different factors such as the system used, the height of the building, number of intrusions, size and type of system, depth of insulation required, whether it is a warm or cold roof and many other factors. Intensive green roofs can vary in cost depending on the amount of vegetation cover and the type of vegetation. An indicative cost is £140/m2[13] inclusive of waterproofing and insulation. The use of large trees, furniture, planters and irrigation will increase costs.

Green roofs or walls have not been considered in this study but their incorporation will be sought wherever it is physically possible, in new build developments or major extension projects.

4.1.8 Ventilation and Cooling

As buildings become more airtight, the need for mechanical ventilation increases to maintain good air quality for the occupants and reduce the possibility of overheating in summer. The energy efficiency of the ventilation system can be improved, where applicable, by employing heat recovery devices, efficient types of fan motor and/or energy saving control devices in the ventilation system.

Mechanical systems require electrical power to operate, including power to the fans, any compressor(s) and transformer(s) and control and safety devices. The term 'specific fan power[14]' is used to compare the electrical energy use for different ventilation systems as installed (i.e. allowing for system resistance).

For most of the commercial development groups tested in this study, ventilation was provided as part of the main heating, ventilation and air conditioning (HVAC) system. Where natural ventilation was provided, such as warehouse and restaurant, mechanical extract fans have been assumed. The specific fan power assumed for the baseline and good fabric standards was set at 1.5 W/l/s while for best and advanced fabric standards was set at 1 and 0.9 W/l/s, respectively. There is however possibility for further reducing the energy consumption of the fans to 1.5 or 1 W/l/s. In addition, local mechanical exhaust ventilation set at 5 l/s/m2 was assumed in areas

[13] Design for London – Living Roofs and Walls – Technical Report: Supporting London Plan Policy
[14] The power consumption, in Watts, of the fan (plus any other electrical system components) divided by the air flow through the system, in Watts per litre per second (W/l/s).

such as WC and eating areas while the exhaust specific fan power was set at 1.5 W/l/s for the baseline and good practice and 1 and 0.9 W/l/s for the best and advanced practice. Heat Recovery units were also assumed for the best and advanced practice standards and more particularly plate heat exchanger with a 65% efficiency which is the most common type of such systems for commercial buildings. MVHR was assumed in all the commercial buildings except the warehouse and the restaurant.

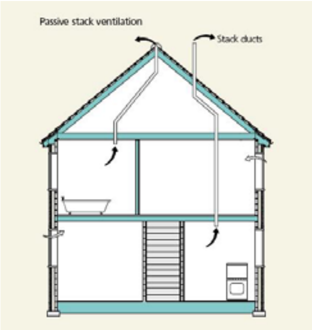
For domestic properties, there is currently a range of systems that are being used for providing ventilation and these include passive stack ventilation (PSV), intermittent extract fans and background ventilators, mechanical extract ventilation (MEV) and whole house mechanical ventilation with heat recovery (MVHR). For the baseline and good fabric standards, natural ventilation has been chosen with cross ventilation possible and the number of extract fans set at 2 for flats and 3 for houses. For best and advanced practice, standard mechanical ventilation with heat recovery was compared with mechanical ventilation with heat recovery using Appendix Q[15]. It became obvious from the results derived from the SAP software that by using Appendix Q to assess the effect of the MVHR to the overall energy performance, the electricity savings were significantly higher compared to the conventional system.

Table 4.5 presents the assumptions taken for the baseline and good practice and best and advanced practice standards. The system chosen was Ventaxia Sentinel Kinetic for best practice and Ventaxia Sentinel Kinetic Plus for advanced practice standards.

	Standard MVHR		Best Parctice		Advanced Parctice	
	SFP W/l/s	System Efficiency %	SFP W/l/s	System Efficiency %	SFP W/l/s	System Efficiency %
Flats (1 wet room)	2	66	0.72	92	0.56	92
Houses (2 wet rooms)	2	66	0.74	91	0.49	92

Table 4.5. MVHR specifications and assumptions used for the different scenarios

Passive stack ventilation is mostly applicable to new build of good practice and major refurbishments. A PSV system is a natural ventilation system and comprises vents (usually located in kitchens and bathrooms) connected by near-vertical insulated ducts to ridge or tile terminals on the roof. Warm, moist air is drawn up the ducts via a combination of the stack effect and wind effect. These systems do not require energy to run, have no direct running costs and are silent in operation. However, installation as a retrofit measure may be difficult depending on layout of the dwelling.



Typical unit installation prices for 3 bed semi can start from £1,300[16] dependant on ease of installation of ductwork.

A simple PSV system is not recommended for best practice standard. This is because the system is reliant on weather conditions (e.g. can under-ventilate in warmer weather), and the high level of airtightness required to achieve this standard.

Figure 4.3. Passive Stack Ventilation
Source: GPG268-Energy Efficient Ventilation in Dwellings

[15] Standard Assessment Procedure Appendix Q: Special features and specific data
[16] Source: Energy Saving Trust

Intermittent extract fans and background ventilators are actually electrical fans usually installed in bathrooms, kitchens and toilets to provide rapid ventilation. They are mostly suitable for new build of good practice and major and minor refurbishments where there has been a significant improvement in air-tightness. They are easy to install and provides rapid extraction of pollutants but are noisy. Typical unit installation prices can start from £150[17] dependant on size and method of installation.

Mechanical extract ventilation (MEV) system continually extracts air from 'wet' rooms. It usually consists of a central ventilation unit positioned in a cupboard or loft space ducted throughout the dwelling to extract air from the wet rooms. They are mostly suitable to new build of good and best practice, major and minor refurbishments. They are easy to install, provide continuous 'low-level' background ventilation and easy to understand. The good practice standard is met by following the relevant national standards and regulations. To qualify as best practice standard, the whole system must have a specific fan power of 0.6W/l/s or less when running at each of its settings.

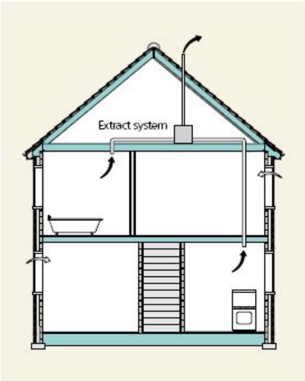


Figure 4.4. Mechanical Extract Ventilation (MEV).
Source: GPG268-Energy Efficient Ventilation in Dwellings

Whole house mechanical ventilation with heat recovery (MVHR) combines extract ventilation and supply of fresh air in one system. Systems incorporate a heat exchanger to recover heat from extracted air, which is then used to preheat incoming air. They are particularly suitable to new build of good, best and advanced practice and major refurbishments. These systems provide controlled preheated fresh air through the building and offers air filtration of the incoming air from outside while the heat exchanger reduces the heat demand.

Mechanical Ventilation with Heat Recovery requires a very airtight construction to function effectively. MVHR also requires ducting to be installed, which might present problems for retrofit. Fan motors should be low energy DC types, and the system sized to deliver a volume of air appropriate to the size of the dwelling. The good practice standard is met by following the relevant national standards and regulations. To qualify as best and advanced practice standard, the whole system must have a specific fan power of 1W/l/s or less when running at each of its settings and a heat recovery efficiency of 85 per cent or higher. Typical cost of installation for a 3 bed semi can start from £1,800 dependant on size of system and ease of installation of ductwork.

Further guidance on these issues is provided in Appendix E of Approved Document F.

[17] Source: Energy Saving Trust

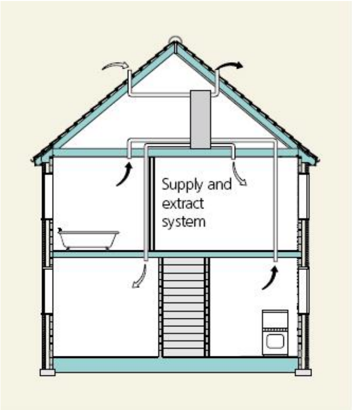


Figure 4.5. Whole Mechanical Ventilation with Heat Recovery (MVHR)
Source: GPG268-Energy Efficient Ventilation in Dwellings

Grid supplied air cooled chillers have been assumed as part of the HVAC system to provide cooling to most of the commercial development groups such as hotel, office, supermarket, school and restaurant. The seasonal energy efficiency ratio (SEER)[18] for baseline, good, best and advanced practice was assumed to be 2.5 (default value), 3, 3.5 and 3.5, respectively while the energy efficiency ratio (EER)[19] was set at the 3.12 (default value) for the baseline and 3.5 for all the other standards.

4.1.9 Heating

Energy efficient design should establish the appropriate local temperature for use. Prior to the construction of a building, heating needs to be designed appropriately in order to ensure that appropriate temperatures are achieved throughout as specified in the CIBSE design guide[20], to use lower temperatures for these areas which will not have a continuous demand for heating such as corridors, bathrooms, toilets, kitchens and storage areas. Each degree reduction in temperature will reduce the CO2 emissions associated with the development.

Gas fired boilers have been assumed for the commercial buildings for all practice standards with efficiencies starting at 89% for the baseline and 91% for good, best and advanced practice standards. Main gas heating systems providing both space heating and how water have been assumed for the residential properties with 90.3% efficiency for all practice standards. In addition, secondary heating systems have been assumed for the residential development groups due to the insufficient provision of the main heating system to heat all habitable rooms in the dwellings to the level on which the SAP is based (21°C in the living area and 18°C elsewhere). The efficiency of the secondary heating system was set at 63% (SAP default value) but a higher efficient system was assumed for the best and advanced practice standards, with an efficiency of 89%. As a general rule of thumb, any gas fired boilers installed at the development need to be of a high efficiency type with efficiencies above 90%. Prices of gas boilers with such efficiencies are in the range of £600 to £1,200.

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[18] Seasonal Energy Efficiency Ratio (SEER) is most commonly used to measure the efficiency of a central air conditioner. The higher the SEER, the more efficient the system. SEER measures how efficiently a cooling system will operate over an entire season.

[19] Energy Efficiency Ratio (EER) is the a measure of how efficiently a cooling system will operate when the outdoor temperature is at a specific level (35 ºC /95ºF). The higher the EER, the more efficient the system.

[20] CIBSE Guide B – Heating, ventilating, air conditioning and refrigeration, 2005

It should be noted that industrial buildings, such as warehouses, have generally minimal heat demand. Warehouses are most commonly electric heated but they might be gas heated especially when the offices are not part of the industrial building.

A number of heating controls were tested for the residential case studies but most of them were found unsuitable and without providing energy and carbon savings to the property or they did not even comply with the 2006 Building Regulations. Therefore, two heating control systems have been assumed for the residential case studies, the CBD Programmer, room thermostat and thermostatic radiator valves (TVR's) for the baseline and good practice and CBI Time and Temperature Zone Control for the best and advanced practice. As a general rule of thumb, turning down the room thermostat by 1°C could save you around 350 kg per year. A recent report from the Energy Saving Trust indicated that turning down the room thermostat by 1°C could save you up to 10% of your heating bill, around £54 per year.

The energy consumption of a building is largely dictated by occupant behaviour, which can be difficult to control, however passive controls and sensors on lighting and heating can assist in minimising energy use.

In regards to the prices of the above control systems, approximate prices for room thermostats can be between £10 and £30, while a thermostatic radiator valve costs between £5 and £20 and the time and temperature zone control's prices vary between £50 to £100. It should be noted that the prices of the above controls depend on the manufacturers and retailers.

4.1.10 Domestic Hot Water (DHW)

Dedicated hot water system has been used for all the commercial buildings with efficiencies starting at 80% for the baseline and good practice and 89% and 91% for best and advanced practice.

For the residential case studies any DHW storage assumed to be in pre-insulated cylinders with a minimum of 50mm of insulation for the baseline and good practice and 80mm for best and advanced practice and rapid recovery heating coils. Time control will ensure hot water is only provided during occupational periods. Cylinder volume was assumed 110 litres and represents the proportion of the hot water supplied to the dwelling from the community system.

Reduced flow rate taps for areas such as office areas, mess facilities, showers, will reduce the requirements for DHW and assist in energy and water savings.

4.1.11 Energy Management

The energy consumption of residential and commercial buildings is largely dictated by energy use that can be regulated directly through insulation, draught proofing etc, and by other energy uses such as small power, appliances, cooking, which can be regulated indirectly through a variety of measures.

Most of the accredited softwares that are currently used for demonstrating compliance with Building Regulations Part L do not give the option to the user to determine the energy rating for non-regulated energy use but they provide an indication of the non-regulated energy use based on the building type. The results from this study showed that a significant proportion (~40%) of the overall energy consumption of a building derives from non-regulated energy use.

Because of the limitations of the accredited softwares currently in the market and the difficulty to monitor and influence the non-regulated energy use through the planning process, it was suggested that measures such as Energy Management Systems (EMS), particularly applicable to commercial buildings, smart metering, intelligent controls and motion sensors, photoelectric controls and timers on lighting and heating will be encouraged in order to minimise the overall energy use and especially the non- regulated.

When building occupants can identify the cost of energy waste, it assists in changing their behaviour. Smart metering provides this information in simple form to ensure that occupants are aware of the cost associated with leaving equipment and lighting on at night and during periods when they are out of the building.

Building Regulations require that in non domestic buildings, metering enables at least 90% of energy consumption of each fuel to be assigned to specific end uses. Taking this further and installing "smart" metering enables users to understand how and when they use energy to assist in changing behaviour and habits. Smart metering provides half hourly consumption data and can identify anomalous energy use.

4.1.12 Appliances

The amount of energy used by most electrical appliances such as fridges, freezers, washing machines and dishwashers can vary significantly. The energy efficiency of the product is rated in energy levels ranging from A to G on the outside label. 'A' stands for the most energy efficient and 'G' for the least energy efficient.

An "A" rated fridge will typically use 60% less energy and produce approximately 125 kg less CO_2 per year than a "D" rated unit. Recently, also the qualification A+ and A++ were introduced for refrigerated appliances.

All planning applications proposing residential developments will need to ensure that "A" rated appliances will be incorporated on the residential units.

4.2 Clean – Combined Heat and Power (CHP)

A combined heat and power system (CHP) or cogeneration is the simultaneous generation of both heat and power (thermal energy and electricity). This is achieved through recovering heat generated in the production of electricity, which can be utilised in providing space heating and hot water.

The most common fuel used in the UK to power a CHP engine is natural gas although LPG, biogas, ethanol, methane, hydrogen, biofuel, oil or any fuel that can drive an engine can be used. When CHP operates on fossil fuels, e.g. gas, diesel, is not considered a renewable technology. A biomass CHP, however, is considered to be a renewable energy technology but it is only suitable for developments with larger heat and electricity demands.

A CHP system uses on average 35% less primary energy compared to conventional heat-only boilers and power stations approaching efficiencies as high as 75%. Although not a renewable technology, except if biomass is being used, CHP is considered very efficient, reducing carbon emissions related to a site's energy consumption while providing electricity and heat to occupiers at competitive costs and with enhanced security of supply.

Figure 4.6 – CHP generation vs Conventional Power generation.

Currently in the market there are three categories of CHP according to its electricity output. The general principals are the same for all sizes and different definitions for large, small, mini and micro CHP ranges most of which overlap.

- **Micro CHP** – This type of CHP can serve small groups of dwellings and small commercial applications, typically providing around 5kWe output and 10-15 kW heat. Examples of current application are sheltered housing, residential care homes. Smaller units of around 1kWe based on Stirling engines are planned for the market.

- **Mini CHP** – This type of CHP has similar applications to the micro-CHP with outputs ranging from 5kWe to 500kWe. Due to output range, however, it can also serve hospitals, university campuses, data centres, leisure centres, prisons etc.

- **Small scale CHP** – Small-scale CHP units are in a range of providing outputs between 500kWe to 5MWe and they are usually come with all components assembled ready for connection to a building's central heating and electrical distribution systems. These systems can provide significant benefits in new buildings, however they are most commonly retrofitted to existing building installations. This type of system can also be utilised for community eating and district heating systems often serving many different types of buildings within a variety of sectors.

- **Large scale CHP** – Large-scale CHP units have electricity outputs above about 5MWe and are designed specifically for each application. Their application is more common in large multi-building developments (e.g. hospitals, universities). Its applications can also include community heating which is a particularly efficient means of supplying large portfolios of domestic and/or commercial properties;

In order for the use of CHP to be economically viable and provide the maximum environmental benefits, it is essential to run for as many hours as possible with high and simultaneous demands for electricity and heat throughout the year.

Small scale CHP can be applied anywhere where there is need for electricity, heat or cooling and on-site emergency generation such as hospitals, large nursing homes, bank IT data centres and large call centres. In addition, in locations which have a steady electrical and heating requirement the CHP can be matched to give optimum efficiency such as paper mills. Another possible application of small scale CHP is in sites where there is a continual heating or cooling requirement but the electrical requirement may vary such as in factories. In this case the excess electricity can be exported to the national grid and the supply company charged accordingly. An increasingly popular application is community heating an cooling projects such as at university campuses where a number of local buildings can be fed from a central CHP providing heating and cooling. Finally, in CHP applications where there is variable heating or cooling load thermal storage can be used in underground vessels when the demand is low which is then used to supplement the requirement when the heating or cooling load is high. The vessels can be filled with granite chips or come other medium with high thermal mass and the hot or cold water from the main system fed through them to either heat or cool as required.

A CHP system does not differ in its physical appearance from a conventional boiler and therefore when installed in a unit, a gas supply and a flue will be required. They can be placed in separate buildings or within the building if there is sufficient space and therefore should not be visible. If biomass will be used to fuel the CHP system, then storage and adequate space for the fuel need also to be considered.

Another advantage of CHP systems is that they can also provide cooling. The process is called trigeneration (CCHP) and means that the unit can provide three energies, electricity, heat and chilled water. Chilled water is achieved by incorporating an absorption chiller into a Cogeneration system. Absorption chillers take the waste heat from a Cogeneration plant to create chilled water for cooling a building.

All CHP should be designed to comply with the Quality Assurance for CHP, CHPQA scheme to achieve Climate Change Levy exemption.

Prices depend on size and location and vary by installation, but a typical system for small commercial premises will cost between £30,000 and £35,000 fully installed. In terms of running costs, fuel is the main issue to consider while good maintenance underpins economic outcome, maximising availability and minimising downtime. Maintenance is nearly always contracted out to a specialist company, usually the CHP supplier itself.

4.3 Community Heating

In recent years, the preference has been for all buildings and apartments to have their own boiler for space heating and hot water. Lots of small boilers running at part load for large parts of the year is very inefficient use of energy and so community heating systems are now encouraged by London planning policy.

Community heating provide all of the domestic hot water and space heating from central boilers and these large boilers operate at much higher efficiencies reducing total gas consumption and hence associated emissions of CO_2.

To obtain greatest benefit from community heating, it is important that distribution and pumping losses are minimised and the location of the heating plant must be considered early in the design.

The cost of supplying heat to occupiers needs to be recovered. The use of remote metering linked to central billing system can automate this task, reducing management time and ensuring timely receipt of revenue. In residential blocks the cost of utilities may be included in the rent. This reduces the need for metering but also reduces occupants' incentive to save energy.

Community heating will be also encouraged by Ealing Council with intention to be future proofed for potential connection to decentralised energy networks. This will facilitate the process of connecting this system to such a network instead of replacing individual boilers with a communal heating system.

4.4 Green – Renewable technologies

This section provides an overview of the renewable energy and low carbon technologies which have been considered to achieve significant CO_2 emissions targets. These are technologies that either use renewable sources such as wind, solar, geothermal, biomass or fossil fuels, but at a higher efficiency than conventional technologies. Although low carbon technologies such as Combined Heat and Power (CHP) and district heating are now placed higher in the energy hierarchy than renewable energy sources, they should only be considered once all appropriate and feasible energy saving measures have been applied.

For each technology, a short description and the design requirements, to be considered by developers when assessing the feasibility of these technologies, are presented.

4.4.1 Wind Energy

Wind turbines produce electricity by using the natural power of the wind to drive a generator. Recognition of the value of wind energy as a low cost, clean source for electricity is continuously increasing.

All wind turbines place a rotor into the wind flow. This rotor is turned by the wind and this rotary motion is then connected to an electricity generator. The energy is determined by the wind speed which vary between heights above the ground. Mostly wind turbines are placed in uninterrupted wind flows away from tall trees or even designed to be mounted on buildings. Wind turbines need to be orientated towards the prevailing wind, southwest.

A desk-based assessment was undertaken on wind speeds at the different sub-regions within the borough. These comprised the DTI's 'NOABL' UK wind speed database which is offered as a free download from the British Wind Energy Association (BWEA) website[21]. It contains estimates of the annual average wind speed throughout the UK at $1km^2$ resolutions for heights of 10m, 25m and 45m above ground level. The data is the result of an air flow model that estimates the effect of topography on wind speed, but does not take into account local thermally driven winds such as sea breezes or mountain/valley breezes. Variations in local surface roughness caused by buildings, trees, etc are also ignored.

Table 4.6 shows the maximum average wind speed identified for all regions in the borough for heights 10, 25 and 45 metres above the ground. There is therefore sufficient wind in Ealing to support wind technology.

Maximum Wind Speed	
10m agl (in m/s)	5.1
25m agl (in m/s)	5.8
45m agl (in m/s)	6.3

Table 4.6. NOABL Maximum Wind Speed at Ealing Borough for different heights above the ground

There are two main types of wind turbines: horizontal and vertical axis turbines. Free-standing horizontal axis wind turbines require a large area of land which is normally limited in urban environments. An alternative to free-standing horizontal axis turbines can be the smaller free-

[21] http://www.britishwindenergy.co.uk/noabl/index.html

standing vertical axis wind turbines which do not need to face into the wind and have smaller footprints.

Roof-mounted wind turbines are more appropriate for urban environments and they contribute to the overall energy requirements by designed to make best use of the wind flows around the building while generating small amounts of electricity.

Wind turbines have a large number of characteristics that has a potential planning impact. The most important are the size and height, the mounting method, the effect of potential noise, colour and reflectivity, vibration and visual intrusion, electromagnetic and electrical interference, shadows and reflection, access for installation and maintenance and birds and animal strike. Additional forces on structures and available roof space need also to be considered for roof-mounted wind turbines.

Figure. 4.7 - Vertical axis wind turbines and roof mounted turbines in low and high rise buildings

Most wind turbines start generating electricity at wind speeds of around 3-4 metres per second (m/s); generate maximum 'rated' power at around 15 m/s (30mph); and shut down to prevent storm damage at 25 m/s or above (50mph)[22].

Generally wind turbines tend to be more suitable to low density developments such as schools, industrial and business parks. However, they are also appeared in urban environments but in order to provide the maximum of electrical generation, there should be away from nearby obstacles which might reduce the wind speed or create turbulence. These include buildings, trees or hills. An ideal site is a smooth hill top with a clear, open stretch to the prevailing wind.

Prices for wind turbines vary according to the size and type of the system and location. Micro turbines, which are generally in the range of 1kW will cost around £1,500 upwards installed according to the Energy Savings Trust. Bigger in size turbines, ranging in size from 2.5kW to 6kW can cost from £11,000 up to £25,000. Costs include wind turbine, mast, inverters and installation.

4.4.2 Solar Photovoltaics (PV)

Photovoltaic (PV) cells operate by converting energy from the sun directly into electricity. Solar PV can be connected to the main electricity grid by connecting the system through an inverter. There are three main types of solar PV cells: monocrystalline and polycrystalline and thin film

[22] BWEA

amorphous silicons. Monocrystalline silicon cells tend to be more expensive, compared to the other two types, due to it's good efficiency and the energy intensive processes used to grow the crystals. Thin film amorphous silicon cells are the cheapest to produce but the current methods of production yield lower performance cells. The electrical output from a cell is usually few watts.




Figure 4.8 Solar PV panels   Figure 4.9 Thin Film Solar PV   Figure 4.10 Thin Film Solar PV   Figure 4.11 Solar Roof Tiles

To provide a higher, more useful amount of electricity, multiple cells are connected together to form a PV module. All types of PV system are measured according to their peak power rating which is measured in kWp (kilowatt peak). This is a guide to how much power the module produces under standard test conditions: it measures the power produced under 1kW per m^2 of light. The more efficient the module, the smaller the array needed.

Table 4.7 presents the different efficiencies for each cell and the corresponding efficiencies when the cells are connected to create a module as well as the required areas of panel to produce the same output.

PV Cells	**Property**		**Average Area Required**[23]
	Cell efficiency (%)	*Module Efficiency (%)*	*m^2 to mount 1kWp*
Monocrystalline silicon	13-17	12-15	8
Polycrystalline silicon	12-15	11-14	10
Thin Film amorphous silicon	5-10	4-7.5	20

Table 4.7 Efficiencies of the three main types of PV Cells.
Source: DTI – Photovoltaics in Buildings

Solar PV panels can be installed vertically, horizontally or on an incline, on building roofs, or as a part of the cladding. The highest efficiencies are achieved when they face south/southwest with an inclination of approximately 30º to the horizontal and are not positioned where it will be shaded for large parts of the day. Typical panel outputs range from 700-900 kWh/m2/annum. The panels will generate electricity in most daylight conditions. PV panels typically have an electrical warranty of 20-25 years and an expected system lifetime of 25-40 years.

[23] London Renewables Toolkit

In theory any building with an electrical demand can apply solar photovoltaic panels subject to roof availability.

The cost of photovoltaic systems tend to range between £5,000 and £8,000 per kWp installed. It is currently considered the most expensive renewable technology that should not be expected to achieve financial payback within their lifetime. However, this is expected to change, as the requirement for incorporating the technology to meet the different levels of the Code for Sustainable Homes will continuously increased.

4.4.3 Solar Thermal

Solar hot water systems use a solar collector to absorb heat from the sun to provide heating for domestic hot water. Water is pumped through the solar collector and is heated by the sun's power. This heated water then flows through a heat exchanger, warming the water stored in a solar hot water cylinder.

There are two types of collectors, flat-plate and evacuated tube. Although evacuated tube collectors give higher outputs and are more useful in cooler climates with less direct sunlight, flat plate collectors are considered to be the predominant type of collectors as they are currently the most cost-effective type.

Figure 4.12 Flat Plate Collector

Figure 4.13 Evacuated Tube Collector

The systems can usually provide all the hot water requirements during the summer and require a top-up from the main heating system during the winter months as the panels give a lower output. Solar panels are compatible with most existing hot water systems, but there will be cases where a new cylinder that is tall and thin with two coils, and ideally big enough to hold two days worth of hot water might be required. It is more difficult with a combi boiler. If you have a combi boiler it is important to check with the manufacturer that it will accept pre-heated water.

Solar collectors can be mounted onto buildings in a wide variety of ways including roof-mounted, integrated into a wall or placed on a mounting superstructure if a flat roof is available. It is also possible to mount the system on the ground if a suitable area of un-shaded space is available. To maximize the energy that the systems will produce, it is important the systems to face south/southwest at an incline of approximately 30° and be free of overshadowing such as trees, buildings and chimneys.

As most solar hot water systems are retrofitted onto the roof or a wall of a building, the surface of the hot water panel is around 10cm above the roofline. Space for the hot water tank and additional forces on the roof due to strong guts of wind need to be considered. As a rule of thumb you need between 1 and 2 m^2 of panels per person.

Typically panel manufacturers predict outputs of approximately 400-700 kWh/m^2/annum.

Solar hot water systems are mostly applicable to buildings such as year-round hot water demand such as low-density housing, hotels, restaurants (if available space to place the panel). Solar thermal systems tend not to be compatible with hot water generated technologies and are preferable implemented with electricity generated technologies such as wind turbines or solar PV.

Solar thermal systems prices range from £1,000 to £8,000. The cost will vary a good deal from one contractor to another, and will depend on the type and quality of the panels, whether scaffolding is required, and how easy it is to integrate into the existing plumbing system. Evacuated tube panels are generally more expensive than flat plate panels, but you need a smaller surface area.

4.4.4 Biomass Heating

Biomass is considered a renewable energy source as the CO_2 released in the transport and during combustion is offset by the CO_2 absorbed from the atmosphere during the plant growth stage.

Biomass heating is a well-proven technology and it can usually involve the use of room heaters or stoves for domestic applications and larger boilers and automatic wood chip boilers for very large commercial or industrial applications.

Generally speaking, biomass is more applicable to lower density housing areas due to fuel supply and storage issues although it only covers the space heating requirements. Alternatively, a boiler system is available to provide the heat and water demand for all type of applications with efficiencies typically between 80% and 90%.

Consideration needs to be given at an early stage to what type of fuel will be used, how it will be sourced and the space heating required for delivery and storage. These three factors usually have a decisive role in the operational costs of the system.

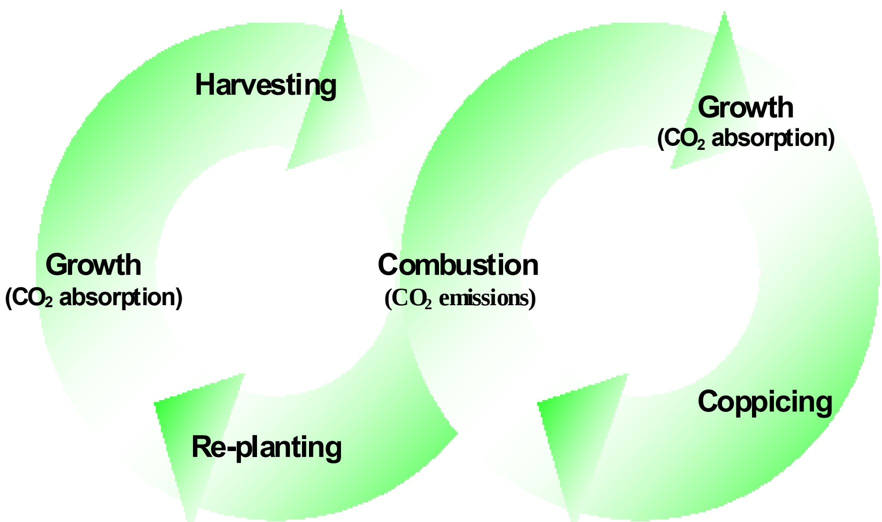

Figure 4.14 - Biomass wood chip and wood pellet cycle

Wood fuels are now commercially sourced into three main forms, logs, wood pellets and wood chips. Although wood pellets are more expensive, they are recommended in preference to other biomass fuels, as they are dense, have low moisture content and require less storage space. Logs are considered to be the cheapest and easiest to access but they are not as energy efficient as pellets and therefore more wood is required to produce the same amount of heat/energy.

Sufficient space for the boiler and the auxiliary equipment e.g. buffer tank, fuel transfer, gas boiler must be ensured. For safety reasons, the fuel storage and the plant room need to be separated. The boiler room should also allow for adequate space for maintenance and repair-work.

Fuel storage is another important factor to consider when a biomass boiler is being installed. This will depend on the type of fuel, the fuel demand, the handling system (manual or automatic feed) and the reliability of delivery. The most common types of fuel storage are the hopper or fuel silo, which can be located just outside the building in a least sensitive, but accessible location or alternatively in an underground lined pit. Fuel silos are used mainly in cases where there is sufficient space or in cooler regions as where the heat demand is higher. Fuel silo's advantage is that they remove the need for daily handling compared to common hoppers where they do require more attendance for cleaning and periodic removal of ash from the boiler room. In addition to this, a fuel silo is also used in biomass CHP schemes due to the quantities of fuel required to operate these systems.

Careful design of the fuel storage means fewer deliveries and less CO_2 emissions from transport.

The fuel is usually delivered to the site by lorries, and then either tipped or blown into the fuel store. Access is required for delivery of the fuel and vehicle access and parking arrangements need to be considered in the early design of a development.

Without proper design and careful selection of equipment, the combustion of biomass can impact local air quality, particularly Nitrous Oxides and particulates.

The selection, location and installation of the chimney and flue pipe need also to be considered as they determine the efficiency and operation of a biomass system.

Table 4.8 presents a summary of the woof fuel characteristics available currently in the UK market.

	Logs	**Chips**	**Pellets**
Properties (typical)			
Moisture Content when used	20 - 25% (air dry)	20 - 30% (small scale) 30 - 50% (larger boilers)	5 - 10%
Energy Content	3 - 4 MWh/tonne	2.5 - 3.5 MWh/tonne	4.8 - 5 MWh/tonne
Financial			
Typical price	£ 30 - 100/ tonne	£ 40 - 80/ tonne	£ 140/ tonne (bulk) £ 180 - 200/ tonne (bags)
Typical energy cost	£ 8 - 25/ MWh	£ 10 - 22/ MWh	£ 28 - 42/ MWh
Practicalities			
Suitable boilers	10 - 80 kW	30 - 10,000 kW	30 - 500 kW
Storage facility	Covered area, 2 years' fuel	Bin, bunker or silo: several weeks' supply for small scale	Vented room or flexible tank; 3 months' supply or more
Typical storage volumes	2 years, seasoning	(1 month peak load) 6 deliveries/ year	(for 3 deliveries/ year)
Handling	Manual; forwarder, log processors for large volumes	Front loaders, tippers; automated fuel feed	Bags - manual; tanker supplies us blowers; fuel feed automatic

Table 4.8 Wood Fuel Characteristics[24]

Biomass boilers are more applicable to low density housing areas due to fuel supply and storage issues. However, there are automatic woof chip boilers which are designed for very large commercial and industrial applications and rooms heaters or stoves for domestic applications.

Biomass boilers' compatibility with other low carbon technologies is limited. As a rule of thumb, biomass boilers tend to provide favourable savings when combined with electricity-generated technologies and not when combined with heating and hot water generation technologies. It might be more favourable however when biomass heating is used as top-up to the main heating system.

The prices for biomass boilers depend on system and fuel choice. Automated wood pellet stoves 5-7kW in output range from £2,000 - £4,000. Boilers are in the range £3 - £16k including installation, flue and commissioning.

4.4.5 Geothermal

Geothermal systems extract the low-grade heat found at relatively shallow depths within the earth's crust and utilize heat pumps to convert it into heating and cooling. These systems exploit the earth's temperature, which remains reasonably constant throughout the year (temperature of the earth at about 1.5m deep is 11-12 °C.

The most common application of ground source heat pumps (GSHP) is currently the provision of space heating. However, water heating and space cooling are also included in the GSHP's applications.

Heat pumps are not considered strictly a renewable technology, as they require electricity for their operation with resultant CO_2 emissions. However, this technology has the potential to become a zero carbon technology if electricity could be generated by another form of renewable energy. These systems are very energy efficient due to their efficiencies, which are indicated by their "Coefficient of Performance" (CoP), and can produce four or five times the amount of heat energy for every unit of electrical energy needed.

The technology operates on the same principle as refrigerators, transferring energy from a cool place to a warmer place. GSHP's can be broken down into three main components including the heat pump, the heat distribution network, either underfloor heating or radiators, and the heat source. The most efficient heat distribution system is underfloor heating as it operates better at a low temperature compared to conventional or modern radiators.

There are two types of geothermal installation - open loop and closed loop. Open loop systems require certain geological conditions, are considered typically as more efficient systems, and often used for large cooling loads. Closed loop systems circulate a fluid around a heat exchanger comprising of a series of pipes in boreholes or alternatively a horizontal network of pipes, extracting low-grade heat from the ground. The main criteria that determines the capacity of the closed loop system is the thermal response of the soil and the area available for the heat exchanger.

Borehole systems typically require 6 - 9 metres between each borehole, and so the available area will partly determine the capacity of the system. The alternative is to lay the pipework

[24] Energy in Industry and Buildings (June 2007) Fundamental – Series 5, Module 02, Produced in association with Energy Saving Trust "Biomass Boilers".

horizontally in a grid much closer to the surface level. Typically this grid, or heat exchanger, will be laid about 1.6 metres below ground level using polyethylene pipes.

In a horizontal system the majority of the heat exchanger should be under open land where it can be recharged by sunlight. For this reason, horizontal systems are not generally feasible for urban schemes where the land is not available.

Where foundation piling is used in building construction, the heat exchange pipework can be integrated into the piles to reduce the costs associated with drilling

Figure 4.15 Installing ground loop

Figure 4.16 Drilling a borehole

For the development groups identified, a GSHP with CoP of 4 and closed loop was assumed.

Ground source heat pumps tend to be better suited to new energy efficient housing or commercial applications and are less suited for retrofitting to existing dwellings. If ground source heat pumps are retrofitted, it is normally beneficial to be in conjunction with measures to reduce heat demand. They can be particularly cost effective in areas where mains gas is not available or for developments where there is an advantage in simplifying the infrastructure provided. Prices will depend on the size of pump and the distribution system. In a well insulated domestic property prices might range between £6,000 to £9,000 including supply and installation of a horizontal ground loop, heat pump and buffer cylinder.

As for biomass heating, ground source heat pumps tend to be more favourable when installed with electricity generated technologies as the installation of two technologies, which provide the same outputs, cannot be compatible as they won't offer extra savings.

4.4.6 Air Source Heat Pumps (ASHP)

Air source heat pumps (ASHP) operate similarly to ground source heat pumps with the only difference that the heat is being extracted from the outdoor air, rather than the ground. Their main application is the provision of space heating and hot water but they can also provide cooling.

Due to the variability of the air temperature these systems are not considered as efficient as the ground source heat pumps as the efficiency and capacity of the heating mode decrease with decreasing outdoor air temperature and the efficiency and capacity of the cooling mode decrease with increasing outdoor air temperature.

These systems are generally cheaper compared to ground source heat pumps, as they do not have high installation costs including extensive digging or drilling of the ground. They operate most efficiently when supplying at lower temperatures, typically up to 35^{o}C, and are therefore more effective with air cassette units.

ASHP can either be installed on the roof or the external plant area. When they are placed within a loft area, it helps boost the efficiency and might also be used as a method for heat recovery from exhaust systems such as kitchen and bathroom extractors. The heat recovery occurs when the units are in cooling mode.

Air sourced pumps typically provide up to 3 to 3.5 units of heat for every unit of electricity supplied. This is termed the Co-efficient of Performance (COP) and shows how many kW heat produced per kW electricity consumed. They are more applicable to any building with heat and/or cooling demand either new or existing. They are generally much cheaper than GSHP and their prices range between £3,500 to £11,500 excluding the distribution costs and can vary with property and location.

In terms of compatibility, ASHP are falling in the same category as GSHP.

5 Feasibility - Borough wide analysis

5.1 Geographical feasibility of technologies

This section follows on from the previous chapter, be green, where a detailed description of each technology was given and presents a general assessment of the feasibility of individual technologies based on the geography of the borough – typography, geology, wind speeds, flood risk etc. It should be noted that although a general assessment can be provided, much of this will vary on a site by site basis.

5.1.1 Wind Energy

Wind energy is a well and established technology in UK. Wind turbines is the technology which harnesses the energy from the wind and they are normally seen on hill-tops and, increasingly, out to sea. Generally this technology works better in high wind speeds and relatively smooth airflows: the technology matches the conditions where they are sited. Stand-alone wind turbines will be mostly seen in areas with high wind speeds and hill-tops.

However, urban areas can be very different. It is a general conception that wind turbines are better suited in low density areas as well as business and/or industrial parks due to the absence of surrounding buildings or other features which might cause turbulence and wind speed reduction. There are however, some sites in urban environments such as parks, riverbanks and edge-of-town areas which might have relatively high wind speeds and low turbulence. The challenge of urban wind turbine design is to harness these mixed wind conditions in useful ways.

Ealing borough is an area with low topography, however, the results from the desk based assessment showed that the wind speeds in Ealing vary, but typically can be expected to be around 4.7 to 5.1m/s at 10m above ground level, 5.5 to 5.7m/s at 25m above ground level and 6 to 6.3m/s at 45m above ground level.

Within the borough, the locations that would be more suitable for stand-alone wind turbines because of their higher ground are around Horseden and Hanger Lane areas. One of the most important milestones in any wind project in Ealing will be to secure a determination from the Federal Aviation Administration (FAA) that the project does not adversely affect air traffic or radar systems. Areas which might be more difficult to obtain consent for installing a wind turbine are located towards the south west of the borough covering Southall Broadway, Southall Green and Norwood Green.

There are also complications with the physical location of wind turbines. In order to contribute to reducing a development's emissions, all low carbon electricity generating technologies must be connected to a development by dedicated cables. This effectively limits the distance from the development to a few hundred metres at most. The table below gives an indication of the space requirements for a range of wind turbines:

Turbine output	Nominal Physical dimensions	Minimum distance from homes to avoid problems with noise
<2kW	1m dia, roof mounted	Roof mounted
10kW	3m dia, 10m mast	30m
50kW	7m dia, 20m mast	100m
200kW	15m dia, 40m mast	200m
1MW	30m dia, 60m mast	300m
2MW	40m dia, 60m mast	400m

Table 5.1 Space Requirements for wind turbines

Another significant milestone for placing wind turbines in the borough will be the extensive number of protected areas (including open spaces). Exception to the above can include buildings that are already located in Green Belt and Metropolitan Open Land where the installation of wind turbines or other alternative renewable options do not have a significant impact on the wider area or they do not alter the existing building's footprint.

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 is another option which can be investigated specifically in urban environments and can provide small but significant amounts of electricity. There are however several issues to consider which are the following:

- Increased turbulence might be an issue which can result in higher stresses on the turbine and lower energy capture for any given wind speed.
- Safety issues and lower noise generated need to be applied as there will be more people living and working near the turbine.
- Transmission of vibrations into the structure of the building need also to be limited.

Potential constraints for the application of this technology in the wider area of Ealing could be the following:

- 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.

Although all the different types of wind turbines have been investigated in this study, a wind feasibility assessment and site survey will always be required in order to demonstrate the feasibility of the technology to each proposed location.

5.1.2 Solar Energy

It is evident from the figure below that there is sufficient solar gain in southeast England and hence in the London Borough of Ealing. Figure 5.1 shows the annual cumulative solar irradiation in the UK in kWh/m^2. It also shows that London should benefit from an annual irradiation providing on average of 1,100kWh/m2, which is sufficient for the efficient operation of solar thermal collectors or solar photovoltaic panels.

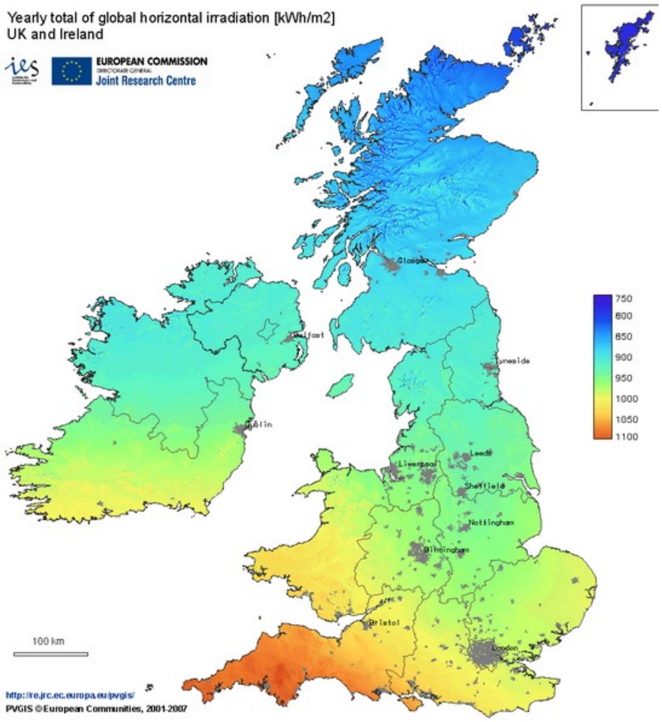

Figure 5.1 Map showing average solar radiation on a 30° incline facing due south
Source: PVGIS –European Communities, 2001-2007 (http://re.jrc.ec.europa.eu/pvgis/)

More specifically for solar photovoltaics technology the annual irradiation for London is approximately 3090 kWh/m^2 at 36 degrees, which is the optimal inclination angle. Table 5.2 and figure 5.2 show the monthly and daily solar irradiation for London, respectively.

Month	Irradiation at inclination: (Wh/m2/day) Opt. angle
Jan	1235
Feb	2007
Mar	2758
Apr	4107
May	4657
Jun	4669
Jul	4817
Aug	4491
Sep	3466
Oct	2441
Nov	1487
Dec	880
Year	**3090**

Table 5.2 The table presents the monthly solar irradiation at 36 degrees inclination for London. Source: http://re.jrc.ec.europa.eu/pvgis/apps/radmonth.php?lang=en&map=europe

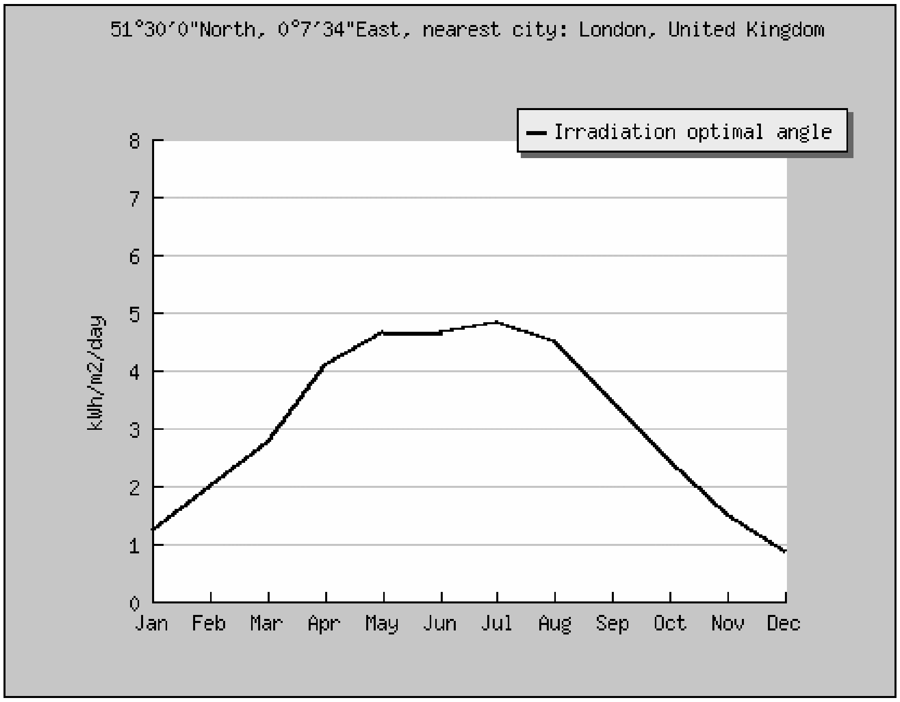

Figure 5.2 The graph presents the daily solar irradiation at 36 degrees inclination for London.
Source: http://re.jrc.ec.europa.eu/pvgis/apps/radmonth.php?lang=en&map=europe

It is obvious that the solar gain reaches its optimum during the summer months and particularly in July. However, this will not prevent solar photovoltaics to harness the energy from the sun even in days when the sky is overcast. This is a significant advantage of the solar PV technology against solar thermal technology which requires direct sunlight. It should be noted though that the more light, the greater the electrical generation.

Solar technologies are generally considered easier to integrate into buildings either new build or in retrofit. They are also considered acceptable to be integrated into buildings within sensitive areas such as Conservation Areas subject to the panel is not visible from the highway and protects and enhances the appearance of the building and the surrounding area. In Ealing there are few cases where solar PV tiles have been incorporated into buildings within Conservation Areas but the south facing roof was at the back of the building. There are, however, limitations in buildings and areas of special historic or townscape importance subject to high quality and innovative design techniques. In all other occasions, solar technologies are applicable depending on the individual building's constraints.

5.1.3 Biomass

Biomass is a renewable, low carbon fuel that is already widely, and often economically, available throughout the UK. Several fuel types such as pellets, logs and chips and different sizes are currently in the market which can serve buildings of different scale. Log and pellet stoves and boilers of up to 50kW are particularly designed for serving individual domestic properties and community facilities. Pellet and wood chip boilers of up to 200kW can serve schools, primary and secondary, community facilities, mixed-use developments and local authorities' buildings.

For biomass heating systems there are several factors that will influence the type of boiler suitable for a particular project and need to be factored into the design process at the earliest possible opportunity. Below is a list of the most important points for consideration.

- <u>Space</u>

Generally limited space on site restricts the required storage of the wood fuel. Wood chips will occupy up three times more room than wood pellets for the same weight of wood. Biomass boilers also tend to be larger than conventional fossil fuel boilers, therefore you will need to have a large enough space to house the unit.

Generally if space and access are not a problem larger projects would consider wood chip; however if space is at a premium or the area is sensitive to a greater number of fuel deliveries then pellets are the preferred option.

- <u>Size of the building</u>

The size of the building has a significant role to play in determining the size of the boiler and the fuel storage. Larger buildings, generally, tend to have higher space heating and hot water requirements and hence the boiler will need to meet the specific energy needs. Larger systems will consume more fuel and therefore tend to be automated systems with minimal manual intervention. These systems are particularly designed for large commercial buildings and not for domestic installations. However, domestic systems allow the user to fill a hopper attached to the boiler.

- <u>Access & Transport</u>

Access is very important when considering biomass boiler for a development. It needs to be easily reached as for most systems a fuel delivery vehicle will need to access the site. Fuel can be delivered in a variety ways, however for bulk chips and pellet orders direct access to the fuel store is critical. For small domestic deliveries it is important to have a dry place to stack logs or store bags of pellets. The number of fuel deliveries (large vehicle movements) necessary throughout the year needs to be carefully considered especially in urban environments as this may have planning implications. In the event where frequent fuel deliveries are necessary to a site, the applicant will be required to demonstrate that the transport movements will not have a detrimental effect on local amenity or the operation of the highways network. Early discussions with should be held with the planning and highways departments to ensure that the cumulative impact with other developments has been thoroughly considered and the number of deliveries are minimised through careful boiler sizing and fuel storage.

- <u>Fuel supply</u>

As afore-mentioned, there are several fuels that can be used to fuel the biomass boilers. However, wood pellets and wood chips are of the most common forms than can be used in all building scales. Woodchip is small pieces of wood ranging in size from around 5mm to 50mm and their quality depends on the raw material, chipper type (drum, disc or screw), and the chipping process. Wood pellets are usually made from shavings and fines which have been compressed under high pressure to form a cylindrical shape usually between 6 – 10mm in diameter and 10 – 30mm long. The production process does not use chemical additives although organic additives such as potato starch and corn flour can be added to improve mechanical stability. As a result of the production process pellets are highly standardised cost-effectively and require less storage space compared to woodchips.

Both fuels have advantages and disadvantages. While wood chips can be sourced locally, pellets due to the required production process cannot. Although wood chips are considered cheaper fuel source than pellets, they require larger storage space which makes it prohibitive specifically when there is limited space available for the fuel. Pellets require minimum maintenance and service and are easier to transfer and handle compared to chips.

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 SouthEast, and some companies operate nationally. Most wood pellet used in the UK comes from Europe, Ireland or Canada. Several south east suppliers are included in the appendix.

- Air Quality

In common with other types of combustion appliances, biomass boilers are potentially a source of air pollution. The pollutants associated with biomass combustion include particulate matter (PM10/PM2.5) and nitrogen oxides (NOx) emissions. These emissions can have an impact on local air quality and affect human health.

In response to current and projected breaches of national Air Quality Objectives for nitrogen dioxide (NO2) and particulate matter (PM10), the whole of the London Borough of Ealing has been declared an Air Quality Management Area. The borough also comprises a number of Smoke Control Areas designated under the Clean Air Acts. It is therefore essential that any new biomass boilers installed in the borough meet certain emission control requirements in order to protect local air quality.

In addition to any approval needed for planning purposes, biomass boilers of 16.12 kW or greater maximum heating capacity require approval by the Council of plans and specifications under section 4 of the Clean Air Act, 1993. This section of the Act also requires that the furnace (i.e. the boiler) is "so far as practicable capable of being operated continuously without emitting smoke when burning fuel of a type for which the furnace was designed". Where section 4 applies to the boiler concerned, the information supplied will also be used to determine an application for Clean Air Act purposes.

- Visual Impact

The use of biomass boiler will require the installation of a chimney flue, which could have a visual impact in protected areas of Ealing. 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.

Biomass heating is generally considered a highly efficient technology to use when seeking to significantly reduce the CO_2 emissions of a development. As such, traffic nuisance and the potential for air quality issues across the Borough will be limited. Woodfuel 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.

5.1.4 Geothermal

Geothermal systems extract the low-grade heat from the ground and utilise heat pumps to convert it into heating or cooling to a wide range of building types and sizes while hot water can also be provided.

Sub soil temperatures are reasonably constant and predictable in the UK, providing a store of the sun's energy throughout the year. Ground source heat pumps (GSHP) operate on the same principle as fridges, transferring energy from a cool place to a warmer place. In heating mode, they operate most efficiently when providing space heating at a low temperature, typically underfloor heating or warm air systems.

Heat pumps are not considered strictly a renewable technology, as they require electricity for their operation with resultant CO_2 emissions. However, this technology has the potential to become a zero carbon technology if electricity could be generated by another form of renewable energy. These systems are very energy efficient due to their efficiencies, which are indicated by their "Coefficient of Performance" (CoP), and can produce four or five times the amount of heat energy for every unit of electrical energy needed.

A GSHP system consists of a ground heat exchanger, the heat pump and a heat distribution system. The most common geothermal installation is the closed loop system where the ground heat exchanger consists of a sealed loop of pipe buried either horizontally or vertically in the ground.

In cases where ground source heat pumps are recommended for a site, they need to be designed with a view to reducing the risk of groundwater pollution or derogation that might result. In addition, it is important to determine the depth of soil cover, the type of soil or rock and the ground temperature. Ground source heat pumps are better installed in wet soil, hard rock and clay.

However, the disadvantages are that water availability is limited, fouling and corrosion may be a problem depending on water quality and most importantly environmental regulations covering the use of groundwater are becoming increasingly restrictive. Another factor to consider is when GSHP are proposed to be installed in Sites of Special Scientific Interest (SSSIs) or sites of international geological importance, sites that are scientifically important because they contain exceptional features or sites that are nationally important because they are representative of a geological feature, event or process which is fundamental to understanding Britain's geological history.

Based on the consultation draft Geodiversity[25] report produced by the Mayor for London, Ealing borough does not have sites of geological importance except of Horsenden Hill and Hangar Hill. These two sites have been identified as sites where a geodiversity auditing would be required. The geological formation of Ealing borough is clay soil which, as aforementioned, is favourable for ground source heat pump installations.

Finally ground source heat pumps may be a restricted technology in a retrofit if there is no access to available land. In cases where the building falls within sensitive or protected areas, the application will need to consider all the afore-mentioned factors.

5.1.5 Decentralised Energy Generation and decentralised energy networks – CHP or biomass CHP

A Decentralised Energy (DE) system produces heat as well as electricity at or near the point of consumption. It includes high efficiency co-generation or combined heat and power (CHP); on-site renewable energy systems and energy recycling systems. CHP plants, although often fuelled by fossil fuels, are much more efficiently than in large centralised plants, because the heat is used either as process heat in industry or distributed around buildings via a district heating

[25] Mayor for London, Consultation Draft, Geodiversity of London, The London Plan, (Spatial Development Strategy for Greater London), Draft London Plan Implementation Report, July 2008

system. The availability of district heating networks means the CHP plant can be converted to run on other fuels such as biomass, geothermal energy, or solar collectors.

Generally decentralised energy networks are easier to install in combination with a communal heating system than individual heating systems. This is mainly due to the difficulty and unaffordability of converting the individual heating systems to community heating. These networks are more favourable and feasible to high density developments where they can connect multiple buildings within a reasonable proximity. In particular these networks are more suitable to developments such as high heat demand, mixed-use developments (with complementary energy demand profiles) and anchor loads for example large energy users with (close proximity) constant heat demand such as leisure centres, hotels, care homes, large public buildings, universities, prisons, hospitals, supermarkets, offices, residential properties. Their combination ensures a minimum level of heat required throughout the day, rather than peak heat demands in the morning and evening which results in increasing the feasibility of the heat network.

Major regeneration projects are particularly appropriate for the integration of a heat and/or power network. The London Borough of Ealing has several regeneration projects which are primarily concentrated in:

- The Uxbridge Road/Crossrail corridor – particularly focused in town centres and around key stations in particular at Southall.
- The A40 Corridor, focused around Greenford town centre, North Acton Station, Park Royal and other industrial estates.

These growth areas provide excellent opportunities in the borough for district heating schemes given the high density and mix of uses. In addition, proposals for major developments, especially large scale housing developments, within the Borough's boundaries are planned to be built in the coming years. The Core Strategy for Ealing includes all the regeneration projects that are being considered for development in the next 26 years.

The results of the Heat Mapping Study, which was carried out in collaboration between the GLA/LDA and the London Borough of Ealing, identified eight focus areas with a high potential for developing a decentralised heat network(s), given the reasonably mix of developments that is planned for each one of them:

1. South Acton Estate (16 phases): 3,200 units. Potential connection with Oaks Shopping Centre, Bollo Lane and Acton Town Hall Complex, 55 buildings/connections identified.

2. a)Ealing Metropolitan Centre: Potential connection between Arcadia and Dickens Yard.
   b)Green Man Lane Development: Potential connection with the Ealing Metropolitan Centre, 53 buildings/connections identified.

3. Copley Estate: residential buildings currently operate on community heating schemes, 53 buildings/connections identified.

4. Southall Gas Works: 2600 units, community buildings, some commercial / retail floorspace, 13 phases.
5. Ealing Hospital Area: There major hospital site is adjacent to an extensive development of residential properties, with a light industrial estate further to the west. The hospital would form an ideal anchor load for any development in this area.
6. Housing units in the Ferrier Road/Union Road area are believed to benefit from communal boiler systems. This presents an ideal opportunity to link these together, 7 buildings/connections identified.

7. Greenford Road: 25 buildings identified.

8. North Acton - Southern Park Way – Park Royal – EfW: Potential interest due to a proposed EfW facility, 8 buildings identified.

Although the above focus areas have been identified having a high potential for decentralised energy network(s), this does not preclude future developments that are to be built within a reasonable proximity from these areas to connect to that system or future proof their community heating systems to connect to such a network. As such, it will be required any development planned to be built within the next years to investigate the potential to either develop, connect or future proof their systems to a decentralised energy network(s).

Further information and maps about the potential focus areas identified within the Borough can be found in the Heat Mapping Study.

The following recommendation, based on Policy 4A.6 of the London Plan[26], is to establish a rule that should be followed for all new large developments in the London Borough of Ealing 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 ≥149 units 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. Whilst Ealing does not currently have any district heating networks, there are individual community heating systems across the borough. Several of these communal systems use Combined Heat and Power plant and feed electricity into the local grid and will be the subject of a detailed feasibility study to identify potential opportunities for development or connections and in later stages expansion of the network(s).

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).

5.2 Geographical constraints

This section will analyse the feasibility of the measures/technologies based on the geographical and planning constraints that exist in the borough. This involved a general assessment of the feasibility of individual technologies based on the geography of the borough – considering for example typography, geology, wind speeds, flood risk etc. This allowed us to identify if there

[26] The London Plan, Spatial Development Strategy for Greater London, Consolidated with Alterations since 2004

was anything distinctive about Ealing physically which makes certain technologies better or suitable, or rules out others. For example there may be certain parts of the borough more suited to wind power or ground source heat pumps. In addition to geographical constraints, we also identified planning designations in the borough which may effect the suitability/application of measures – These included various open space designations, Heritage Land designations such as Conservation Areas, Listed buildings, air quality management areas, areas at risk of flooding.

While sustainable measures will be prompted in line with national, regional and local planning policy, the specific measures will need to be more carefully considered. For this reason, each planning application that falls within the following categories 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.

5.2.1 Planning constraints

5.2.1.1 National and regional constraints

<u>Conservation Areas within Ealing borough wide</u>

The London Borough of Ealing contains so far some 30 conservation areas which are spread across the borough[27]. Their protection and enhancement is a significant priority of planning policy. Sustainable energy measures will need to be considered in relation to their visual impact. Further guidance can be found in section 5.1.

<u>Listed Buildings and Scheduled Ancient Monuments</u>

Listed buildings and Scheduled Ancient Monuments (SAMs) such as Fairlawn Court 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 that 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.

PPS 22 - In sites with nationally recognised designations (Scheduled Monuments, Conservation Areas, Listed Buildings, Registered Historic Battlefields and Registered Parks and Gardens) planning permission for renewable energy projects should only be granted where it can be demonstrated that the objectives of designation of the area will not be compromised by the development, and any significant adverse effects on the qualities for which the area has been designated are clearly outweighed by the environmental, social and economic benefits. local planning authorities should set out in regional spatial strategies and local development documents the criteria based policies which set out the circumstances in which particular types and sizes of renewable energy developments will be acceptable in nationally designated areas.

<u>Sites of Metropolitan Importance for Nature Conservation (SMI) and Sites of Interest for Nature Conservation (SINCs)</u>

The borough has many attractive green spaces, ranging from countryside areas such as the Green Belt and Horsenden Hill, to small open spaces and back gardens. It also has a wealth of other features from its agricultural heritage. Planning Policy seeks from developments that will be apply sustainability measures to assist in retaining bio-diversity, unless it can be clearly shown

[27] More information on Conservation Areas can be found on Ealing website – Environment/Planning/Planning Services/Conservation

that it would not harm the nature conservation interests at the site, and that an ecological evaluation has been satisfactorily completed. Development adjoining sites must also demonstrate no damage to the amenity and nature conservation interest of the site, and the satisfactory completion of an ecological evaluation.

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.

Policy on development in the green belt is set out in PPG2. When located in the green belt, elements of many renewable energy projects will comprise inappropriate development, which may impact on the openness of the green belt. Careful consideration will therefore need to be given to the visual impact of projects, and developers will need to demonstrate very special circumstances that clearly outweigh any harm by reason of inappropriateness and any other harm if projects are to proceed. Such very special circumstances may include the wider environmental benefits associated with increased production of energy from renewable sources.

Metropolitan Open Land (MOL)

A key feature of the Borough of Ealing 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.

Green Corridors

Green Corridors provide important links, between networks of strategic open spaces providing environmental, recreational and infrastructure facilities. They comprise roads, railways, walking and cycle routes, and corridors for the movement of wildlife, as well as green landmarks in their own right. The Council will seek to enhance the visual and environmental continuity between open areas, by planting and landscaping schemes and nature conservation management. Sustainable measures in these corridors will need to be considered in relation to their visual impact. Further guidance can be found in section 5.1.

Heritage Land

Planning Policy seeks to preserve or enhance the special character, landscape and planting of the Heritage Land. The sites designated as Heritage Land include Walpole Park, Pitshanger Manor, Osterley Park and Twyford Abbey. 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 Heritage Land in Ealing.

5.2.1.2 Local Constraints

Areas of Value Façade

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.

Locally Listed Buildings

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

The Borough contains long established parks and other open spaces with public access. There is also a range of Community Open Spaces, in the form of playing fields, allotments, cemeteries and other green areas with more limited access to specific user groups.

The Council recognises the importance of preserving, increasing and enhancing the amount of open space for leisure, education, recreation and conservation activities, particularly in areas where there is a deficiency. The Council's intention is to designate, protect and where possible enhance public and community open space, promoting positive use and accessibility for all sectors of the population.

Sustainable energy measures will need to ensure that do not change the essential open character and setting of such areas as well as they contribute to their preservation and enhancement.

Local Views (historic and culturally significant areas)

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

Generally the borough of Ealing does not lie within a flood zone. However, the area near Ealing Hospital is adjacent to River Brent floodplain and Southall is close to flood plain of Yeading Brook[28]. Therefore, 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.

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. The land use planning process needs to ensure that developments do not result in a net increase in such pollutants, and the Council will therefore require an Air Quality Assessment in cases where there is potential for significant increase. Non - polluting developments undertaken in areas already identified as having poor air quality raise issues of exposure, where they will be occupied for significant parts of the day. The Council will expect mitigation measures to be brought forward, where these are appropriate to secure an acceptable development. Sustainable energy measures that would result in an increase in pollution will not be acceptable.

Conservation areas

[28] London Regional Flood Risk Appraisal, October 2009

The London Borough of Ealing contains so far some 30 conservation areas and over 1000 listed assets[29] and their protection and enhancement is a significant priority of planning policy. Although, it is widely recognised, that improvements in the thermal performance of the building's elements of architecturally or historically important buildings are particularly difficult and sometimes impossible without unacceptable damage to the historic fabric or cultural record, it should not preclude all opportunities for energy saving measures just because of the building type. Ealing's commitment for sustainability in old buildings will be to retain existing elements of construction in buildings falling within this category and seek to enhance their thermal performance in benign ways, rather than replacing them.

English Heritage also recognises the importance of tackling the long effects of climate change and has produced a guidance document on energy conservation and microgeneration[30]. Through these guidance documents, it is evident that there are opportunities of making these buildings more energy efficient by either applying energy efficiency measures or renewable technologies but taking into account certain considerations in terms of design and characteristics of the Conservation Area.

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.

Better energy efficiency can be achieved by physical change to the building fabric and services and/or by more mindful behaviour by occupants. Building Regulations tend to influence only the physical changes – though they can facilitate better behaviour, for example by improving controls and usability and by beginning to require better sub-metering, commissioning records and log books for heating and cooling systems, and power and lighting.

While energy efficiency measures specifically when applied internally do not have a direct impact on the appearance of the building, they will also need to be carefully considered as they have an effect on the character of the area.

Particularly in conservation areas the main considerations that the London Borough of Ealing adopt, which are in line with English Heritage, when thinking to install a microgeneration technology are as follows:

- Efforts should be made to minimise visual impact
- Locating on principal elevations should normally be avoided
- Equipment should not damage key views in, out or within the conservation area, and this may include some very visible secondary elevations
- There should be no loss in the overall character or historic interest of the conservation area
- The local planning authority should consider cumulative impacts of the installation of different types of equipment

In listed buildings of all grades the main considerations regarding the installation of microgeneration equipment attached to the building or within the curtilage of the buildings will be the following:

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[29] More information on Conservation Areas can be found on Ealing website – Environment/Planning/Planning Services/Conservation

[30] English Heritage, Energy Conservation in Traditional Buildings (2008) & Microgeneration in the Historic Environment (2008)

- Consider non-intrusive alternatives first
- Choice of the least damaging type of technology in terms of damage to historic fabric
- Ensure that equipment is not visible from important viewpoints and does not damage historic fabric

<u>Design Considerations for Sustainable Energy Measures</u>

In consideration of the all 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 main principle will be the 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 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.

6 Viability – Methodology for economic assessment

This section presents the methodology that has been employed to determine the feasibility of sustainable energy targets for different development groups in the London Borough of Ealing. The development groups which have been selected to test the feasibility and viability of the various sustainability measures are explained in Section 7. In order to conduct an economic 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.

The sustainability measures aim to reduce the energy consumption and therefore the associated CO_2 emissions and are defined in terms of improving the energy efficiency of a building through improved thermal performance of the building's elements, energy efficient lighting and controls, highly energy efficient heating systems and controls, and the use of onsite low and zero carbon technologies. The energy efficiency measures considered in this study have been based on the Energy Saving Trust's energy efficiency standards of 'Good', 'Best' and 'Advanced' as aforementioned in Section 4.

Good Fabric Standards do not differ significantly from the 2006 Building Regulations requirements and therefore it can be assumed that their viability is not prohibitive to any development. Best and Advanced Fabric Standards exceed 2006 Building Regulations and as expected are more costly.

However, as the regulations become more stringent and the improvement in the insulation and air tightness will get higher, the cost of reducing CO_2 emissions from buildings will be periodically reviewed and possibly decreased. A number of policies that encourage the CO_2 emissions reduction from buildings are currently in force such as the adoption of a strategy for Zero Carbon housing by 2016, the tightening of the Building Regulations with respect to energy performance and the plethora of government consultations about the feasibility of various carbon targets, incentives like the Feed in Tariffs.

The capital costs of the sustainable energy measures have been estimated based on ballpark figures provided by various established suppliers including Kingspan Insulated Limited, Rehau Limited and other suppliers and installers for specific low and zero carbon technologies.

It should be noted that when dealing with future costs there is always considerable uncertainty. For this reason, this report is based on the most up to date cost information available (both from supplier's information and from the energy officer's previous experience of implementing energy strategies in practice and therefore provides the best possible assessment of costs of delivering low carbon schemes.

The methodology used to assess costs is described below.

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

6.1 Residual land value

Further work is still underway in terms of understanding how these measures will effect the overall viability of a proposal based on the land values in the borough and the development costs. We are envisaging using data from the affordable housing viability study as soon as this is available. An addendum will be published to this report.

6.2 Methodology to define appropriate measures and quantify CO_2 reduction targets

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 associated CO_2 emissions for each scenario chosen using:
    - Residential: data provided by the accredited Standard Assessment Procedure (SAP) model 2005 version 9.81/9.82, and estimated electricity consumption for appliances and cooking[31]
    - Non-residential: data provided by the accredited National Calculation Method (iSBEM) version 3.4.a calculations and estimated electricity consumption for small power any other electrical appliances.
2. Calculate predicted energy (electricity and gas) consumption and the associated CO_2 emissions for each development group after Baseline (2006 Building Regulations Part L), EST Good, Best and Advanced Fabric Standards have been integrated into the development with the objective to achieve reasonably high carbon savings and calculate improvement of Dwelling/Building Emissions Rate[32] over Target Emissions Rate and also calculate improvement of savings derived from both regulated and non-regulated energy use against the baseline carbon emissions.
3. Assess the technical feasibility of the low and zero carbon technologies that can be deemed suitable for the site calculated based on the baseline energy consumption and related CO_2 emissions.
4. Calculate the percentage of a development's CO_2 emissions that can be offset through the use of low and zero carbon technologies
5. Identify design requirements for each of the technologies
6. 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).

With regards to refurbishments there will be specific issues and limits to improving fabric on refurbishments due the pre-existing building typology and conservation issues. The options for sustainability measures for refurbishments are limited compared to new build. While energy efficiency measures which do not require significant 'fabric' changes are easier to be integrated in refurbishments, such as energy efficient lighting, other measures such as improving the insulation of walls, floors, roofs etc, 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.

[31] 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

[32] Dwelling Emission Rate (DER) in case of residential, Building Emission Rate (BER) in case of non-domestic buildings

In any case, all applications regarding refurbishment will need to at least comply with the Building Regulations for refurbishments (Part L1B and Part L2B) as a minimum. 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.

With regards to mixed-use developments including in this scenario 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.

The methodology therefore adopted in this study assumes that the building to be refurbished will comply with the Building Regulations.

The costing of energy efficiency measures and low and zero carbon technologies falls naturally into two separate exercises, fabric and services. With regards to the fabric, Table 6.1 below presents the indicative cost of the fabric standards. It is evident that as the U-Values are being decreased, the less cost-effective the application of these U-Values is. It is expected, however, that these costs will gradually come down as legislation will make these U-Values compulsory and builders will acquire the techniques. It should also be noted that the cost of doors is assumed for the different measures to be £1,000 for a common door to meet the current Building Regulations Part L (2006) and good fabric standards and £1,500 and £2,000 for best and advanced fabric standards, respectively.

With regards to the services, the costs may vary depending on the application. While the cost of installing more compact fluorescent bulbs, reducing hot water usage and installing no secondary heating can be low, the integration of heat recovery units to more air-tight buildings has become standard adding an extra cost of approximately £1,500 per unit.

The costs of the low and zero carbon technologies have been compiled through discussions with manufacturers and have been assessed with consideration to capital and operational costs, emissions and energy savings, space requirements and logistics. Maintenance costs have been assumed as 0.75% of the capital cost.

In order to correctly assess the cost-effectiveness of each of these measures for each development group, the cost beyond the baseline, Building Regulations Part L 2006, and the cost per percentage have been also estimated. The cost beyond the baseline was calculated only for the energy efficiency scenarios and expresses the additional cost for implementing the good, best and advanced fabric standards, while the cost per percentage was measures for all measures and indicates the cost for each percentage increase in carbon reduction.

Despite the effort of trying to gather information regarding costs for the different sustainability measures, there are some gaps in the data. Notwithstanding the limitations on some of the data, they are the best most comprehensive and up-to-date available.

Building Element	Building Regulations Part L 2006 Limiting U-Values Standards	EST Good Fabric Standards	EST Best Fabric Standards	EST Advanced Fabric Standards
Cavity Walls	**0.35W/m^{2}K**	**0.3 W/m^{2}K**	**0.25 W/m^{2}K**	**0.15 W/m^{2}K**
-Indicative price (£/m^2)	17.70	21.00	24.00	~30.00
Floors	**0.25 W/m^{2}K**	**0.22 W/m^{2}K**	**0.2 W/m^{2}K**	**0.15 W/m^{2}K**
-Indicative price (£/m^2)*	15.80	20.00	22.00	16.80
-Indicative price (£/m^2)**	10.70	12.70	14.80	20.40

Building Element	Building Regulations Part L 2006 Limiting U-Values Standards	EST Good Fabric Standards	EST Best Fabric Standards	EST Advanced Fabric Standards
Roofs	**0.25 W/m²K**	**0.16 W/m²K**	**0.13 W/m²K**	**0.15 W/m²K**
-Indicative price (£/m²)*	16.80	20.40	20.40	20.40
-Indicative price (£/m²)**	26.10	~42.00	~54.00	~44.00
Windows, roof windows, rooflights and curtain walling	**2.2W/m²K**	**D*/2.2 W/m²K**	**C*/1.6 W/m²K**	**0.8 W/m²K**
-Indicative price (£/m²)	£250.00	£250.00	£267.50	£400.00
Doors	**2.2 W/m²K**	**2.2 W/m²K**	**1 or 1.5 (if glazed) W/m²K**	**0.8 W/m²K**
-Indicative price (£/m²)	£1,000.00	£1,000.00	£1,500.00	£2,000.00
Other Parameters				
Air permeability (m3/m2/hr@50Pa)	10.0	5.00	3.00	1.00

Floors	**Roofs**
*between timber floor joists	*Pitched roof loft flat insulating from the inside
**under a concrete slab	** Flat roof insulating into a stripped-down concrete, steel or timber

Table 6.1 EST Energy Standards 2006 U-values (W/m² K), energy efficiency measures & indicative price in £/m²

The energy savings from the renewable and low and/or zero carbon technologies have been calculated using the values presented in Table 6.2. The Renewables Obligation Certificate (ROC) buy-out price will be £36.99 per ROC[33]. Renewable Obligation Certificates, ROCs, are issued for each whole MWh of renewable electricity generated. All the energy costs have been taken from Department of Energy and Climate Change (DECC) quarterly energy report published on December 2009. The price for biomass is applied to all the development groups.

Energy Values						
	Hotel/Restaurant/ School/Warehouse	**Office**	**Supermarket**	**Flats/Houses**	**Flats (≥100 units)**	
	p/kwh(1)	*p/kwh(1)*	*p/kwh(1)*	*p/kwh(1)*	*p/kwh(1)*	*Efficiency*
Gas	2.98	2.98	3.34	4.01	4.01	89%
Electricity	9.88	8.75	9.47	14.39	13.64	100%
Biomass			2.90			80%
ROC	£	36	/MWh			

Table 6.2 Energy values and system efficiency for the different fuels and Renewables Obligation Certificate

Additionally, the costs of connecting to a community system or district heating network, although not being investigated in this study, are likely to be variable in practice, depending on the level of disruption of existing services caused by trenching in the street.

The derivation of costs data for the low carbon and renewable technologies is summarised in the following tables:

[33] http://www.ofgem.gov.uk/Media/PressRel/Documents1/RO%20BuyOut%20price%202010%2011%20FINAL%20FINAL.pdf

Technology	Budget cost of installation	maintenance cost
	£/kwh heating capacity	*(% of capital)*
CHP	based on ballpark figures from suppliers	1.5%
Solar PV	£1k/m^2 for hybrid panels[34]	0.5%
Solar thermal	£3,000[35]	0.5%
GSHP	£1,700	75%
ASHP	£1,000	75%
Biomass	~£150	5%
Wind	based on ballpark figures from suppliers	1%

Table 6.3 Assumptions and derivation of cost data

	Calorific value	Density	£/Tonne
Wood Pellets	5	600	140
Wood Chip	4	246	56

Table 6.4 Assumptions and costs data for the biomass fuels

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

Further work is still underway in terms of understanding how these measures will effect the overall viability of a proposal based on the land values in the borough and the development costs. We are envisaging using data from the affordable housing viability study as soon as this is available. An addendum will be published to this report.

6.4 Financial Incentives and Regulation Changes

The Ealing Development Strategy will cover the period up to 2026 where it is reasonably expected that there will be a number of changes in market conditions and the political and regulatory framework. One important element that is expected to change within this period is the costs of technologies as their equipment performance is likely to improve over this time. It is envisaged that their costs will come down over time; however this will vary between technologies. With regards to combined heat and power technology, its cost is unlikely to drop significantly as it is already an established technology while biomass heating will become more established and sophisticated. Biomass CHP although available for industrial purposes, it is still not established in the market yet but it is expected that it will become better and more efficient and potentially provide an alternative option for developers.

With regards to renewable technologies, their costs are likely to drop as demand grows and the manufacturing process becomes optimised. The reduction in prices is likely to influence the

[34] Price provided by Solar Century
[35] Solartwin single installed aprox £3k

uptake of solar technologies and heat pumps. The costs of energy efficiency measures and specifically triple glazed windows, which at the moment are very expensive, is also likely to come down as demand increases in order to satisfy more stringent regulations. The Element Energy Report for the Renewable Advisory Board[36] estimates that the marginal cost of PV and micro wind will half by 2025. Solar thermal will come down by 40% over the same period, and heat pumps by 35%. As the cost of technology reduces over time, the application of such technologies will become more viable.

On the other hand, the delivery of low and zero carbon technologies and decentralised energy networks could be facilitated by a number of mechanisms including financial incentives and current market structures. However, some of the mechanisms described in this report are not fully implemented and defined as yet so they may not be applicable at the time of writing but are due to come into effect shortly and within the lifetime of the LDF.

Not all mechanisms will facilitate successful delivery of low and zero carbon developments, including the improvement of the viability of the CO_2 reduction target and therefore each development case will need to be considered individually.

6.4.1 The Feed-In-Tariffs (FIT)

The Feed in Tariffs is one element of the Clean Energy Cashback Scheme introduced by the Government. The feed in tariffs scheme has been in operation since April 2010 and it covers electricity generation only. The scheme can assist customers to generate income from the export of surplus electricity from renewable energy generation and has the potential to stimulate carbon emission reductions from micro-renewables such as PVs, wind turbines, CHP or anaerobic digestion.

The scheme guarantees a minimum payment for all electricity generated by the system, as well as a separate payment for the electricity exported to grid. These payments are in addition to the bill savings made by using the electricity generated on-site.

FIT eligibility remains with the installation, even if the ownership of the home or generating technology changes. Therefore the technology must have been eligible before you move in, even if it is not registered yet. Ownership of the technology is linked to the site and, therefore, in the case where a building or homeownership changes, the ownership of the technology would also transfer to the new owner.

6.4.2 Renewable Heat Incentive (RHI)

The Renewable Heat Incentive is the second element of the Clean Energy Cashback Scheme. It is a forthcoming piece of legislation, which is due to come into force in April 2011 and has been designed to provide a fixed rate financial incentive for renewable heat. The scheme will cover the majority of renewable sources including solar thermal, heat pumps (ground, air and water), biomass heating, biomass or biogas CHP (combined heat and power) and anaerobic digestion.

The RHI will cover all scales, from large industrial sites down to the domestic level where organisations or householders will be paid based on an estimate of how much energy it can produce from its renewable system.

Given that the support levels are yet to be announced or any implementation methodology finalised, it is difficult to say what effect the RHI will have on financial viability apart from that it is likely to improve it to some degree by providing a long-term revenue stream from the installation of certain heat producing low and zero carbon technologies. If these revenue streams

[36] The Role of On Site Energy Generation in Delivering Zero Carbon Homes

are factored into a financial analysis they should in theory improve the financial viability case for certain technologies.

6.4.3 Allowable Solutions

Whilst the definition of "Zero Carbon" is still to be finalised, the government has announced that a set of "Allowable Solutions" will be created that will enable developers to meet the Zero Carbon emissions target to be brought into force by 2016 for residential dwellings.

The Zero Carbon definition is based on a hierarchical approach requiring high-levels of energy efficiency, followed by a mandatory level of on-site carbon mitigation (including district heating/cooling networks), followed by a list of "allowable solutions" for dealing with the remaining emissions (considering both regulated and regulated energy). Figure 6.1 presents the Government's preferred hierarchy.

The current list of 'Allowable Solutions' mentions mechanisms that may be incorporated into the planning framework such as s106 or Community Infrastructure Levy (CIL) contributions that may provide future-funding for Ealing that could be put towards infrastructure developments.

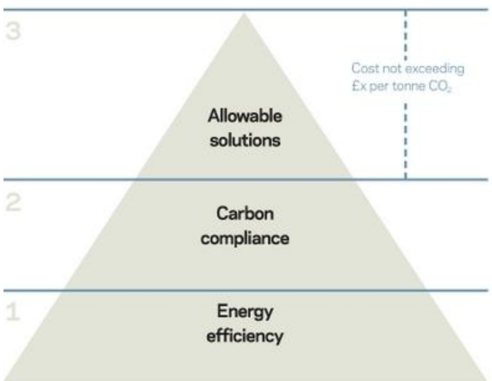

Figure 6.1 The Government's preferred hierarchy

The "Allowable Solutions" include any or all of the following

- On-site renewable energy generation
- Installation of energy efficient appliances/building control systems
- Exports of low-carbon or renewable heat (or cooling) to surrounding developments
- S106 planning obligations towards allowable solutions
- Retrofitting of existing buildings in the locality
- Investments in LZC energy infrastructure (benefits of ownership transferred to homebuyer)
- Offsite renewable electricity connected via direct physical connection
- Any other measures announced by government

6.4.4 Impact of future policy changes on viability

Whilst a considerable degree of uncertainty still exists surrounding the delivery of the mechanisms outlined above, it is clear that over the lifetime of the LDF, a greater level of financial incentivisation will be available to developers to support the use of low and zero carbon technologies. Due to the number of and uncertainty surrounding how the different mechanisms will interact with each other, it is not possible to give an order of estimation on the likely financial impact that they will have. However it is clear that simply through the provision of increasing levels of financial incentivisation through the lifetime of the LDF, that the financial viability of the policy targets will be improved over time.

7 Analysis by development type / size

7.1 Defining development groups / scenarios

A series of steps have been employed in carrying out this study. The initial step involved analysing the feasibility of the measures based on geographical and planning constraints existing in the borough. The second step was to understand the development groups/scenarios common or representative in the borough, which are to be subject to further testing to identify optimum solutions for carbon reduction. Having identified representative development types, other criteria such as application type (new build/ refurbishment/change of use), size (size range) and in some instances location have been taken into account in forming the development groups. It should be noted that the above was identified through analysing permissions and completions data (AMR Report 2008/09). The identification of the above criteria allowed us to identify the future development profile in the borough.

Planning permission analysis

An analysis of the planning permissions granted in the year 2008/2009 has been undertaken. The analysis was based on the permissions data set out in the Annual Monitoring Report (AMR):

- C3 - Residential Permissions involving a change or increase in the number of units between 1st April 07 to 31st March 08. Residential extensions, unless forming part of application involving a change in the number of units are not monitored here.
- A1, A2 permissions between 1st April 07 to 31st March 08
- A3, A4, A5 permissions between 1st April 07 to 31st March 08
- B1, B2, B8 permissions between 1st April 07 to 31st March 08
- D1, D2, OS permissions between 1st April 07 to 31st March 08
- C1, SGH permissions between 1st April 07 to 31st March 08

7.1.1 Residential

The analysis of planning permissions for residential has identified the following: new build (26%), mixed-use developments (28%), redevelopments (5%), conversion (35%), change of use (4%), continued use (3%). This is illustrated in Figure 7.1 below. The percentages are calculated on the basis of the number of units rather than the number of applications granted consent.

It is apparent from Figure 7.1 that conversions represent the second highest proportion at 35% of the total new build residential units which most commonly involve the refurbishment of an existing house to from several flats or enlargement of an existing building to provide individual flats. Conversion will therefore be considered as refurbishment according to the scenarios mentioned above.

Change of use and continued use represent only 4% and 3% of the total residential units created, respectively.

For the purposes of this report change of use is defined as a change of use class, while conversion implies that the use class remains the same but there is an increase in the number of units, i.e. a sub-division. Therefore, refurbishment may be undertaken under both of these scenarios. Refurbishment per se, unless undertaken as part, of a change of use/conversion application does not constitute development requiring planning consent.

Those applications categorised as either redevelopment or mixed use, are in effect also new build developments. When added to the new build category, this constitutes almost two thirds of all units granted consent.

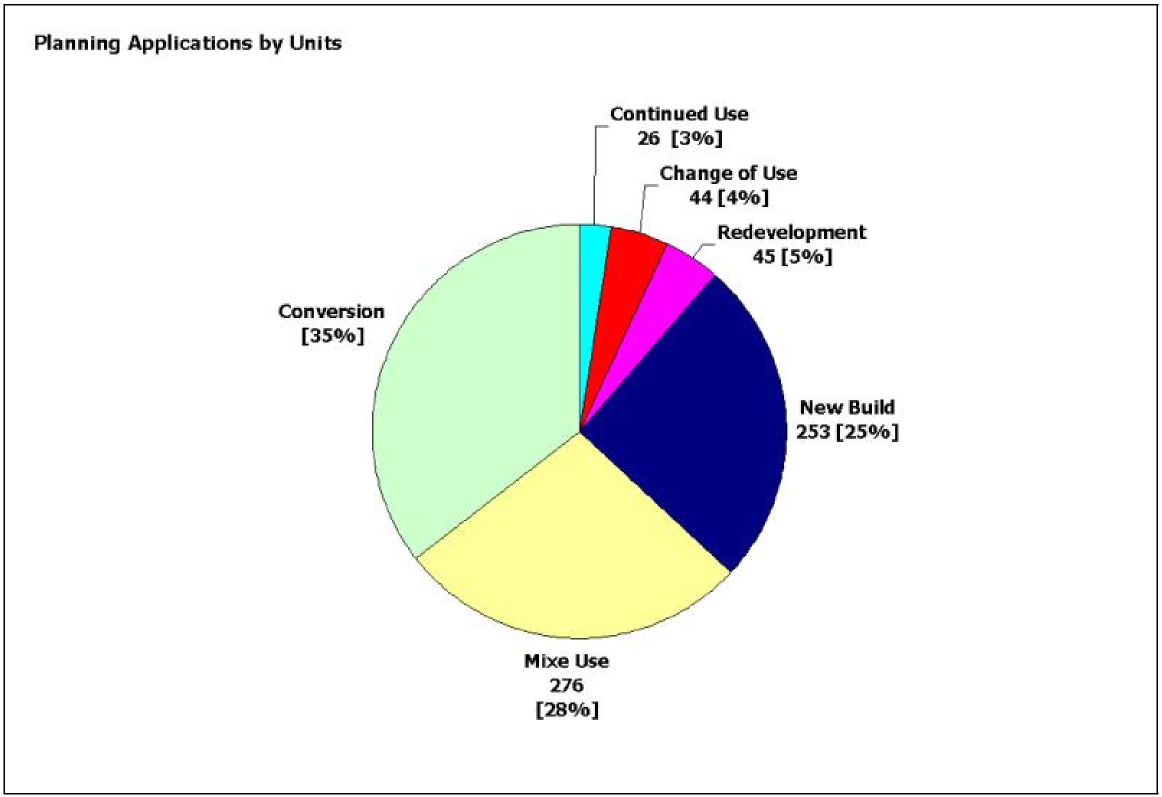

Figure 7.1 Breakdown of planning applications for residential

In respect of proposal sizes, i.e. the number of units being created, the following analysis presented in figure 2 has been possible. Figure 2 presents the percentage of the total units by size of the applications granted permission between 17th April 2007 to 31st March 2008.

The analysis of the results below show that the majority involved blocks of equal to 1 to 5 units consisting of either flats or houses (82%). Planning permissions proposing 11 to 50 residential units or equal or more than 51 units made the lowest proportions with 6% and 1% for the year 2007/08, respectively. In addition flats/houses of up to 10 units represent an 11% of the total planning permissions analysed for the purposes of this study.

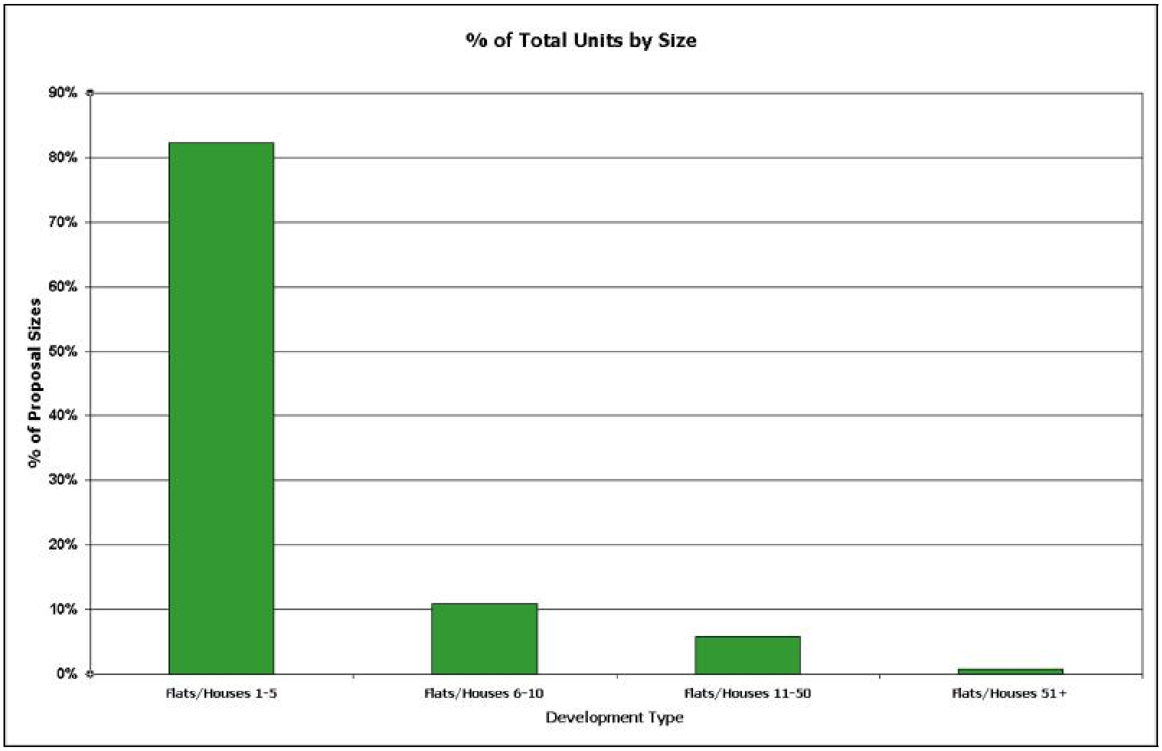

Figure 7.2 Breakdown of the planning permissions per size

Based on the findings of the above analysis the following residential development groups are defined for further analysis:

- New Build House
- Flats (1-5 units) – New Build – Purpose built block
- Flats (6-10 units) – New Build – Purpose built block
- Flats (11-50 units) – New Build – Purpose built block
- Flats (51+ units) – New Build – Purpose built block

Whilst it has not been possible to undertake a more detailed and robust analysis in terms of building/house type, based on the available monitoring data, it is possible to identify some general trends in terms of common building/housing types. Smaller residential schemes consisting of up to 10 units, converted terraced houses to flats and detached houses made up a significant proportion of the planning applications analysed for the period between 17th April 2007 to 31st March 2008. Applications regarding larger schemes consisting of more than 10 units and bungalows showed a lower proportion. It was decided, however, to examine the most representative residential development types mentioned above. These will be analysed in section 7.4

7.1.2 Non–residential

Planning permissions identified from the Annual Monitoring Report 2008/2009 for non-residential properties are listed below. It should be noted that the commercial applications have been analysed based on the proposed floor area and not based on units as is the case with the analysis of residential permissions. Figure 7.3 illustrates the percentage of floor area permitted under each commercial use class.

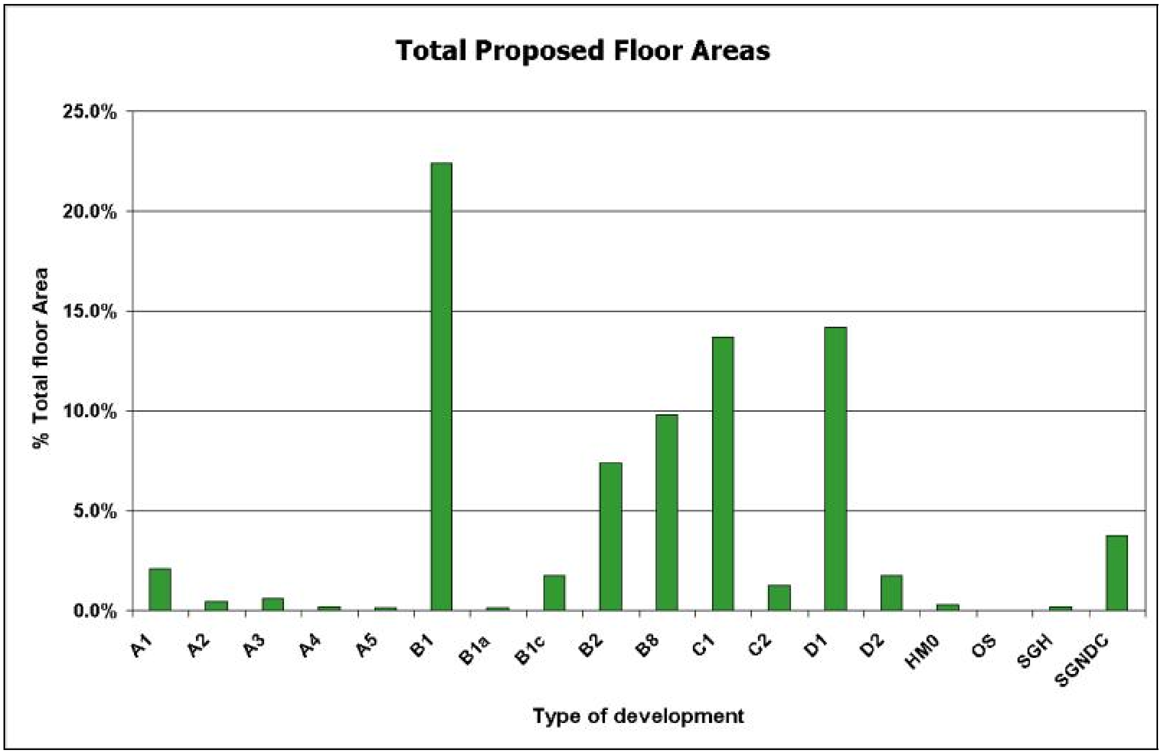

Figure 7.3 Breakdown of planning permissions for non-residential

For the purposes of this study, however, it was decided to group similar uses into one classification as described below.

Business, General Industrial and Warehousing

The analysis of B1, B2 and B8 types of planning applications showed a much higher proportion of new-build, extensions and change of use for general industrial (45.13%) than any other category. Based on the data provided, planning applications for offices, which falls under the use class of B1a, did not show a significant increase (0.14%) compared to all the permitted planning applications analysed. In addition, when looking at the nature of new-build planning applications for offices, it appears that many of them are involved in mixed-use developments.

It is however suggested that different sustainable measures will be tested for warehouses, new build which showed the highest proportion and offices new build regardless the very low increase.

Non-residential institutions (including schools) and Leisure

The analysis of D1 and D2 types of planning permissions represented the second highest proportion with 15.97%. The majority of the planning permissions of new-build and extensions involved new build and extensions for schools and community centres. Therefore it was suggested that only new-build schools should be considered and that although community centres have been also proposed, sustainability requirements applying to them should be the same. In addition to this, regardless the range in surface areas for both the schools and the community centres permitted, it was suggested that the same sustainability measures should be applied. Therefore, schools category identified to be tested with 2 or more classrooms, new build.

Hotel

The analysis of C1 type of planning applications showed a much higher proportion of new-build and extensions for hotels (13.91%) of the total non-residential permissions. As in D1 and D2, despite the variation in surface areas of the hotels, it was suggested that the sustainability measures applied should be the same for all the ranges. Moreover, the planning applications showed an increase in hotel proposals in the borough and therefore, hotel was one of the use classes that decided to be tested against all the sustainable measures included in this study.

<u>Retail and Financial & Professional Services</u>

Although the analysis of A1 and A2 types of planning permissions showed a decline in proposals with 2.56% of the total non-residential planning applications, it was suggested to examine one retail category against the sustainability measures mentioned in this study. The majority of the applications involved change of use but a significant proportion involved extension and new-build as well. For this reason, it was decided to examine one category of all the retail and financial and professional services, which is supermarket, new-build.

<u>Restaurants, Pubs and Hot Food Takeaways</u>

The analysis of the planning permissions of A3, A4, A5 types of planning permissions represent only 0.96% of the overall planning applications for non-residential developments. The majority of the permissions involved change of use and conversion but also extension. This indicates that the proposed surface areas will be smaller than 1000m2 and for this reason it was suggested to examine the various sustainability measures to a restaurant representative to the borough in order to identify those measures that could be applicable and cost-effective to such developments.

In light of the findings from the above analysis the following development groups have been defined for further testing:

- Offices (B1a) (≥1000 m^2 – including mixed-use) – New build
- Warehouses (B8) (≥1000 m^2 - including mixed-use) – New build
- Schools (D1) (2+ class rooms) – New build
- Hotel (C1) (≥1000 m^2) – New build
- Supermarket (A1) (≥1000 m^2) – New Build
- Restaurant/Hot Food Takeaways (A3/A4/A5) (<1000m^2) – New Build

It was decided that the categories to be investigated should involve new build developments only, however it should be noted that, sustainable options for refurbishments and conversions will be considered too. It should be also noted that major extensions (i.e. involving a 1,000m^2 +) are treated as new-build and therefore the sustainability measures employed would be the same as for new build major applications. Real life case studies from Ealing have been identified for each of the above categories which will be subject to further testing.

7.2 Geographical and building type criteria

Based on the analysis of the geographical and planning constraints (section 5) as well as the specific characteristics of a development site such as type, size, whether they are new build or refurbishment etc, an assumption was made that for all the development groups that will be tested in this study these are located outside of sensitive areas.

Whilst it may be possible to establish some general parameters which could apply to such sites, the unique character of each area which is to be protected, makes it difficult to establish requirements that could apply across all of the sites. For this reason the solution in terms of energy measures and target requirements in terms of CO_2 emission reductions would need to be established on a case by case basis, although being mindful of the recommendations set out in chapter 5.

7.3 Development scenarios

The table below identifies each of the development groups (both residential and non-residential) which are to be subject to further testing. The scenarios described for each group/development type have been defined on the basis of the findings of the analysis and the availability of real life case studies. Each of the scenarios will be subject to further testing in terms of the application of energy efficiency modelling, sizing of renewable energy technologies and estimation of CO_2 emissions reduction.

Development Types	Scenarios
Flats (1-5)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50m^2, /60 m^2/70 m^2 Total area 296 m^2
Flats (6-10)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50 m^2 /60 m^2/70 m^2 Total area 593 m^2
Flats (11-50)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50 m^2 /60 m^2/70 m^2 Total area 2,963 m^2
Flats (51+)	Ground, mid and top floor 1, 2 &3 bed/ 2, 3 or 4 persons/ 50 m^2 /60 m^2/70 m^2 Total area 5,926 m^2
Houses	Detached 3-bed / 4 persons/ 87 m^2
	Semi- Detached Detached 3-bed / 4 persons/ 87 m^2
	Mid-Terrace 2 bed / 3 persons/ 70 m^2
	End -Terrace 2 bed / 3 persons/ 70 m^2
Office	7 storey building 9,577 m^2
Warehouse	2 storey building 3,369 m^2
Schools	3 storey building 4,178 m^2
Hotel	5 storey 1,855 m^2
Supermarket	2 storey building 12,631 m^2
Restaurant	1 storey building 104 m^2

Table 7.1 Development scenarios investigated

7.4 Analysis of scenarios – by type / size

The purpose of this section is to test the different energy efficiency measures and low and zero carbon technologies, in order to identify the optimum solution in terms of feasibility and viability for each development group defined in Section 7.4 above. As well as looking at measures separately, different combinations of measures will also be considered in order to understand their compatibility, and to establish the overall carbon savings that could be achievable for each group. Estimated costs, payback and CO_2 emissions savings are also presented for the different measures and their combinations based on systems sized to meet the targets defined in Section 4 of this report.

- Residential / Non-Residential: The following targets of 5%, 10%, 20%, 40%, 60% and 100% reduction in total CO_2 emissions (including emissions derived from both regulated (heating, hot water, lighting, cooling, fans &pumps) and non-regulated (small power, cooking, appliances) energy use through the installation of renewable energy technologies on site), are established.

It should be noted that the above targets have been tested prior to incorporating energy efficiency measures in order to assess separately the impact of the low and zero carbon technologies on carbon savings for each development group.

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 feasibility analysis seeks to identify what is physically achievable on a site, as 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).

With regard to viability, the report seeks to analyse the cost effectiveness of different measures, allowing a comparison to be made between each of the measures. It should be noted however that further work still needs to be undertaken to assess the impact of the measures on the overall viability of the development proposals. In this regard the forthcoming affordable housing viability study will assist. An addendum to this report will be published, providing further analysis in respect of viability.

7.4.1 Residential

New Build

Given the number of scenarios identified in respect of flatted development, it was not possible to identify real life case studies for all size groups, that would be comparable in terms of construction types, location etc. Accordingly it was decided that one case study would be selected, which would be proportionally 'upsized and downsized' in terms of floorspace. The case study selected was for 14 flats. SAP calculations were carried out to all fourteen flats due to the difference in the energy requirements from ground, middle and top floor flats. Based on the findings, all the areas and energy consumption for all the groups of flats were then measured as a proportion of the areas and energy requirements of this residential block.

In respect of houses, a typical 87m^2 detached and semi-detached 3 bedroom houses and typical mid- and end- terrace 2 bedroom houses were modelled using SAP.

7.4.1.1 Flats (1-5 units)

Energy Efficiency Measures

For this development group, a typical flatted development of 5 units was studied to derive conclusions on the technical feasibility, and cost effectiveness of energy efficiency measures and renewable energy installations.

This development has a total floor and roof area of 296 m^2 and 294 m^2, respectively. The roof area is a combination of both flat (110 m^2) and sloping (184 m^2) roof. The initial step involved measuring the baseline energy and associated carbon dioxide emissions, which are designed to conform to the current Part L Building Regulations (2006). Having established the baseline, energy efficiency measures and low and zero carbon technologies, covered in Section 4, were tested in order to establish which measures are most physically feasible and cost effective in delivering CO_2 emissions savings.

As mentioned in Section 4, the Energy Saving Trust's Good, Best and Advanced Fabric Standards were applied combined with a range of other energy efficient measures including energy efficient lighting, heating controls, mechanical ventilation with heat recovery, better insulated cylinder etc, The estimated costs of the energy efficiency measures have been provided by suppliers, Kingspan and Rehau.

Table 7.2 presents the average Dwelling Emission Rate (DER) and the Target Emissions Rate (TER)[37] for the different fabric measures, their percentage improvement and the Heat Loss Parameter. It is evident that the best and advanced fabric standards achieve significant carbon savings demonstrating savings of 33% and 44% respectively, and therefore exceeding Code Level 3 and 4 of the Code for Sustainable Homes. It should be noted that the heat loss parameter is an average for all the flats tested for this development group and is therefore an indication only as each flat has its own heat loss parameter.

The table below also presents estimated costs for meeting the different energy efficiency standards. The cost of each of the fabric measures has been calculated as the additional costs beyond the application of Building Regulations, i.e. the baseline. The cost for each percentage saving of CO_2 has also been calculated in order to allow for a comparison between the measures and to assist in our understanding of which of these measures are most cost effective in delivering carbon savings. For each percentage saved in terms of CO2, a cost of £1,708 would need to be spent, if good fabric standards were implemented, whilst £439 would need to be spent if best fabric standards were to be applied. The most cost-effective solution for this development group is to apply advanced fabric standards as for every percentage increase in carbon reduction it costs only £408.41.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	22.48	22.54	0.3%	1.29	£15,113	£0.00	£0.00
Good Fabric Standards	22.09	22.54	2.0%	1.16	£18,522	£3,409	£1,708

[37] The TER is a figure describing the maximum annual CO2 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).

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Best Fabric Standards	15.19	22.54	32.6%	0.81	£29,435	£14,323	£439.23
Advanced Fabric Standards	12.68	22.54	43.7%	0.58	£32,978	£17,866	£408.41

Table 7.2 Performance of different fabric scenarios and energy efficiency costs

Table 7.3 presents the annual energy consumption of the 5 new build flats for the different energy efficiency standards and also the percentage reduction in carbon dioxide emissions derived from both regulated and un-regulated energy use. It should be noted the total amount of energy and especially electricity that is saved when mechanical ventilation with heat recovery (MVHR) has been incorporated in each flat. Although MVHR is not currently cost-effective for it to be applied to each individual unit while it is normally applied to a selective number of units in residential developments, table below proves its significant contribution to carbon dioxide emissions reduction.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	12,803	10,838	5,474	3,120
Hot Water	13,714	13,774	13,488	13,345
Auxiliary	875	875	1,526	1,497
Lighting	2,517	2,222	1,939	1,499
Cooking+ Appliances	13,503	13,503	13,503	13,503
Savings from MVHR (Appendix Q)	-	-	- 2,173	- 2,784
Total Gas	**26,517**	**24,612**	**18,962**	**16,465**
Total Electricity	**16,895**	**16,600**	**16,968**	**16,499**
Grant Total	**43,412**	**41,212**	**38,104**	**35,749**
CO_2 Total ($kgCO_2$/yr)	**12,290**	**11,780**	**9,922**	**8,982**
Percentage CO_2 reduction	**-**	**4.15%**	**19.27%**	**23.75%**

Table 7.3: Baseline breakdown of the annual energy requirements of 5 new build flats

CHP / CCHP/ Decentralised Energy Options

Biomass or gas combined heat (CHP) and power or combined heating, cooling and power (CCHP) systems are unlikely to be feasible and viable for this development group owing to the low energy demand, the heat profile, and the disproportionate share of the development's costs that a communal plant room would represent.

Solar photovoltaics (PV)

The development modelled as part of this group had a roof area of 294m^2. Although the full extent of the roof has been modelled, in practice the full area may not be available. It is possible for example that this roof area may be reduced if plant equipment needs to be accommodated on this roof space, or if green/brown roofs are proposed. The increasing need to provide for green and open space in innovative ways, including on roofs, as densities increase, will compete with the available space for roof mounted technologies.

However, although 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, there is still the potential to install panels on the flat roof.

Table 7.4 below shows the amount of panels that can be installed on the roof. Although the solar PV technology was not tested together with the energy efficiency measures, it can be assumed from the table below and table 7.3 above that the more energy efficient the building is, the fewer panels are required to comply with the mandatory ENE1 target. Installing between 8m^2 and 29m^2 of hybrid PV panels on the flat roof will enable both the mandatory energy requirements for level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER) when only regulated emission have been considered and at least 25% reduction in total CO_2 emissions when both regulated and non-regulated have been included in the calculations.

In addition, the results below show that a significant proportion of carbon emissions can be reduced despite the contribution of both regulated and non-regulated energy use. Regardless of the high capital cost associated with the different PV options, the feed-in tariff of 36p/kWh and the ROC income can reduce the payback period of photovoltaics from 40 to 50 years down to just 10 to 15 years. The options below can meet around 10% to 70% of the electrical load of a similar development.

The cost for each percentage saved in carbon emissions have also been calculated in order to assist in identifying which is the most cost–effective solution in terms of system size for this development group. Due to the balance between the capital costs and the net savings for all PV panel sizing options, the cost per percentage saved in carbon emissions remains the same. These calculations will however be useful in allowing a comparison to be made in terms of the cost effectiveness of other technologies.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
8 m^2	1.27	1,188	675	5.5%	£8,000	£40	£36	49	£1,457
15 m^2	2.29	2,228	1,265	10%	£15,000	£80	£72	49	£1,457
29 m^2	4.50	4,307	2,446	20%	£29,000	£150	£143	48	£1,457
59 m^2	9.20	8,762	4,977	40%	£59,000	£300	£286	48	£1,457
88 m^2	13.50	13,068	7,423	60%	£88,000	£440	£465	47	£1,457

Table 7.4 Solar Photovoltaics options and costs for the 5 flats development group.

Solar Thermal

Both types of solar thermal collectors have been tested for this development group. It is considered that a flat plate system is generally cheaper as they usually have less engineering costs associated with their manufacture. Yet in ideal conditions, in terms of measuring peak performance, a flat plate system could compete or even beat the performance of an equivalent evacuated tube system.

An area of flat plate and evacuated tube collectors of 2.9 m^2 and 2.25 m^2, respectively, were chosen in order to work out the required amount of solar collector needed to reduce CO_2 emissions.

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 contribution of this technology to the CO_2 emissions can be anywhere from between 6% and 41% for the flat plate collector or 6% to 22% for evacuated tube if installed on a similar type of development, and measured in terms of both regulated and un-regulated emissions.

Tables 7.5 and 7.6 below indicate CO_2 emissions savings and costs associated with solar thermal technology. It can be possible to achieve the mandatory ENE1 level of Code Level 3 and 4 when a solar thermal collector is combined with best or advanced fabric standards. However, to achieve even greater emissions savings through the installation of renewable energy technologies on site, the solar thermal installation should be supplemented either with additional PV panels or a GSHP. Comparing the two standard collector types, it is obvious that evacuated tube requires less roof area to achieve the same CO_2 emission savings, while the cost per each percentage saved in terms of carbon emissions is also less than that of a flat tube system.

The costs shown in the tables below indicate that none of these solar thermal collector types are currently cost effective for the specific development due to the long payback period. However, various future changes in market conditions, the policy framework, as well as financial incentives, will reduce costs and therefore the payback period, which will ultimately make this technology a more affordable proposition.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
8.7 m^2	3,480	759	6%	9,000	£50	82	£1,458
14.5 m^2	5,800	1,264	10%	15,000	£80	84	£1,458
29 m^2	11,600	2,529	21%	30,000	£150	82	£1,458

Table 7.5 Flat Plate solar collector CO_2 contributions for the 5 flats

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
6.75 m^2	3,645	795	6%	9,000	£50	82	£1,392
11.25 m^2	6,075	1,324	11%	15,000	£80	79	£1,392
22.5 m^2	12,150	2,648	22%	30,000	£150	75	£1,392

Table 7.6 Evacuated tube solar collector CO_2 contributions and costs

Ground Source Heat Pumps (GSHP)

For a new build development of this scale a 10 kWh heat pump will be required which will provide space and water heating. This size of pump will usually require approximately five boreholes, subject to the geological ground conditions.

The percentage reduction in overall CO_2 consumption (assuming gas as the other fuel source) reduces the baseline carbon emissions by approximately 24%, while if combined with the best or advanced fabric standards could decrease the emissions by either 57% or 68%, respectively, both exceeding Code Level 4.

Table 7.7 provides details of the percentage CO_2 reductions that would result from the installation of GSHP and the associated costs. The net savings as well as the payback period make this option a feasible and cost effective alternative for new developments of this scale. The cost per each percentage increase in carbon reduction is also given.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
10 kW	26,496	2,980	24.25%	£17,000	£127.50	29	£701

Table 7.7 GSHP, carbon savings and costs for 5 new build flats

As a general rule of thumb, the percentage CO_2 reduction from on-site renewable energy generation 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 generally at the same level. Because the Coefficient of Performance (CoP) for hot water is smaller than for space heating, this decreases the CO_2 reduction figure.

Air Source Heat Pumps (ASHP)

An installation of a 10kW ASHP with CoP 3.5 is predicted to generate 26MWh per annum resulting in 2.5 tonnes CO2 emissions reduction and at a budget premium cost of £10,000. This size of heat pump can cover the total space heating and hot water demand of the development; however, the increased electricity prices do not offer significant energy savings which leads to a long payback period making this technology not a cost-effective investment.

System	Energy Generated (kWh/yr)	CO_2 Savings (kgCO2/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
10 kW	26,496	2,581	21.00%	£10,000	£80.00	>100	£476

Table 7.8 ASHP, carbon savings and costs for 5 new build flats

Biomass

Biomass heating is a very effective technology for significantly reducing carbon dioxide emissions. Table 7.9 below shows that for a small development of this scale, an 8kW pellet boiler is predicted to reduce the CO_2 emissions associated with the development by 34.48%, at a budget premium cost of £2,800.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
8 kW	21,807	4,238	34.48%	£2,800	£140	56	£81

Table 7.9 Biomass heating, carbon savings and costs for 5 new build flats

The use of a biomass boiler would require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost. A fuel pellet delivery of $0.63m^3$ would be required every week during the main heating season with less frequent deliveries throughout the remainder of the year. The payback period of 56 years makes this technology currently not a cost effective solution for the specific development. However, the cost per each percentage reduction in carbon emission savings is much less when compared to the other technologies and hence it might be worthwhile to explore this option further. In addition, when grants and other financial incentives are factored into the equation, this option may be more affordable.

Wind Turbines

Although wind turbines are not considered an appealing technology for urban environments, it was suggested that they will also be assessed in minor developments. The table below presents the sizes of the wind turbines that would potentially be appropriate for a development of this scale in an urban environment subject to roof availability.

If there was sufficient roof area for the installation of a roof-mounted turbine without any obstructions and would comply with Ealing's policies about air and noise quality, 1No of 1.2kW turbine is predicted to generate 3.75MWh of electricity per annum resulting in a CO_2 emission saving of 2.13 tonnes per annum. This option proves the most cost-effective of the options presented in Table 7.10 with only 4 years payback and the lowest cost per each percentage increase in carbon reduction.

The most suitable place for building mounted wind turbines is on the highest roof. This specific development is assumed to be low rise so roof mounted wind turbines will not meet the required wind speeds needed to generate valuable amounts of electricity.

System	Energy Generated (kWh/yr)	CO2 Savings (kgCO2/yr)	CO2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Pay back (yrs)	Cost per %
1.2kW Windsave	3,750	2,130	17.3%	1,898	£20	£107	4	£110
2x2.5 kW Proven	8,564	4,864	40%	25,200	£250	£286	20	£637

Table 7.10 Wind turbines options, carbon savings and costs for 5 flats new build development

<u>Conclusions</u>

This section outlines the optimum solution for this development group of 5 flats in terms of measure/measures based on their physical feasibility and cost effectiveness. The results are presented in table 7.11.

With regards to the energy efficiency measures, advanced fabric standards are deemed to be the most cost-effective option for this development group as they have the lowest cost per percentage saved of carbon emissions when compared to the other fabric standards. Comparing the feasible renewable technologies, biomass heating is the most cost effective solution followed by wind turbines, and full consideration of noise impacts. GSHP are also effective with the potential to achieve emission reductions of 24% with a cost of £701 for each percentage reduction achieved. Solar technologies although feasible for this development group and generally preferable for small scale residential developments surprisingly perform least well as their costs for each percentage saved proved to be the highest when compared with the other technologies. Based on physical feasibility only and assuming cost was not an issue, then solar PV panels with a capacity of 13.5kWp would achieve the greatest overall reduction.

	Measure	% Emissions Reduction	Cost per %
EM[38]	Advanced fabric standards	43.7%	£ 408
	Best fabric standards	32.6%	£439
	Good fabric standards	2.0%	£1,708
RES /LZCT[39]	8kW Biomass	34%	£ 81
	1.2kW Windsave	17%	£110
	10kW GSHP	24%	£ 701
	22.5 m2 evacuated tube thermal collector	22%	£1,392
	13.5 kWp Solar PV	60%	£1,457

Table 7.11 Feasible and cost-effective measures for the 5 flats

[38] Energy Efficiency Measures
[39] Renewable Energy Sources/ Low Zero Carbon Technologies

As it is afore-mentioned, various financial incentives and regulation changes could potentially alter these findings adjusting the relative cost effectiveness of individual technologies.

If advanced fabric standards are combined with biomass an overall reduction of 32% (both regulated + non-regulated) or 86% (regulated) can be achieved. The emission savings achieved, when only regulated energy is considered, is close to Code Level 5 of the Code for Sustainable Homes. It is important to mention that the renewable technologies shown in Table 7.11 have been assessed based on both regulated and non-regulated energy use which implies that biomass heating can achieve even higher emissions reduction if non-regulated energy was not included in the calculations.

7.4.1.2 Flats (6-10 units)

Energy Efficiency

The development's areas for this group were measured as a proportion of the real life example tested. The total floor and roof areas are 593m^2 and 294m^2, respectively. The roof area is a combination of both flat (110 m^2) and sloping (184 m^2) roof. The measures mentioned in Section 4 were tested for this development and the results are presented in tables 7.12 and 7.13.

Table 7.12 presents the average Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) for the different fabric measures, their percentage improvement and the Heat Loss Parameter[40]. Because the same real life example has been used for all the blocks, the average DER and TER will not change. It is apparent that good fabric standards will not provide major savings as it reduces the CO_2 emissions by only 2%. On the other hand, best practice achieves almost 33% emission savings more than Code Level 3 of the Code for Sustainable Homes requires. Passivhaus standards, however, achieve the highest savings with almost 44% reduction in CO_2 emissions which conforms to the Code for Sustainable Homes Level 4.

The table below also details the costs to meet the different energy efficiency measures standards which increase proportionally as these get improved. The cost beyond the baseline and the cost for each percentage increase in carbon reduction have also been calculated in order to assist in understanding which of these measures are the most cost-effective options for this development. For each percentage increase achieved in carbon reduction, a cost of £2,678 would need to be spent, if good fabric standards were being implemented while £799 would need to be spent if best and advanced fabric standards were to be applied. Despite spending the same cost for each percentage increase in carbon reduction, advanced or passivhaus standards can be considered the most cost-effective option as greater emission savings can be achieved through their implementation.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	22.48	22.54	0.3%	1.29	£27,808	£0.00	£0.00
Good Fabric Standards	22.09	22.54	2.0%	1.16	£33,154	£5,346	£2,678
Best Fabric Standards	15.19	22.54	32.6%	0.81	£53,870	£26,062	£799
Advanced Fabric Standards	12.68	22.54	43.7%	0.58	£61,881	£34,073	£779

[40] The building's specific heat loss (in units of W/K) divided by the building's floor area (measured internally – i.e. within the thermal envelope). Units W/K.m2

Table 7.12 Performance of different fabric scenarios and energy efficiency costs for 10 units

Table 7.13 presents the annual energy consumption of the 10 new build units resulted from the different energy efficiency scenarios tested and also the percentage reduction in CO_2 emissions derived from both regulated and un-regulated energy use. Despite the current high cost of MVHR systems, it is apparent that after their incorporation to the 10 units the energy and carbon savings achieved are significant.

Cooking and appliances, which are categorised as non-regulated emissions, as they are not covered by the Building Regulations, remain the same, while space heating, hot water and lighting consumption are reduced. The energy from the fans and pumps is increased due to the MVHR systems.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	25,605	21,676	10,948	6,240
Hot Water	27,428	27,548	26,977	26,690
Auxiliary	1,750	1,750	3,053	2,995
Lighting	5,035	4,444	3,877	2,998
Cooking & appliances	27,006	27,006	27,006	27,006
Savings from MVHR (Appendix Q)	-	-	-4,346	-5,568
Total Gas	53,033	49,224	37,925	32,930
Total Electricity	33,791	33,200	29,590	27,431
Grant Total	**86,824**	**82,425**	**67,515**	**60,361**
CO_2 Total (kgCO2/yr)	24,581	23,553	19,844	17,964
Percentage CO_2 reduction	-	**4.2%**	**19.3%**	**26.9%**

Table 7.13 Baseline breakdown of the annual energy requirements of 10 new build flats

CHP / CCHP/ Decentralised Energy Options

Biomass or gas combined heat (CHP) and power or combined heating, cooling and power (CCHP) systems are unlikely to be feasible and viable for this development group owing to the low energy demand, and the disproportionate share in the development's costs that a communal plant room would represent.

Solar photovoltaic

The development modelled for this group comprise up to 294m^2 of roof area of which 110 m^2 is flat and 184 m^2 is sloping roof. Although the full extent of the roof has been modelled, in practice the full area may not be available. It is possible for example that this roof area may be reduced if plant equipment needs to be accommodated on this roof space, or if green/brown roofs are proposed. The increasing need to provide for green and open space in innovative ways, including on roofs, as densities increase, will compete with the available space for roof mounted technologies.

However, although 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, there is still the potential to install PV panels.

Table 7.14 below shows the amount of panels that can be installed on the roof. Installing between 29m^2 and 58m^2 of hybrid PV panels on the flat roof is predicted to generate between 4 to 8MWh per annum resulting in 10 to 20% reduction in CO_2 emissions. Assuming that half of the flat roof and 1/3 of the sloping roof could be covered by hybrid PV panels, then an area of 117m^2 hybrid PV panels can provide 51% of the electricity demand of the development reducing the emissions by almost 10 tonnes per annum.

If non-regulated emissions were included in the calculations, then an area of 94m^2 could reduce the CO_2 emissions by 60%, which also enables the mandatory energy requirements for level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER).

Despite the long payback period of this technology, feed-in tariffs of 36p/kWh and the ROC income, which is issued for each whole MWh of renewable electricity generated, can make it cost effective by reducing it down to just 10 to 15 years.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
15m^2	2.31	2,228	1,265	5.1%	£15,000	£80	£72	49	£2,914
29 m^2	4.46	4,307	2,446	10.0%	£29,000	£150	£143	48	£2,914
58 m^2	8.92	8,613	4,892	19.9%	£58,000	£290	£286	47	£2,914
117 m^2	18.00	17,375	9,869	40.1%	£117,000	£590	£608	47	£2,914

Table 7.14 Solar PV options and costs for the 10 flats development group

The costs for each percentage increase in carbon reduction have been also calculated in order to assist in identifying which is the most cost effective solution for this development group. Due to the balance between the capital costs and the nett savings for all PV panel options, the cost per percentage increase in carbon reduction remains the same.

Solar Thermal

Both types of solar thermal collectors have been tested for this development group. It is considered that a flat plate system is generally slightly cheaper as they usually have less engineering costs associated with their manufacturer. Yet in ideal conditions, measuring peak performance a flat plate system could compete or even beat the performance of an equivalent evacuated tube system.

An area of flat plate and evacuated tube collectors of 2.9 m^2 and 2.25 m^2, respectively, were chosen to work out the required amount of solar collector that would reduce the CO_2 emissions.

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 contribution of this technology to the CO_2 emissions can be between 5% and 20% for both the flat plate and evacuated tube collectors if these were installed on a similar type of development covering both regulated and un-regulated emissions.

Tables 7.15 and 7.16 below indicate CO_2 emissions savings and costs associated with solar thermal technology. Although solar thermal itself cannot achieve Code Level 3 of the Code for Sustainable Homes, if combined with energy efficiency measures, it will probably achieve and exceed the 25% required target.

An installation of 67 m^2 of PV panel can supply 100% of the development's hot water demand while reducing the CO_2 emissions by 24% at a budget premium cost of approximately £75,000 and a payback period of 90 years.

Both tables also present the costs of the different solar panel options. It is obvious from the payback period that this technology would not be considered cost effective for similar developments but various future changes in market conditions and policies as well as financial incentives will reduce the costs and therefore the payback period. The cost for each percentage increase in carbon reduction has also been calculated and shown in the table below. Although evacuated tube collectors offer the same emissions reduction as flat plate collectors, their cost for each carbon reduction percentage achieved is lower and hence between the two evacuated tube collectors seem to be more favourable for this scale of development.

System	Energy Generated (kWh/yr)	CO_2 Savings (kgCO2/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
14 m^2	5,800	1,264	5%	15,000	£80	84	£2,916
29 m^2	11,600	2,529	10%	30,000	£150	82	£2,916
55 m^2	22,040	4,804	20%	57,000	£290	82	£2,916

Table 7.15 Flat Plate solar collector CO_2 contributions and costs for the 10 flats

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
11.3 m^2	6,075	1,324	5%	15,000	£80	79	£2,784
20.3 m^2	10,935	2,384	10%	27,000	£140	78	£2,784
43 m^2	23,085	5,032	20%	57,000	£290	76	£2,784

Table 7.16 Evacuated tube solar collector CO_2 contributions and costs for the 10 flats

Ground Source Heat Pumps (GSHP)

For a new build development of this scale, 2 No. 10 kWh heat pumps with CoP 4 will be required to supply 100% of the development's space heating and hot water requirements. This size of pump will usually require approximately 10 boreholes, subject to the geological ground conditions.

The percentage reduction in overall CO_2 emissions resulted from the GSHP (assuming gas as the other fuel source) reduces the baseline carbon emissions by approximately 24% as it seems from table 7.17 below, while if combined with best or advanced fabric standards could decrease the emissions by either 43% or 51%, respectively, which both exceed Code Level 4. The budget premium cost is £34,000 and the payback period is 21 years.

However, with a minimum separation between the boreholes of 6-9 meters and 100m deep, there is insufficient space at the development for GSHP. This technology could, however, be feasible if there was either amenity area surrounding the building on the ground floor or parking area which can increase the development's available area. The cost per each percentage increase in carbon reduction is also given.

It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2 x10 kW	52,992	5,960	24.25%	£34,000	£255	21	£1,402

Table 7.17 GSHP, carbon savings and costs for 10 new build flats

Air Source Heat Pumps (ASHP)

An installation of 2 No. 10 kW ASHP's with CoP 3.5 is predicted to generate 26MWh per annum resulting in 2.5 tonnes CO_2 emissions reduction and at a budget premium cost of £20,000. This size of heat pump can cover the total space heating and hot water demand of the development; however, the increased electricity prices do not offer significant energy savings which leads to a long payback period making this technology not a cost-effective investment.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2 x 10kW	52,992	5,162	21.00%	£20,000	£150	>100	£952

Table 7.18 ASHP, carbon savings and costs for 10 new build flats

Biomass

Table 7.19 below shows that for a development of this scale, a 15kW pellet boiler is predicted to reduce the CO_2 emissions associated with the development by 34.21% while supplying 100% of the space heating and 64% of the hot water demand, at a budget premium cost of £2,800. The 12 years payback period makes this technology a feasible and viable option for this development group.

Furthermore, the cost per each percentage increase in carbon reduction is much less when compared to the other technologies and as such it can be considered the most cost effective option for this development group. Factoring grants and other financial incentives can make this option an even more affordable solution for similar developments.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
15 kW	43,279	8,410	34.21%	£2,800	£140	12	£82

Table 7.19 Biomass heating, carbon savings and costs for 10 new build flats

The use of a biomass boiler would however require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost. A fuel pellet delivery of 1.22m^3 would be required two weeks during the main heating season with less frequent deliveries throughout the remainder of the year. If wood chips would be used then fuel storage of 3.86m^3 would be required.

Wind Turbines

Although wind turbines are not considered an appealing technology for urban environments, it was suggested that they will also be assessed in all development groups. The table below presents the sizes of the wind turbines that would potentially be appropriate for similar developments in an urban environment subject to roof availability.

Table 7.20 details the options for roof mounted wind turbines facing south west. Generally the most suitable place for building mounted wind turbines is on the highest roof. A series of 6 No. 1kW roof mounted wind turbines is predicted to generate 10MWh of electricity per annum resulting in 5.7 tonnes of CO2 emissions reduction at a budget premium cost of £30,000. The annual ROC income and nett savings make this option feasible and viable for this development. Alternatively, an 1 No. 2.5kW roof mounted wind turbine would reduce the emissions by 10% providing 13% of the development's electricity demand and at a budget premium cost of £12,600. An approximate 13m space alongside the roof would be required for the installation of wind turbines shown in the table below.

As both options have the same payback period, it can be assumed that the most feasible could be the series of 6 turbines as it achieves greater savings throughout the year despite the slightly higher cost that needs to be spend for each percentage increase in carbon reduction.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
6 x 1kW Aeroenvironment AVX1000 (@18m agl)	10,098	5,736	23.3%	£30,000	£300	£358	20	£1,286
1x2.5 kW Proven	4,282	2,432	9.9%	£12,600	£130	£143	20	£1,273

Table 7.20 Wind turbines options, carbon savings and costs for 10 flats

Conclusions

Table 7.21 presents the optimum solution for the 10 flats in terms of measure/measures based on physical feasibility and cost effectiveness.

With regards to the energy efficiency scenarios, advanced fabric standards can be considered the most cost-effective option for this development group as they offer the highest emission savings with the lowest cost, £799, per each percentage increase in carbon reduction.

Comparing the feasible renewable technologies, biomass heating seems to be the most cost effective solution for the 10 flats, while the series of 6 No. 1kW roof mounted wind turbines come next achieving 23% CO2 emissions reduction at a cost of £1,286 for each percentage increase achieved in carbon reduction. The installation of 2 No. 10kW GSHP is following offering similar emission reduction as the wind turbines but with almost £116 more for each percentage reduction achieved. It can therefore be assumed that GSHP although slightly more expensive can be more cost effective than the series of the roof mounted wind turbines.

Solar technologies although feasible for this development group and generally preferable for small scale residential developments come last as their costs for each percentage increase in carbon reduction proved to be the highest when compared to the other technologies. It is apparent from the table that a 43m^2 evacuated tube collector provides the same CO_2 emission savings as the 8.92kWp solar PV or the 55m^2 flat plate collector but seems to have the lowest cost for each percentage increase achieved in carbon reduction.

Comparing the solar technologies, despite the different energy generation provided, it is evident that a solar PV panel with 18kWp capacity can reduce the emissions by 40% while having the same or similar cost per percentage emission reduction as the 8.92 kWp solar PV panel or the solar thermal collectors. It can be therefore concluded that the option of the solar PV panel with 18kWp capacity is more cost effective than the other solar options. Factoring grants and other various financial incentives and regulation changes will potentially reduce the overall costs of the solar technologies making them more affordable.

	Measure	% Emissions Reduction	Cost per %
EEM	Advanced fabric standards	43.7%	£779
	Best fabric standards	32.6%	£799
	Good fabric standards	2.0%	£2,678
RES /LZC	15kW Biomass	34%	£82
	6x1kW Aeroenvironment AVX1000	23%	£1,286
	2x10kW GSHP	24%	£1,402
	43 m^2 evacuated tube thermal collector	20%	£2,784
	8.92 kWp Solar PV	20%	£2,914
	18 kWp Solar PV	40%	£2,914
	55 m^2 flat plate thermal collector	20%	£2,916

Table 7.21 Feasible and cost-effective measures for the 10 flats

If the most cost-effective options were combined, namely advanced fabric standards and biomass heating, they can reduce CO_2 emissions by 86%, which is close to Code Level 5 of the Code for Sustainable Homes or 32% when both regulated and non-regulated energy are considered. It is important to note that the renewable technologies shown in Table 7.21 have been assessed based on both regulated and non-regulated energy use which implies that biomass heating can achieve even higher emissions reduction if non-regulated energy was not included in the calculations.

7.4.1.3 Flats (11 -50)

Energy Efficiency

The development's areas for this group were measured as a proportion of the real life example tested. The total floor and roof areas are 2,963m^2 and 1,052m^2, respectively. The roof area is a combination of both flat (394 m^2) and sloping (658 m^2) roof. The measures mentioned in Section 4 were tested for this development and the results are presented in tables 7.22 and 7.23.

Table 7.22 presents the average Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) for the energy efficiency scenarios, the CO_2 emissions savings and the Heat Loss Parameter. Because the same real life example has been used for all the blocks, the average DER and TER will not change. However, as the building's footprint is bigger, the costs for implementing the various energy efficiency measures will get increased due to the bigger development's footprint.

The table demonstrates that best or advanced fabric standards can achieve greater emissions savings which exceed Code Level 3 compared to good fabric standards. Best practice standards can exceed Code Level 3 with 33% in emissions reduction while passivhaus standards meet almost Code Level 4 (44%) of the Code for Sustainable Homes.

The table below also details the costs to meet the different energy efficiency measures standards which increase proportionally as these get improved. The cost beyond the baseline and the cost for each percentage increase in carbon reduction have also been calculated in order to assist in understanding which of these measures are the most cost-effective options for this development.

It is evident that best fabric standards have the lowest cost for each percentage increase in carbon reduction while advanced come second with slightly higher cost. Good fabric standards not only result in minimum improvement in CO_2 emissions against the baseline but also the cost for each percentage reduction achieved is almost 64% higher.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	22.48	22.54	0.3%	1.29	£124,924	£0.00	£0.00
Good Fabric Standards	21.09	22.54	2.0%	1.16	£145,312	£20,388	£10,212
Best Fabric Standards	15.19	22.54	32.6%	0.81	£244,588	£119,663	£3,670
Advanced Fabric Standards	12.68	22.54	43.7%	0.58	£286,290	£161,366	£3,689

Table 7.22 Performance of different fabric scenarios and energy efficiency costs for 50 units

The three energy efficiency scenarios were assessed against the baseline for the 50 new build flats (Building Regulations 2006) and the results are shown in Table 7.23.

It is obvious that significant savings are achieved in space heating and lighting and a small decrease in hot water, while the energy from auxiliary is increased due to the MVHR application. Cooking and appliances, which are categorised as non-regulated emissions, as they are not covered by the Building Regulations, remain the same but if "A" rated appliances and smart metering would be applied; the energy and associated emissions would get reduced.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	128,027	108,382	54,738	31,201
Hot Water	137,139	137,740	134,885	133,452
Auxiliary	8,750	8,750	15,265	14,973
Lighting	25,173	22,220	19,386	14,990
Cooking & appliances	135,031	135,031	135,031	135,031
Savings from MVHR (Appendix Q)	-	-	- 21,732	- 27,839
Total Gas	265,166	246,122	189,623	164,652
Total Electricity	168,954	166,001	147,950	137,155
Grant Total	**434,120**	**412,123**	**337,573**	**301,807**
CO_2 Total ($kgCO_2$/yr)	122,904	117,766	99,222	89,822
Percentage CO_2 reduction	-	**4.2%**	**19.3%**	**26.9%**

Table 7.23 Baseline breakdown of the annual energy requirements of 50 new build units

CHP / CCHP/ Decentralised Energy Options

Natural gas-fired CHP is not considered to be a renewable energy technology rather a low carbon technology. Biomass CHP is yet a proven technology and although there is currently in the market, the size units are for larger developments.

A single 25kWe/38.4kWth natural gas-fired CHP engine could potentially satisfy the development's base heat and hot water load whistle generating up to 92% of its electrical requirements. This would result in a 41% annual reduction in CO_2 emissions. It is predicted to generate for 6,215 hours per annum at a budget premium cost of £102,634. A summary of the calculations for the CHP unit are shown in table 7.24. The costs outlined have been based on ballpark figures provided by CHP suppliers, Ener-G.

The significant savings that CHP achieves as well as the short payback period make this technology option feasible and cost effective for this development type. However, when the cost per each percentage increase in carbon reduction will be compared with other feasible alternative technologies it will assist in identifying the most cost effective option for this development group.

System	Hours operation	Heat Generated (kWh/yr) / % heat & HW demand	Electricity Generated (kWh/yr)/ % of electricity demand	CO_2 Savings ($kgCO_2$/yr)/ % reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Pay back (yrs)	Cost per %
Ener-G 25Y	6,215	238,650 / 47% heat / 47% HW	155,371/ 92%	50,448 41%	£102,634	£1,540	16	£2,503

Table 7.24 CHP size, carbon savings and costs for 50 units

<u>Solar photovoltaic</u>

The development modelled for this group comprises up to 394m^2 of flat roof and 658 m^2 of sloping roof. Although the full extent of the roof has been modelled, in practice the full area may not be available. It is possible for example that this roof area may be reduced if plant equipment needs to be accommodated on this roof space, or if green/brown roofs are proposed. The increasing need to provide for green and open space in innovative ways, including on roofs, as densities increase, will compete with the available space for roof mounted technologies.

However, although 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, there is still the potential to install PV panels.

Table 7.25 presents the options for hybrid solar PV areas that could be installed on the roof of this development. The roof area assumed to be feasible for mounting the panels is 723m^2. An installation of 145m^2 to 291m^2 PV panels could generate around 12 to 25 MWh of electricity per annum resulting in 10-20% CO_2 emissions reduction. The capital cost is between £145,000 to £291,000 with annual ROC income for each MWh of electricity generated between £751 and £1500.

If an area of 583m^2 hybrid PV panels was installed on the roof, combining flat and pitched, it could potentially satisfy 51% of the development's electricity demand, reducing the CO_2 emissions by 49 tonnes per annum at a budget premium cost of £583,000.

If non-regulated emissions were included in the calculations, an area of 313m^2 could reduce the CO_2 emissions by 40% which also enables the mandatory energy requirements for level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER). The budget premium cost is £313,000 with annual nett savings and ROC income of £6,415 and £1,645, respectively and at a payback period of 49 years.

Despite the long payback period of this technology, feed-in tariffs of 36p/kWh and the ROC income, which is issued for each whole MWh of renewable electricity generated, can make it cost effective by reducing it down to just 10 to 15 years.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
73 m^2	11.23	10,841	6,157	5.0%	£73,000	£370	£358	48	14,571
145 m^2	22.31	21,533	12,230	10.0%	£145,000	£730	£751	47	14,571
291 m^2	44.77	43,214	24,545	20.0%	£291,000	£1,460	£1,538	47	14,571
583 m^2	89.69	86,576	49,175	40.0%	£583,000	£2,920	£3,075	47	14,571

Table 7.25 Solar Photovoltaics options and costs for the 50 flats development group.

The cost for each percentage increase in carbon reduction has been also calculated in order to identify the most cost effective solution for this development group. Due to the balance between the capital costs and the nett savings for all PV panel options, the cost per percentage increase in carbon reduction remains the same.

Solar Thermal

Both types of solar thermal collectors have been tested for this development group. An area of flat plate and evacuated tube collectors of 2.9 m^2 and 2.25 m^2, respectively, were chosen to work out the required amount of solar collector that would reduce the CO_2 emissions. It should be noted that the carbon emission savings presented in the tables below, have been derived from both regulated and non-energy use.

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 contribution of this technology to the CO_2 emissions can be between 5% and 20% for both the flat plate and evacuated tube collectors if these were installed on a similar type of development covering both regulated and un-regulated emissions.

The results of an initial study into the feasibility of incorporating a solar thermal collector system on the roof in order to meet a proportion or the total, if possible, of the development's domestic hot water requirements as well as CO_2 emissions savings and costs are presented in tables 7.26 and 7.27.

An installation of solar thermal collectors of either 276m^2 flat plate or 211 m^2 evacuated tube can reduce the CO_2 emissions of the development by 20% while both generating 58MWh of electricity per annum. It is obvious that evacuated tube requires less area to provide the same electricity generation whistle having higher nett savings resulting in a lower payback period than that of flat's plate.

In order to supply 100% of the development's hot water demand, an area of either 342m^2 of flat plate collector or 254m^2 of evacuated tube collector could potentially be installed on the development's roof and both reduce the CO_2 emissions by 24.3% at a budget premium cost of approximately £340,000 and a payback period of 76 years.

It is obvious from the payback period that this technology would not be cost-effective for similar developments but various future changes in market conditions and policies as well as financial incentives will reduce the costs and therefore the payback period. The cost for each percentage increase in carbon reduction also proves that it would not be recommended for similar developments.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reductio n	Capital Cost (£)	Maintenanc e Cost (£/yr)	Paybac k (yr)	Cost per %
73 m^2	29,000	6,321	5%	75,000	£380	81	£14,582
145 m^2	58,000	12,643	10%	150,000	£750	81	£14,582
276 m^2	110,200	24,021	20%	285,000	£1,430	81	£14,582

Table 7.26 Flat Plate solar collector CO_2 contributions for the 50 flats

System	Energy Generated (kWh/yr)	CO2 Savings (kgCO2/yr)	CO2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
56 m^2	30,375	6,621	5%	75,000	£380	76	£13,922
108 m^2	58,320	12,712	10%	144,000	£720	76	£13,922
211 m^2	114,210	24,895	20%	282,000	£1,410	76	£13,922

Table 7.27 Evacuated tube solar collector CO_2 contributions and costs for 50 units

Ground Source Heat Pumps (GSHP)

For a new build development of this scale, an installation of 2 No. 50 kWh heat pumps with CoP 4 will be required to supply 100% of the development's space heating and hot water requirements. This size of pump will usually require approximately 50 boreholes, subject to the geological ground conditions.

Table 7.28 presents the CO_2 emissions savings achieved over the baseline (assuming gas as the other fuel source) when GSHP is implemented. A reduction of 21% in carbon emissions are achieved, while if combined with the best or advanced fabric standards could decrease the emissions by either 40% or 48%, respectively, which both exceed Code Level 4. The budget premium cost is £170,000 and the payback period is 17 years. The cost per each percentage increase in carbon reduction is also given.

However, with a minimum separation between the boreholes of 6-9 meters and 100m deep, there is insufficient space at the development for GSHP. This technology could, however, be feasible if there was either amenity area surrounding the building on the ground floor or parking spaces which increase the total available footprint area for their installation. For horizontal heat exchangers, an approximate area of £2,600m2 would be required.

It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2 x50 kW	264,959	25,809	21.00%	£170,000	£1,275	17	£8,096

Table 7.28 GSHP, carbon savings and costs for 50 new build flats

Air Source Heat Pumps (ASHP)

An installation of 2 No. 50 kW ASHP's with CoP 3.5 is predicted to generate 265MWh per annum resulting in 26 tonnes CO_2 emissions reduction and at a budget premium cost of £100,000. This size of heat pump can cover the total space heating and hot water demand of the development; however, the increased electricity prices do not offer significant energy savings which leads to a long payback period making this technology not a cost-effective investment.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2 x 50kW	264,959	25,809	21.00%	£100,000	£750	>100	4,762

Table 7.29 ASHP, carbon savings and costs for 50 new build flats

Biomass

Table 7.30 below shows that for a development of this scale, a 80kW pellet boiler is predicted to reduce the CO_2 emissions associated with the development by 34.5% while supplying 100% of the space heating and 66% of the hot water demand, at a budget premium cost of £11,300. The 9 years payback period makes this technology the most feasible and cost effective option for this development group.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
80 kW	218,066	42,377	34.48%	£11,300	£570	9	£328

Table 7.30 Biomass heating, carbon savings and costs for 50 new build flats

The use of a biomass boiler would however require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost. A fuel pellet delivery of 7m^3 would be required two weeks during the main heating season with less frequent deliveries throughout the remainder of the year. If wood chips would be used then fuel storage of 20m^3 would be required.

Comparing the cost for each increase in carbon reduction for biomass heating with that of the other technologies, it is evident that it is the lowest with £328.

Wind Turbines

Although wind turbines are not considered an appealing technology for urban environments, it was suggested that they will also be assessed in minor developments. The table below presents the sizes of the wind turbines that would potentially be appropriate for similar developments in an urban environment subject to roof and/or land availability.

Table 7.31 details the options for roof mounted and small free standing wind turbines facing south west. Generally the most suitable place for building mounted wind turbines is on the highest roof. A series of 6 No. 1kW roof mounted wind turbines is predicted to generate 10MWh of electricity per annum resulting in 5.7 tonnes of CO_2 emissions reduction at a budget premium cost of £30,000. The annual ROC income and nett savings make this option favourable for this development.

A further 6 series of roof mounted wind turbines increase the predicted output by 4.3MWh per annum resulting in an overall emissions reduction of 6.7%. The budget premium cost of the 12 series of turbines is £50,000 with a payback period of 25 years. A 12m space alongside the roof would be required for the installation of the 6 wind turbines and 24m for the 12 turbines.

The negligible emission savings resulting from the potential installation of the 2.5kW Proven and 6kW Quiet Revolution turbines make them not feasible for this development type.

Given the costs for each percentage achieved in carbon reduction, the series of 12 No 1kW roof mounted wind turbines not only offer the highest emission savings, but also at the lowest cost per each percentage emissions achieved and it can therefore be assumed that they are the most cost-effective option.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
6 x 1kW Aeroenvironment AVX1000 (@18m agl)	10,098	5,736	4.7%	£30,000	£300	£358	20	£323
12 x 1kW Aeroenvironment AVX1000 (@18m agl)	14,400	8,179	6.7%	£50,000	£500	£501	25	£311
1x2.5 kW Proven	4,282	2,432	2.0%	£12,600	£130	£143	20	£320
1x6kW Quiet Revolution	8,500	4,828	3.9%	£25,000	£250	£286	20	£320

Table 7.31 Wind turbines options, carbon savings and costs for the 50 new build flats

Conclusions

This section outlines the optimum solution for the 50 flats in terms of measure/measures based on physical feasibility and cost effectiveness and the results are presented in table 7.32.

With regards to the energy efficiency scenarios, although best fabric standards can be considered the most cost-effective option for this development group due to the lowest cost given for each percentage increase in carbon reduction, passivhaus standards offer higher emission savings with only 1% difference in the cost shown below. It can be therefore assumed that advanced fabric standards are the most cost effective solution for this development group.

Comparing the feasible renewable technologies, the roof mounted wind turbines seem to be the most cost effective technology option for the 50 flats. However, while wind turbines reduce the CO_2 emissions by only 7%, biomass heating with £328 for each percentage increase in carbon reduction achieves 81% more in emission savings.

CHP reduces the emissions by 41% with a cost £2,503 for each percentage emission reduction achieved while GSHP results in 21% improvement in carbon emissions with a cost of £3,689. Solar technologies seem by far too expensive based on the costs for each percentage reduction achieved when compared with the other feasible technologies and therefore they are not recommended for the specific development group.

Various financial incentives and regulation changes will potentially reduce the overall costs of some of the technologies assessed and this can be particularly applied in solar technologies.

If advanced fabric standards are combined with CHP, a reduction of 83% (regulated) or 30% (regulated + non-regulated) can be achieved which is close to Code Level 5 of the Code for Sustainable Homes. Following the Energy Hierarchy, if biomass heating is chosen as a back up to the CHP system, then a reduction 64% (regulated) or 32%(regulated + non-regulated) can be achieved which still exceeds Code Level 4 of the Code.

It is important to mention that while the percentage reduction in CO_2 emissions achieved from the energy efficiency scenarios have been based on only regulated energy use, the renewable technologies' contribution in the emission savings have been based on both regulated and non-regulated energy use.

	Measure	% Emissions Reduction	Cost per %
EEM	Best fabric standards	19.3%	£3,670
	Advanced fabric standards	26.9%	£3,689
	Good fabric standards	4.2%	£10,212
RES /LZC	12x1kW Aeroenvironment AVX1000	7%	£311
	80kW Biomass	34%	£328
	25kWe CHP	41%	£2,503
	2x50kW GSHP	21%	£8,096
	211 m2 evacuated tube thermal collector	20%	£13,922
	89.7 kWp Solar PV	40%	£14,571
	276m2 flat plate thermal collector	20%	£14,582

Table 7.32 Feasible and cost-effective measures for the 50 flats

7.4.1.3 Flats 51+

Energy Efficiency

The development's areas for this group were measured as a proportion of the real life example tested. The total floor and roof areas are 5,926m^2 and 2,104m^2, respectively. The roof area is a combination of both flat (788 m^2) and sloping (1,316 m^2) roof. The annual energy consumption and associated CO_2 emissions have been estimated for this development group and the CO_2 emission savings are based on the energy efficiency scenarios explained in Section 4. Tables 7.33 and 7.34 present the results.

Table 7.33 presents the average Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) for the energy efficiency scenarios, the CO_2 emissions savings and the Heat Loss Parameter[41]. Because the same real life example has been used for all the blocks, the average DER and TER has not changed. However, as the building's footprint is bigger, the energy, emissions and costs for implementing the various energy efficiency measures will get increased due the bigger development's footprint.

[41] The building's specific heat loss (in units of W/K) divided by the building's floor area (measured internally – i.e. within the thermal envelope). Units W/K.m2

Implementing good fabric standards will not result in significant emission savings, whistle best and advanced practice will exceed 25% reduction in CO_2 emissions which is the required target for meeting Level 3 of the Code for Sustainable Homes. Advanced fabric standards particularly achieve almost 44% reduction in emissions which conforms to Code Level 4.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Cost	Cost beyond baseline	Cost per %
Baseline	22.48	22.54	0.27%	1.29	£204,132	£0.00	£0.00
Good Fabric Standards	21.09	22.54	2.0%	1.16	£244,907	£40,775	£20,424
Best Fabric Standards	15.19	22.54	32.6%	0.81	£443,458	£239,327	£7,339
Advanced Fabric Standards	12.68	22.54	43.7%	0.58	£499,433	£295,302	£6,751

Table 7.33 Performance of different fabric scenarios and costs for 51+ flats

As it is afore mentioned, the Building Regulations Part L 2006 have been used to establish the baseline for all development groups. The cost beyond baseline expresses the additional cost for implementing the good, best and advanced fabric scenarios, while the cost per percentage indicates the cost for each percentage increase in carbon reduction. It is evident that £20,424 will have to be spent for each CO_2 emissions reduction percentage achieved for good fabric standards (2%). The most cost-effective solution for this specific development seems to be the advanced fabric standards scenario with £6,751 for each percentage increase in carbon reduction achieved.

The three energy efficiency scenarios were also assessed when both regulated and un-regulated energy use was included for the 100 new build flats and the results are shown in Table 7.34. The contribution of the cooking and appliances (non-regulated) to the overall energy consumption by almost 10% implies the importance for implementing measures such as very efficient appliances and smart metering.

It is obvious that significant savings are achieved in space heating and lighting and a small decrease in hot water, while the energy from auxiliary is increased due to the MVHR application.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	128,027	108,382	54,738	31,201
Hot Water	137,139	137,740	134,885	133,452
Auxiliary	8,750	8,750	15,265	14,973
Lighting	25,173	22,220	19,386	14,990
Cooking & appliances	135,031	135,031	135,031	135,031
Savings from MVHR (Appendix Q)	-	-	- 21,732	-27,839
Total Gas	265,166	246,122	189,623	164,652
Total Electricity	168,954	166,001	147,950	137,155
Grant Total	**434,120**	**412,123**	**337,573**	**301,807**
CO_2 Total ($kgCO_2$/yr)	122,904	117,766	99,222	89,822
Percentage CO_2 reduction	-	**4.2%**	**19.3%**	**26.9%**

Table 7.34 Baseline breakdown of the annual energy requirements of 51+ new build flats

CHP / CCHP/ Decentralised Energy Options

Natural gas-fired CHP is not considered to be a renewable energy technology; it is rather a low carbon technology. Biomass CHP units are not yet a proven technology and although there are currently in the market, the available size units are for larger developments.

A single 50kWe/86kWth natural gas-fired CHP engine could potentially satisfy the development's base heat and hot water load whistle generating up to 82% of its electrical requirements. This would result in a 31.11% annual reduction in CO_2 emissions. It is predicted to generate for 5,550 hours per annum at a budget premium cost of £140,000. In addition, the cost for each percentage increase in carbon reduction for the CHP is £2,161. A summary of the calculations for the CHP unit are shown in table 7.35.

The significant savings that CHP achieves as well as the short payback period make this technology option feasible and cost effective for this development type.

System	Hours operation	Heat Generated (kWh/yr) / % heat & HW demand	Electricity Generated (kWh/yr)/ % of electricity demand	CO_2 Savings ($kgCO_2$/yr) / % reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yrs)	Cost per %
50kWe	5,550	477,259 / 47% heat 47% HW	321,259/ 82%	76,468 31.11%	£75,000	£1,125	6	£2,161

Table 7.35 CHP size, carbon savings and costs for 51+ units

Solar photovoltaic

The development modelled for this group comprise up to 788m^2 of flat roof and 1,316 m^2 of sloping roof. With regards to the pitch roof, if dormer windows and other features are present on the south side of the roof, which is most appropriate to be used for solar technologies, the available surface area will be less. However, although 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, there is still the potential to install PV panels.

Table 7.36 presents the options for hybrid solar PV areas that could be installed on the roof. The roof area assumed to be feasible for mounting the panels is 1,227m^2. An installation of 160m^2 to 590m^2 PV panels could generate around 24 to 88 MWh of electricity per annum resulting in 5-20% CO_2 emissions reduction. The capital cost will be between £160,000 to £590,000 with annual ROC income for each MWh of electricity generated between £822 and £3,111.

Despite the long payback period of this technology, feed-in tariffs of 36p/kWh and the ROC income, which is issued for each whole MWh of renewable electricity generated, can make it cost effective by reducing it down to just 10 to 15 years. Furthermore, due to the balance between the capital cost and the savings for the three options, the cost per each percentage increase achieved in carbon reduction remains the same.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
160 m^2	24.6	23,760	13,496	5.5%	£160,000	£800	£822	50	29,142
300 m^2	46.2	44,550	25,304	10.3%	£300,000	£1,500	£1,573	49	29,142

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
590 m^2	90.8	87,615	49,765	20.2%	£590,000	£2,950	£3,111	49	29,142

Table 7.36 Solar PV options and costs for the 51+ flats development group.

Solar Thermal

Both types of solar thermal collectors have been tested for this development group. An area of flat plate and evacuated tube collectors of 2.9 m^2 and 2.25 m^2, respectively, were chosen to work out the required amount of solar collector. It should be noted that the carbon emission savings presented in the tables below, have been derived from both regulated and non-regulated energy use.

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 contribution of this technology to the CO_2 emissions can be between 5% and 20% for both the flat plate and evacuated tube collectors if these were installed on a similar type of development covering both regulated and un-regulated emissions.

Tables 7.37 and 7.38 below indicate CO_2 emissions savings and costs associated with solar thermal technology. An installation of solar thermal collectors of either 511m^2 flat plate or 428 m^2 evacuated tube can reduce the CO_2 emissions of the development by 20%, generating between 48-50 MWh of electricity per annum. It is obvious that evacuated tube requires less area to provide the same electricity generation while the difference in the payback period between the two types, make evacuated tube collectors more cost-effective solution for this development.

In order to supply 100% of the development's hot water demand, an area of either 684m^2 of flat plate collector or 509m^2 of evacuated tube collector could potentially be installed on the development's roof and both reduce the CO_2 emissions by 24.3% at a budget premium cost of approximately £690,000 and a payback period of 78 years.

Although evacuated tube collectors are considered as being more cost effective than the flat plate, the long payback period of both collector types makes the solar thermal technology not recommended for similar developments. Potential future changes in market conditions and policies as well as financial incentives might reduce the costs and therefore the payback period. The cost for each percentage increase in carbon reduction has been also calculated and presented in tables below.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
142 m^2	56,840	12,390	5%	147,000	£740	81	£29,164
290 m^2	116,000	25,285	10%	300,000	£1,500	81	£29,164
511 m^2	220,400	48,042	20%	570,000	£2,850	81	£29,164

Table 7.37 Flat Plate solar collector CO_2 contributions and costs for the 51+ flats

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
113 m^2	60,750	13,242	5%	150,000	£750	76	£27,844
214 m^2	115,425	25,160	10%	285,000	£1,430	76	£27,844

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
428 m^2	230,850	50,320	20%	570,000	£2,850	76	£27,844

Table 7.38 Evacuated tube solar collector CO_2 contributions and costs for the 51+ flats

Ground Source Heat Pumps (GSHP)

For a new build development of this scale, 4 No. 50 kWh heat pumps with CoP 4 will be required to supply 100% of the development's space heating and hot water requirements. This size of pump will usually require approximately 100 boreholes, subject to the geological ground conditions.

Table 7.39 demonstrates that the installation of the GSHP will reduce the overall CO_2 consumption (assuming gas as the other fuel source) against the baseline by 24.3%. If GSHP was combined with best or advanced fabric standards could decrease the emissions by either 57% or 68%, respectively, which both exceed Code Level 4. The budget premium cost is £340,000 and the cost to spend for each percentage increase in carbon reduction is £14,022.

In order to supply the total space heating and hot water demand of the development, it is predicted that 100 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is not considered to be sufficient space at the development for GSHP. This technology could, however, be feasible if there was either amenity area surrounding the building on the ground floor or parking area which both options increase the total available footprint area. For horizontal heat exchangers, an area of more than 5000m^2 would be required which is not available.

It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
4 x50 kW	529,918	59,604	24.25%	£340,000	£2,550	17	£14,022

Table 7.39 GSHP, carbon savings and costs for 51+ new build flats

Air Source Heat Pumps (ASHP)

An installation of 4 No. 50 kW ASHP's with CoP 3.5 is predicted to generate 530MWh per annum resulting in 51 tonnes CO_2 emissions reduction and at a budget premium cost of £200,000. This size of heat pump can cover the total space heating and hot water demand of the development; however, the increased electricity prices do not offer significant energy savings which leads to a long payback period making this technology not a cost-effective investment.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
4x 50kW	529,918	51,617	21.00%	£200,000	£1,500	>100	£9,524

Table 7.40 ASHP, carbon savings and costs for 51+ new build flats

Biomass

A 150kW biomass boiler is predicted to reduce the CO_2 emissions associated with the development by 34.22% while supplying 100% of the space heating and 64% of the hot water demand, at a budget premium cost of £22,500. The 9 years payback period and the cost for each percentage increase in carbon reduction, £658, make this technology the most feasible and cost-effective option for this development group. The results are shown in Table 7.41.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
150 kW	432,792	84,105	34.22%	£22,500	£1,130	9	£658

Table 7.41 Biomass heating, carbon savings and costs for 51+ new build flats

The use of a biomass boiler would however require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost. A fuel pellet delivery of $13m^3$ would be required every two weeks during the main heating season with less frequent deliveries throughout the remainder of the year. If wood chips would be used then fuel storage of $39m^3$ would be required.

<u>Wind Turbines</u>

Although wind turbines are not considered an appealing technology for urban environments, it was suggested that they will also be assessed in all development groups. The table below presents the sizes of the wind turbines that would potentially be appropriate for similar developments in an urban environment subject to roof and/or land availability.

Table 7.42 details the options for roof mounted and small free standing wind turbines facing south west. Generally the most suitable place for building mounted wind turbines is on the highest roof. A series of 12 No. 1kW roof mounted wind turbines is predicted to generate 14.4MWh of electricity per annum (4% of electricity demand) resulting in 8.17 tonnes of CO_2 emissions reduction at a budget premium cost of £50,000.

A further 24 series of roof mounted wind turbines increase the predicted output by 28.8MWh per annum resulting in an overall emissions reduction of 10%. The budget premium cost of the 24 series of turbines is £140,000 with a payback period of 24 years. A total of 72m space alongside the south and west facing roof would be required for the installation of the 36 wind turbines. Despite the highest capital cost and the highest cost spent for each percentage increase in carbon reduction, the annual ROC income and nett savings make this option feasible and cost effective for this development.

The negligible emission savings resulting from the potential installation of the 2.5kW Proven and 6kW Quiet Revolution turbines make them not feasible for this development type.

System	Energy Generated (kWh/yr)	CO_2 Savings (kgCO2/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
6 x 1kW Aeroenvironment AVX1000 (@40m agl)	10,098	5,736	2.3%	£30,000	£300	£358	21	£12,857
12 x 1kW Aeroenvironment AVX1000 (@18m agl)	14,400	8,179	3.3%	£50,000	£500	£501	26	£15,026
24 x 1kW Aeroenvironment AVX1000 (@18m agl)	28,800	16,358	6.7%	£90,000	£900	£1,001	23	£13,524
36 x 1kW Aeroenvironment AVX1000 (@18m agl)	43,200	24,538	10.0%	£140,000	£1,400	£1,538	24	£14,025

System	Energy Generated (kWh/yr)	CO_2 Savings (kgCO2/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
1x6kW Quiet Revolution	8,500	4,828	2.0%	£25,000	£250	£286	21	£12,728
2x6kW Quiet Revolution	17,000	9,656	3.9%	£50,000	£500	£608	21	£12,728
1x2.5 kW Proven	4,282	2,432	1.0%	£12,600	£130	£143	22	£12,734
					£250			
2x2.5 kW Proven	8,564	4,864	2.0%	£25,200	£550	£286	21	£12,734
Westwind 20kW	22,660	12,871	5.2%	£55,000	£300	£787	17	£10,504

Table 7.42 Wind turbines options, carbon savings and costs for 51+ flats new build flats

Conclusions

This section outlines the optimum solution for the 100 flats in terms of measure/measures based on physical feasibility and cost effectiveness and the results are presented in table 7.43.

With regards to the energy efficiency scenarios, advanced fabric standards can be considered the most cost-effective option for this development group as they have the lowest cost per each percentage increase in carbon reduction compared to the other fabric standards. Comparing the feasible renewable technologies, biomass heating seems to be the most cost effective solution for the 100 flats, while CHP comes second in cost effectiveness with £2,161. GSHP and roof mounted wind turbines are following in the hierarchy. However, due to the low emissions reduction achieved from the installation of the wind turbines compared to the other technologies and the high cost for each percentage increase in carbon reduction, this option has been discounted for this development group.

Solar technologies although feasible for this development type come last as their costs for each percentage increase in carbon reduction proved to be the highest when compared to the other technologies. Various financial incentives and regulation changes will potentially reduce the overall costs of these technologies and make them more cost effective.

Measure		% Emissions Reduction	Cost per %
EEM	Advanced fabric standards	43.7%	£6,751
	Best fabric standards	32.6%	£7,339
	Good fabric standards	2.0%	£20,424
RES /LZC	150kW Biomass	34%	£658
	50kWe CHP	31%	£2,161
	4x50kW GSHP	24%	£14,022
	36x1kW Aeroenvironment AVX1000	10%	£14,025
	428m2 evacuated tube thermal collector	20%	£27,844
	90.8 kWp Solar PV	20%	£29,142
	511m2 flat plate thermal collector	20%	£29,164

Table 7.43 Feasible and cost-effective measures for the 100+ new build flats

If advanced fabric standards are combined with biomass heating an approximate reduction of 77% can be achieved which is close to Code Level 5 of the Code for Sustainable Homes. If, however, the energy hierarchy was followed, then the optimum energy efficiency measures in combination with CHP could offset the development's emissions by 69% (regulated) or 27% (regulated + non-regulated). If biomass was considered after the CHP's application, the emissions would be reduced by 66% (regulated) or 26% (regulated + non-regulated). It is important to mention that the renewable technologies shown in Table 7.43 have been assessed based on both regulated and non-regulated energy use which implies that biomass heating can achieve even higher emissions reduction if non-regulated energy use was not included in the calculations.

7.4.1.5 Detached

A typical two storey detached house with a floor area of 87m^2 was tested for the detached development group. The energy efficiency measures and low and renewable energy sources mentioned in Section 4 have been assessed and the results are analysed below.

Energy Efficiency

Table 7.44 presents the Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) (kgCO_2/m^2) for the different efficiency scenarios, their percentage improvement and the Heat Loss Parameter. It is evident that the best and advanced fabric standards achieve significant carbon savings with 39% and 53.5% which exceed Code Level 3 and 4 of the Code for Sustainable Homes, respectively. It should be noted that the heat loss parameter for passivhaus[42] standards need to be of 0.8W/m²K or less.

The table below also presents the costs for implementing the different efficiency scenarios provided by supplier's ballpark data. It is apparent that the cost of the different measures increases proportionally as these get improved. The cost beyond the baseline and the cost for each percentage increase in carbon reduction have been also calculated and shown in the table below. It is evident that best fabric standards are the most cost-effective solution for a detached property as it has the lowest cost for each percentage reduction achieved.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	24.83	24.97	0.6%	1.79	£7,366	£0.00	£0.00
Good Fabric Standards	23.08	24.97	7.6%	1.63	£8,611	£1,246	£165
Best Fabric Standards	15.15	24.97	39.3%	1.19	£12,058	£4,692	£119
Advanced Fabric Standards	11.62	24.97	53.5%	0.87	£14,358	£6,993	£131

Table 7.44 DER/TER achieved in new detached houses with different energy efficiency measures, carbon savings and costs

Table 7.45 presents the annual energy consumption for the different energy efficiency standards and also the percentage reduction in carbon dioxide emissions derived from both regulated and un-regulated energy use. It is important to note the contribution of the mechanical ventilation with heat recovery (MVHR) to the overall CO_2 emission savings after this technology has been incorporated in the house.

[42] http://www.passivhaus.org.uk/index.jsp?id=669

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	6,094	5,270	3,129	1,861
Hot Water	3,142	3,142	3,142	3,112
Auxiliary	175	175	380	342
Lighting	679	637	552	425
Cooking & appliances	2,617	2,617	2,617	2,617
Savings from MVHR (Appendix Q)	-	-	-821	-909
Total Gas	9,236	8,412	6,271	4,973
Total Electricity	3,471	3,428	2,728	2,474
Grant Total	**12,707**	**11,841**	**8,999**	**7,447**
CO_2 Total ($kgCO_2$/yr)	3,256	3,079	2,368	2,009
Percentage CO_2 reduction	-	**5.46%**	**27.29%**	**38.31%**

Table 7.45 Overall annual energy consumption, carbon savings and costs for new build detached houses

CHP/CCHP/Centralised Options

For typical developments in Ealing including only houses, combined heat and power or a centralised /gas biomass heating is not considered viable owing to the low demand, heat profile, and the disproportionate share of development costs that such a system would assume.

Solar Photovoltaics (PV)

It is assumed that the dwelling modelled could have up to 23m^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.

As a rule of thumb, the more energy efficient the building is, the fewer panels are required to comply with the mandatory Ene1 target. Installing between 1.23 kWp and 2.46 kWp on a 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 reduce the overall CO_2 emissions by 20% to 41%. In case where the available roof, 23m^2, was covered by PV panels, the total energy demand will be reduced by 27% resulting in almost 60% reduction in carbon dioxide emissions.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
2m^2	0.31	297	169	5.2%	£2,000	£10	£0	67	386
4 m^2	0.62	594	337	10.4%	£4,000	£20	£0	58	386
8 m^2	1.23	1,188	675	20.7%	£8,000	£40	£36	49	386
16 m^2	2.46	2,376	1,350	41.4%	£16,000	£80	£72	49	386
23 m^2	3.54	3,416	1,940	59.6%	£23,000	£120	£107	49	386

Table 7.46 Solar PV options for new detached houses, carbon savings and costs

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.

Solar Thermal

Tables 7.47 and 7.48 below present the savings in carbon emissions resulting from solar flat plate and evacuated tube collectors. It sets out, for the different percentages increase in carbon reduction, the area, system power rating and cost of each option.

Although the tables below demonstrate the more than 10m^2 of collectors can be mounted onto the roof, an installation of 2.7m^2 of either flat plate or evacuated tube can provide the 100% of the domestic hot water requirements of the house. It is important not to over-size the system by adding more collectors as they might result in overheating the system especially during the summer months and therefore it must be avoided. An ideal configuration (south facing roof, 30° pitch and unshaded), depending on the level of energy efficiency, will lead to an overall reduction in CO_2 emissions of 21% with a capital cost of £7,800 and payback period of 78 years.

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 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 20% reduction in overall CO_2 reduction.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1.7 m^2	696	152	5%	1,800	£10	90	£386
3.5 m^2	1,392	303	9%	3,600	£20	90	£386
9 m^2	3,480	759	23%	9,000	£50	82	£386

Table 7.47 Flat Plate thermal collector options, carbon savings and costs for detached houses

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2.0 m^2	1,080	235	7.23%	2,667	£10	67	£369
2.3 m^2	1,620	353	10.84%	4,000	£20	80	£369
6.8 m^2	3,645	795	24.40%	9,000	£50	82	£369

Table 7.48 Evacuated tube thermal collector options, carbon savings and costs for detached houses

The current prices for gas make the payback period longer than anticipated and hence this technology option is not cost effective for this development group. However, the determining for identifying if this technology is an affordable investment or not, is the cost for each percentage increase in carbon reduction when compared with the costs in the conclusions.

Ground Source Heat Pumps (GSHP)

A 3.5 kW ground source heat pump could be used to provide the development with space heating and hot water. In order to supply the total space heating and hot water demand of the development, it is predicted that 2 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is insufficient space at the development for GSHP.

In case there is, however, garden or parking space which increases the total available floor area, the installation of a 3.5kW would be feasible for a development of this type. The technology could supply 100% of the development's space heating and hot water requirements, resulting in a 31.82% emission saving at a budget premium cost of £5,950.

It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology. The cost for each percentage increase in carbon reduction is also given in the table below. The current electricity prices do not offer significant nett savings which in turn result in a long payback period. The above considerations render the option of the GSHP as non cost effective for the specific development.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3.5 kW	9,214	1,036	31.82%	£5,950	£30	99	£187

Table 7.49 GSHP size, carbon savings and costs for new detached houses

Air Source Heat Pumps (ASHP)

An installation of 4kW ASHP could be installed on the development providing 100% of the house's space heating and hot water requirements. The ASHP will reduce the overall CO_2 emissions by 27.6% at a budget premium cost of £945[43].

Given the payback period of 24 years and the low cost for each percentage increase in carbon reduction, the ASHP seems more favourable for this development group than the GSHP despite the higher emission savings achieved by the GSHP.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
4 kW	9,214	897	27.56%	£945	£5	24	£34

Table 7.50 ASHP size, carbon savings and costs for new detached houses

Biomass Heating

A 3kW biomass stove is predicted to reduce the CO_2 emissions associated with the development by 45%, at a budget premium cost of £9,153[44]. This boiler can provide 100% of the space heating and 46% of the hot water demand. A requirement for woodfuel storage and a flue that will terminate above roof level need to be thoroughly considered prior to the design stage.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3 kW	7,529	1,463	44.93%	£9,153	£460	-24	£204

Table 7.51 Biomass heating, carbon savings and costs for new detached houses

[43] Trianco Heating Products Ltd
http://www.airconwarehouse.com/acatalog/Trianco_Activair_Air_Source_Heat_Pumps.html

[44] Price provided by Windhager UK biomass boilers supplier

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of 0.24m^3 would be required. Using wood chips, which have a lower energy density, a quarterly delivery of 1m^3 would be required.

Based on the costs shown in table 7.51, although biomass is considered as feasible for the development, it does not seem to be cost effective solution for new detached houses. This is mainly due to the high costs of biomass fuels which reduces the energy savings leaving the investment without significant yearly nett savings. The cost for each percentage achieved in carbon reduction has been also estimated to be £204 for this technology.

Wind Turbines

There are two standard types of wind turbines, free standing and building mounted. Due to insufficient land around typical detached houses in the borough, free standing wind turbines have been discounted for this type of development.

If the house is not surrounded by high-rise buildings or trees which might cause an obstruction to the wind turbine, then an installation of 1 No. 1.25kW Windsave wind turbine could be installed on the roof of the house. The Windsave is predicted to generate 1.25MWh and reduce the CO_2 emissions by 21.8% at a budget premium cost of £1,898 with a payback period of approximately 10 years.

The cost for each percentage increase in carbon reduction for the roof mounted wind turbine is £87 which makes this technology a cost effective solution for similar developments.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
1.2kW Windsave	1,250	710	21.8%	£1,898	£20	£36	10	£87

Table 7.52 Wind turbines, carbon savings and costs for new detached houses

Conclusions

This section outlines the optimum solution for the detached house in terms of measures based on physical feasibility and cost effectiveness. The results are presented in table 7.53.

With regards to the energy efficiency scenarios, best fabric standards can be considered the most cost-effective option for this development group with the lowest cost per each percentage increase in carbon reduction compared to the other fabric standards. Best practice reduces the emissions by 39.3% when only regulated energy use has been included in the calculations while 27.3% CO_2 emissions reduction is achieved when both regulated and non-regulated have been considered.

Comparing the feasible renewable technologies, the ASHP reduces the emissions by 28% while it has the lowest cost for each percentage reduction achieved in CO_2 emissions, £34. The roof mounted wind turbine comes second in the hierarchy reducing the CO_2 emissions by 22% with £87 for each percentage reduction achieved. Subject to sufficient land, the GSHP can reduce the CO_2 emissions by 32% while spending £165 for each percentage reduction achieved. Biomass heating provides significant emissions reduction with 45% but due to high biomass fuel costs and with £204 for each percentage increase in carbon reduction, it is discounted for this development type.

Solar technologies although feasible for detached properties come last as their costs for each percentage increase in carbon reduction are proved to be the highest when compared with the other technologies. It is obvious from the table that a solar PV panel with 2.46kWp capacity can reduce the emissions by 41%, while 6.8m^2 of evacuated tube collector achieves 24% emissions savings. However, various financial incentives and regulation changes will potentially reduce the overall costs of some of the above technologies and make them affordable.

	Measure	% Emissions Reduction	Cost per %
EEM	Best fabric standards	39%	£119
	Advanced fabric standards	53%	£131
	Good fabric standards	8%	£165
RES /LZC	4 kW ASHP	28%	£34
	1.2kW Windsave	22%	£87
	3.5kW GSHP	32%	£165
	3kW Biomass	45%	£204
	6.8m^2 evacuated tube thermal collector	24%	£369
	2.46 kWp Solar PV	41%	£386
	9m^2 flat plate thermal collector	23%	£386

Table 7.53 Feasible and cost effective measures for new detached houses

The table above indicates that a combination of best fabric standards with ASHP is the potential optimum solution for the detached property resulting in 67% or 55% CO_2 emissions reduction when regulated only or both regulated and non-regulated energy use have been considered, respectively. The above combination exceeds Level 4 of the Code for Sustainable Homes.

7.4.1.6 Semi-Detached

A typical two storey semi-detached house with a floor area of 87m^2 was tested for the semi-detached development group. The energy efficiency measures and low and renewable energy sources mentioned in Section 4 have been assessed and the results are analysed below.

Energy Efficiency

Table 7.54 presents the Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) ($kgCO_2/m^2$) for the different efficiency scenarios, their percentage improvement and the Heat Loss Parameter. As with the detached model used in this study, levels 3 or 4 of the Code for Sustainable Homes can be achieved when best or advanced (passivhaus) standards are applied into a house. The percentages reduction achieved through the energy efficiency scenarios have been estimated based on only regulated energy use.

It is evident from the table below that the better the insulation and air tightness the higher the costs. The cost beyond the baseline and the cost for each percentage increase in carbon reduction have also been calculated in order to identify which of these measures are the most cost-effective options for this development. For each percentage increase achieved in carbon reduction, a cost of £142 would need to be spent, if good fabric standards were being implemented while £112 and £123 would need to be spent if best and advanced fabric standards were to be applied, respectively. Best practice is the most cost effective solution for the semi-detached property, although by spending £11 more on each percentage increase in carbon reduction, an additional increase of 13% can be achieved which conforms to advanced fabric standards.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	22.44	22.44	0.0%	1.57	£6,578	£0.00	£0.00
Good Fabric Standards	20.70	22.44	7.8%	1.41	£7,677	£1,099	£142
Best Fabric Standards	13.59	22.44	39.4%	1.02	£10,990	£4,412	£112
Advanced Fabric Standards	10.68	22.44	52.4%	0.82	£13,023	£6,446	£123

Table 7.54 DER/TER achieved in new semi-detached houses with different energy efficiency measures, carbon savings and costs

Table 7.55 presents the annual energy consumption for the different energy efficiency standards and also the percentage reduction in CO_2 emissions derived from both regulated and un-regulated energy use. It is important to note the savings achieved after the MVHR was incorporated into the house. While good fabric standards, which have similar requirements to the current Building Regulations, reduce the baseline emissions by 5.4%, best and advanced fabric standards exceed Code Level 3 of the Code for Sustainable Homes.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	5,018	4,259	2,417	1,422
Hot Water	3,142	3,142	3,142	3,112
Auxiliary	175	175	380	342
Lighting	679	637	552	425
Cooking & appliances	2,617	2,617	2,617	2,617
Savings from MVHR (Appendix Q)	-	-	-821	-909
Total Gas	8,161	7,401	5,559	4,534
Total Electricity	3,471	3,428	2,728	2,474
Grant Total	**11,631**	**10,829**	**8,287**	**7,008**
CO_2 Total ($kgCO_2$/yr)	3,048	2,883	2,230	1,924
Percentage CO_2 reduction	-	**5.42%**	**26.84%**	**36.89%**

Table 7.55 Overall annual energy consumption, carbon savings and costs for new build semi-detached houses

CHP/CCHP/Centralised Options

For typical developments in Ealing including only houses, combined heat and power or a centralised /gas biomass heating is not considered viable owing to the low demand, heat profile, and the disproportionate share of development costs that such a system would assume.

Solar Photovoltaics (PV)

It is assumed that the dwelling modelled could have up to 23m^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.

An installation of 8m^2 to 15m^2 on a semi-detached house is predicted to generate 1-3MWh per annum resulting in 20-40% reduction in CO_2 emissions. In the case where the assumed roof is covered by solar PV panel, a 61% reduction in emissions can be achieved which meets and exceeds the mandatory energy requirements for Level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER).

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.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings (kgCO_2/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
2 m^2	0.31	297	169	5.5%	£2,000	£10	£0	67	£361
4 m^2	0.62	594	337	11.1%	£4,000	£20	£0	58	£361
8 m^2	1.23	1,188	675	22.1%	£8,000	£40	£36	49	£361
15 m^2	2.31	2,228	1,265	41.5%	£15,000	£80	£72	49	£361
22 m^2	3.38	3,267	1,856	60.9%	£22,000	£110	£107	48	£361

Table 7.56 Solar PV options for new semi- detached houses, carbon savings and costs

Although the long payback period make this technology not a cost effective solution for a semi-detached property, grants e.g. from Energy Saving Trust, and various financial incentives can potentially reduce the costs of this technology. The cost for each percentage increase in carbon reduction is also given in the table above.

<u>Solar Thermal</u>

Tables 7.57 and 7.58 below present the savings in carbon emissions resulting from solar flat plate and evacuated tube collectors. It sets out, for the different percentages increase in carbon reduction, the area, system power rating and cost of each option. The cost for each percentage increase in carbon reduction is also shown in the tables below for both thermal collector types.

It is apparent from the tables that a reduction of 25% in CO_2 emissions can be achieved through then installation of a 9m^2 flat plate or 7m^2 evacuated tube thermal collector subject to ideal configuration (south facing roof, 30 deg pitch and un-shaded).

System	Energy Generated (kWh/yr)	CO_2 Savings (kgCO_2/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1.7m^2	696	152	5%	1,800	£10	90	£362
3.5m^2	1,392	303	10%	3,600	£20	90	£362
9m^2	3,480	759	25%	9,000	£50	82	£362

Table 7.57 Flat Plate thermal collector options, carbon savings and costs for semi-detached houses

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1.4 m^2	729	159	5%	1,800	£10	90	£345
2.3 m^2	1,215	265	9%	3,000	£20	100	£345
6.8 m^2	3,645	795	26%	9,000	£50	82	£345

Table 7.58 Evacuated tube thermal collector options, carbon savings and costs for semi-detached houses

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.

Although all the options shown in the tables are feasible for the specific development type and reduce the CO_2 emissions by 26% maximum, the long payback period makes solar thermal technology to be not so cost effective. However, the comparison of the cost for each percentage increase in carbon reduction for each measure assessed for this development group, it will determine if this technology is an affordable investment or not.

Ground Source Heat Pumps (GSHP)

A 3.5 kW ground source heat pump could supply 100% of the development's space heating and hot water requirements, resulting in a 30.14% emission saving at a budget premium cost of £5,950. In order to supply the total space heating and hot water demand of the development, it is predicted that 2 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is insufficient space at the development for GSHP.

In case however, there is garden or parking space which increases the total available floor area, the installation of a 3.5kW could be feasible. It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology. The cost per each percentage increase in carbon reduction is also given.

Current high electricity prices reduce the yearly nett savings from this technology which results in long payback period which in turn makes it a not affordable investment. However, the cost for each percentage increase achieved in carbon reduction through this technology will be compared with the costs of the other technologies assessed and will determine if GSHP could be considered an affordable investment for the semi-detached group.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3.5 kW	8,167	919	30.14%	£5,950	£30	99	£197

Table 7.59 GSHP size, carbon savings and costs for new semi-detached houses

Air Source Heat Pumps (ASHP)

An installation of 3kW ASHP could be installed on the development providing 100% of the house's space heating and hot water requirements. The ASHP will reduce the overall CO_2 emissions by 26% at a budget premium cost of £945[45].

[45] Trianco Heating Products Ltd

Given the payback period of 24 years, the ASHP seem more favourable for this development group than the GSHP despite the higher emission savings achieved by the GSHP. Given the low cost that needs to be spent for each percentage reduction achieved, ASHP is considered as one of the most cost effective measures for similar development groups.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3kW	8,135	792	26.00%	£945	£5	24	£36

Table 7.60 ASHP size, carbon savings and costs for new semi-detached houses

Biomass Heating

A 3.6kW biomass stove is predicted to reduce the CO_2 emissions associated with the development by 38%, at a budget premium cost of £9,153[46]. This boiler can provide 100% of the space heating and 31% of the hot water demand. A requirement for a woodfuel storage and a flue that will terminate above roof level, need to be thoroughly considered prior to the design stage. Biomass stoves can either located internally or externally of the house.

The costs are detailed in Table 7.61 below. It is obvious from the table below that although biomass is appropriate to provide the space heating and hot water of the development, it is not considered a cost effective solution mainly due to the high biomass fuel costs which result in negative nett savings leaving the investment without yearly savings.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3.6 kW	5,986	1,163	38.16%	£9,153	£460	-23	£240

Table 7.61 Biomass heating, carbon savings and costs for new semi-detached houses

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of $0.21m^3$ would be required. Using wood chips, which have a lower energy density, a quarterly delivery of $0.66m^3$ would be required.

Wind Turbines

There are two standard types of wind turbines, free standing and building mounted. Due to insufficient land around typical detached houses in the borough, free standing wind turbines have been discounted for this type of development.

If the house is not surrounded by high-rise buildings or trees which might cause an obstruction to the wind turbine, then an installation of 1 No. 1.25 kW Windsave wind turbine could be installed on the roof. The Windsave is predicted to generate 1.25 MWh and reduce the CO_2 emissions by 23.3% at a budget premium cost of £1,898 and a payback period of 10 years approximately.

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http://www.airconwarehouse.com/acatalog/Trianco_Activair_Air_Source_Heat_Pumps.html

[46] Price provided by Windhager UK biomass boilers supplier

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
1.2kW Windsave	1,250	710	23.3%	£1,898	£20	£36	10	£81

Table 7.62 Wind turbines, carbon savings and costs for new semi -detached houses

It seems that wind turbines technology offers significant savings in both energy and carbon emissions and their payback period is reasonable. They will therefore be supported and encouraged subject to comply with the air quality and noise policies of the Council.

Conclusions

This section outlines the optimum solution for a semi detached house in terms of measures based on physical feasibility and cost effectiveness. The results are presented in table 7.63.

With regards to the energy efficiency scenarios, best fabric standards can be considered the most cost effective option for this development group as it has the lowest cost per each percentage increase in carbon reduction compared to the other fabric standards. Best practice reduces the emissions by 39.3% when only regulated energy use has been included in the calculations while 26.84% CO_2 emissions reduction is achieved when both regulated and non-regulated have been considered.

With regards to the feasible renewable technologies, the ASHP reduces the emissions by 26% with £36 for each percentage reduction achieved in CO_2 emissions. The roof mounted wind turbine comes second in the hierarchy reducing the CO_2 emissions by 23% with £81 for each percentage reduction achieved.

Subject to sufficient land, the GSHP can reduce the CO_2 emissions by 30% while spending £197 for each percentage reduction achieved. Biomass heating provides 38% emission savings with £240 spent for each percentage reduction achieved. However, GSHP and biomass heating are not considered as cost effective solutions for this development group. This is due to current high electricity and biomass fuel costs which result in long payback periods and minimal financial savings.

Although solar technologies are feasible in semi detached properties, they are coming last due to the high costs spent for each percentage increase in carbon reduction. It is obvious from the table that a solar PV panel with 2.31kWp capacity can reduce the emissions by 42%, while 6.8m^2 of evacuated tube collector achieves 26% emissions savings. The installation of the solar PV panel, however, is more cost effective compared to the solar thermal collector despite the higher cost spent for each percentage increase in carbon reduction.

If best fabric standards are combined with a 4kW ASHP, they will result in 65% CO_2 emissions reduction which exceeds Level 4 of the Code for Sustainable Homes or 53% emission savings if non-regulated energy use has been also included in the calculations. This could be considered as the optimum solution for this development. On the other hand, best practice with 1.25kW roof mounted wind turbine achieve a reduction of 62% in CO_2 emissions and they can be considered as the second most optimum solution for this development. The 62% emission reduction achieved through best practice and wind turbine gets reduced to 50% when non-regulated energy use is included.

Various financial incentives and regulation changes will potentially reduce the overall costs for most of the above technologies and make them more cost effective.

Measure		% Emissions Reduction	Cost per %
EEM	Best fabric standards	39%	£112
	Advanced fabric standards	52%	£123
	Good fabric standards	8%	£142
RES /LZC	4 kW ASHP	26%	£36
	1.2kW Windsave	23%	£81
	3.5kW GSHP	30%	£197
	3.6kW Biomass	38%	£240
	6.8m^2 evacuated tube thermal collector	26%	£345
	2.31 kWp Solar PV	42%	£361
	9m^2 flat plate thermal collector	25%	£362

Table 7.63 Feasible and cost effective measures for the semi-detached property

7.4.1.7 End-Terrace

A typical two storey end-terrace 2 bedroom property with a floor area of 70m^2 was tested by SAP software. The energy efficiency measures and low and renewable energy sources mentioned in Section 4 have been assessed and the results are analysed below.

Energy Efficiency

Table 7.64 presents the Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) (kgCO_2/m^2) for the different efficiency scenarios, their percentage improvement and the Heat Loss Parameter. The table also demonstrates that levels 3 or 4 of the Code for Sustainable Homes can be achieved and exceeded when best or advanced (passivhaus) standards are applied into a house.

In addition, the table shows the costs of implementing these measures to an end-terrace property as well as the cost beyond the baseline and the cost for each percentage increase in carbon reduction. It is evident that the better the insulation and air tightness the higher the costs. However, based on the cost per percentage reduction achieved, best practice seems to be the most cost effective solution for this development. Factoring grants can make the improved fabric measures even more cost-effective.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	23.96	24.00	0.2%	1.74	£5,183	£0.00	£0.00
Good Fabric Standards	22.01	24.00	8.3%	1.55	£6,084	£901	£109
Best Fabric Standards	14.65	24.00	39.0%	1.10	£8,752	£3,568	£92
Advanced Fabric Standards	11.74	24.00	51.1%	0.81	£10,358	£5,174	£101

Table 7.64 DER/TER achieved in new end-terrace houses with different energy efficiency measures, carbon savings and costs

Table 7.65 presents the annual energy consumption for the different energy efficiency standards and also the percentage reduction in CO_2 emissions derived from both regulated and un-regulated energy use. It is important to note the significant savings achieved after the incorporation of the MVHR into the house. While good fabric standards, which have similar requirements to the current Building Regulations, reduce the baseline emissions by 5.82%, best and advanced fabric standards exceed Code Level 3 of the Code for Sustainable Homes.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	5,073	4,250	2,292	1,312
Hot Water	2,910	2,910	2,910	2,878
Auxiliary	175	175	339	1,146
Lighting	541	477	414	318
Cooking & appliances	2,437	2,437	2,437	2,437
Savings from MVHR (Appendix Q)	-	-	-640	-707
Total Gas	7,982	7,160	5,201	4,191
Total Electricity	3,153	3,089	2,549	3,194
Grant Total	**11,135**	**10,249**	**7,750**	**7,384**
CO_2 Total ($kgCO_2$/yr)	2,696	2,539	2,002	1,760
Percentage CO_2 reduction	-	**5.82%**	**25.74%**	**34.72%**

Table 7.65 Overall annual energy consumption, carbon savings and costs for new build end-terrace houses

CHP/CCHP/Centralised Options

For typical developments in Ealing including only houses, combined heat and power or a centralised /gas biomass heating is not considered viable owing to the low demand, heat profile, and the disproportionate share of development costs that such a system would assume.

Solar Photovoltaics (PV)

It is assumed that the dwelling modelled could have up to 18m^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.

An installation of 6m^2 to 13m^2 on an end-terrace house is predicted to generate 891 to 1,931 kWh per annum resulting in 19% to 41% reduction in CO_2 emissions. In the case where the whole 18m^2 is covered by solar PV panel, a 56.3% reduction in emissions can be achieved which meets and exceeds the mandatory energy requirements for Level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER).

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.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
2m^2	0.31	297	63	6.3%	£2,000	£10	£0	67	320
3 m^2	0.46	446	94	9.4%	£3,000	£20	£0	75	320
6 m^2	0.92	891	188	18.8%	£6,000	£30	£0	60	320
13 m^2	2.00	1,931	407	40.7%	£13,000	£70	£36	53	320
18 m^2	2.77	2,673	563	56.3%	£18,000	£90	£72	50	320

Table 7.66 Solar PV options for new end-terrace houses, carbon savings and costs

The cost for each percentage increase in carbon reduction have been also calculated in order to assist in identifying which is the most cost effective solution for this development group. Due to the balance between the capital costs and the nett savings for all PV panel options, the cost per percentage increase in carbon reduction remains the same. However, this will help in identifying the most cost-effective investment when all technologies will be compared at the conclusions section.

Solar Thermal

Tables 7.67 and 7.68 below present the savings in carbon emissions resulting from solar flat plate and evacuated tube collectors. It sets out, for the different percentages increase in carbon reduction, the area, system power rating and cost of each option.

It is apparent from the tables that a reduction of 19% in CO_2 emissions can be achieved when a 5.8m^2 flat plate or 4.5m^2 evacuated tube thermal collector is installed subject to ideal configuration (south facing roof, 30 deg pitch and un-shaded).

System	Energy Generated (kWh/yr)	CO2 Savings (kgCO2/yr)	CO2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1.5 m^2	580	126	5%	1,500	£10	75	£320
2.9 m^2	1,160	253	9%	3,000	£20	100	£320
5.8 m^2	2,320	506	19%	6,000	£30	86	£320

Table 7.67 Flat Plate thermal collector options, carbon savings and costs for end-terrace houses

System	Energy Generated (kWh/yr)	CO2 Savings (kgCO2/yr)	CO2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1.13m^2	608	132	4.91%	1,500	£10	75	£305
2.3 m^2	1,215	265	9.82%	3,000	£20	100	£305
4.5 m^2	2,430	530	19.65%	6,000	£30	75	£305

Table 7.68 Evacuated tube thermal collector options, carbon savings and costs for end-terrace houses

An installation of 7.3m^2 of flat plate or 5.4m^2 of evacuated tube collector, can provide the property with 100% of its domestic hot water requirements, resulting in 23.5% reduction in CO_2 emissions and at a budget premium cost of £7,400.

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 necessary to combine the solar thermal with another low carbon or renewable technology to achieve a higher percentage contribution from renewables. However, if combined with best or advanced efficiency measures, it will potentially exceed the mandatory Ene1 level of Code Level 3 (25% reduction of DER over TER).

Despite all the options shown in the tables are feasible for the specific development, resulting in a maximum 19.65% CO2 emissions reduction, solar thermal technology seems not a cost effective solution due to the long payback periods. Factoring grants and other financial incentive systems can reduce the payback period and make this technology more affordable. Even the cost for each percentage increase in carbon reduction seems a bit high compared to the costs of the other technologies assessed.

Ground Source Heat Pumps (GSHP)

A 3.5 kW ground source heat pump could supply 100% of the development's space heating and hot water requirements, resulting in a 33.3% emission saving at a budget premium cost of £5,950. In order to supply the total space heating and hot water demand of the development, it is predicted that 2 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is insufficient space at the development for GSHP. The long payback period also make this technology currently not viable for this development group.

In case, however, there is garden or parking space which increases the total available floor area, the installation of a 3.5kW could be feasible. It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology. The cost of each percentage increase in carbon reduction is also given and it is £179. Although it does not seem high, the long payback period renders the option of GSHP a non cost effective solution for the end-terrace house.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3.5 kW	7,988	898	33.32%	£5,950	£30	>100	£179

Table 7.69 GSHP size, carbon savings and costs for new end-terrace houses

Air Source Heat Pumps (ASHP)

An installation of 3kW ASHP could be installed on the development providing 100% of the house's space heating and hot water requirements. The ASHP will reduce the overall CO_2 emissions by almost 29% at a budget premium cost of £945[47].

Given the payback period of 32 years, the ASHP seems more favourable for this development group than the GSHP despite the higher emission savings achieved by the GSHP. The £33 cost for each percentage reduction achieved makes this option the most cost effective solution for an end-terrace house.

[47] Trianco Heating Products Ltd
http://www.airconwarehouse.com/acatalog/Trianco_Activair_Air_Source_Heat_Pumps.html

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3 kW	7,962	776	28.77%	£945	£5	32	£33

Table 7.70 ASHP size, carbon savings and costs for new end-terrace houses

Biomass Heating

A 2.9kW biomass boiler is predicted to reduce the CO_2 emissions associated with the development by almost 51%, at a budget premium cost of £9,807[48]. This boiler can provide 100% of the space heating and 67% of the hot water demand. A requirement for a woodfuel storage and a flue that will terminate above roof level, need to be thoroughly considered prior to the design stage.

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of 0.22m^3 would be required. Using wood chips, which have a lower energy density, a quarterly delivery of 0.70m^3 would be required.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2.9 kW	7,019	1,364	50.59%	£9,807	£490	-24	£194

Table 7.71 Biomass heating, carbon savings and costs for new end-terrace houses

The costs are detailed in Table 7.70 below. It is obvious that although biomass is feasible providing great savings to the development, the cost of the biomass fuel and the maintenance cost make it unviable for this development type. Factoring grants and clean energy cashback schemes will potentially make this technology a cost-effective solution for residential properties.

Wind Turbines

If the house is not surrounded by high-rise buildings or trees which might cause an obstruction to the wind turbine, an 1 No. 1.25 kW Windsave wind turbine could be installed on the roof. The Windsave is predicted to generate 1.25 MWh and reduce the CO_2 emissions by 26.3% at a budget premium cost of £1,898 and a payback period of approximately 10 years. The cost for each percentage increase in carbon reduction will be £72.

It seems that wind turbines offer significant savings in both energy and carbon emissions and their payback period is reasonable. They will therefore be supported and encouraged subject to comply with the air quality and noise policies of the Council.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
1.2kW Windsave	1,250	710	26.3%	£1,898	£20	£36	10	£72

Table 7.72 Wind turbines, carbon savings and costs for new end-terrace houses

Conclusions

[48] Budget Price provided by Windhager UK for BioWin pellet boiler

This section outlines the optimum solution for the end-terrace house in terms of measures based on physical feasibility and cost effectiveness and the results are presented in table 7.73.

With regards to the energy efficiency scenarios, best fabric standards can be considered the most cost-effective option for this development group as they have the lowest cost per each percentage increase in carbon reduction compared to the other fabric standards. Comparing the feasible renewable technologies, a 3kW ASHP seems to be the most cost effective solution for this development, while the roof mounted wind turbine comes next in the cost effectiveness hierarchy.

GSHP, biomass and solar thermal, although identified as feasible for an terrace house, due to high fuel costs which result in long payback periods have made them non cost effective options and therefore they will not be recommended for similar developments. Furthermore, despite the high cost for each percentage increase in carbon reduction for the hybrid panel installation with 2kWp capacity, it could be considered as an alternative to wind turbine for supplying green electricity and reducing the emissions by 41%. On the other hand, solar thermal was discounted due to the long payback periods. However, various financial incentives and regulation changes will potentially reduce the overall costs of some of the above technologies and make them more affordable options.

If best fabric standards are combined with a 3kW ASHP, a reduction of 68% can be achieved which exceeds Level 4 of the Code for Sustainable Homes or 54.24% CO2 emissions savings when non-regulated have been included in the calculations. This combination is regarded as the most cost effective option for this development type. Alternatively, best practice with the 1.25kW wind turbine will result in 65% or 51.74% emission savings when regulated energy use or regulated and non-regulated have been included, respectively. This could be considered as the second optimum solution for an end terrace house. As a third option, although it might not be considered as a favourable option, is the combination of best fabric standards with the 2kWp PV panel. Their combination provides 80% reduction in CO_2 emissions when only regulated energy use has been considered or 67% reduction when both regulated and non-regulated energy use have been considered.

Measure		% Emissions Reduction	Cost per %
EEM	Best fabric standards	39%	£92
	Advanced fabric standards	52%	£101
	Good fabric standards	8%	£109
RES /LZC	3 kW ASHP	29%	£33
	1.2kW Windsave	26%	£81
	3.5kW GSHP	33%	£197
	2.9kW Biomass	51%	£240
	4.5m2 evacuated tube thermal collector	20%	£345
	2 kWp Solar PV	41%	£361
	5.8m2 flat plate thermal collector	19%	£362

Table 7.73 Feasible and cost effective measures for the end-terrace house

7.4.1.8 Mid-Terrace

A typical two storey mid-terrace 2 bedroom property with a floor area of $70m^2$ was tested by SAP software. The energy efficiency measures and low and renewable energy sources mentioned in Section 4 have been assessed and the results are analysed below.

Energy Efficiency

Table 7.74 presents the Dwelling Emission Rate (DER) and the Target Emissions Rate (TER) ($kgCO_2/m^2$) for the different efficiency scenarios, their percentage improvement and the Heat Loss Parameter. It is evident from the table below that best and advanced fabric standards can achieve 38% and 49%, respectively which exceed Levels 3 and 4 of the Code for Sustainable Homes. It is important to note that the significant savings have been achieved not only after the improved thermal performance of the building elements but also from the application of MVHR and energy efficient lighting and all the measures detailed in Section 4 (see Table 7.74 below).

The costs related to these measures are also presented in the table below for a mid-terrace house. It is apparent that as the measures get better, the costs get increased. In addition the cost beyond the baseline and the cost for each percentage increase in carbon reduction for the energy efficiency scenarios have been also calculated and presented in the table below. Best fabric standards are clearly the most cost effective solution with £87 for each percentage reduction achieved in CO_2 emissions.

Measure	DER	TER	Percentage CO_2 reduction	HLP	Costs	Cost beyond baseline	Cost per %
Baseline	21.55	21.64	0.4%	1.74	£4,568	£0.00	£0.00
Good Fabric Standards	19.95	21.64	7.8%	1.55	£5,354	£786	£101
Best Fabric Standards	13.35	21.64	38.3%	1.10	£7,917	£3,349	£87
Advanced Fabric Standards	11.03	21.64	49.0%	0.81	£9,314	£4,747	£97

Table 7.74 DER/TER achieved in new mid-terrace houses with different energy efficiency measures, carbon savings and costs

Table 7.75 presents the annual energy consumption for the different energy efficiency standards and also the percentage reduction in CO_2 emissions derived from both regulated and un-regulated energy use. It is evident the great savings achieved from the energy efficiency measures assessed on this development type. While space heating gets significantly reduced, the incorporation of the MVHR increases the consumption coming from fans and pumps which is balanced by the savings in the electricity.

The un-regulated energy consumption (e.g. cooking and appliances) do not show a change as the energy efficiency measures get improved. This can be explained by the fact that up to now there is no way of regulating this use as it is largely dictated by occupant behaviour. Comparing the percentage improvements from tables 7.74 and 7.75, it is obvious that more than 10% of the emissions is coming from un-regulated energy use. Despite this difference, applying best or advanced fabric standards can meet Code Level 3.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Heating	4,013	3,339	1,706	979
Hot Water	2,910	2,910	2,910	2,878
Auxiliary	175	175	339	308
Lighting	541	477	414	318

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Cooking & appliances	2,437	2,437	2,437	2,437
Savings from MVHR (Appendix Q)	-	-	-640	-705
Total Gas	6,923	6,248	4,616	3,857
Total Electricity	3,153	3,089	2,549	2,358
Grant Total	**10,076**	**9,337**	**7,165**	**6,216**
CO_2 Total ($kgCO_2$/yr)	2,529	2,395	1,910	1,708
Percentage CO_2 reduction	-	**5.28%**	**24.48%**	**32.45%**

Table 7.75 Overall annual energy consumption, carbon savings and costs for new build mid-terrace houses

CHP/CCHP/Centralised Options

For typical developments in Ealing including only houses, combined heat and power or a centralised /gas biomass heating is not considered viable owing to the low demand, heat profile, and the disproportionate share of development costs that such a system would assume.

Solar Photovoltaics (PV)

It is assumed that the dwelling modelled could have up to 18m^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.

An installation of 6m^2 to 12m^2 on a mid-terrace house is predicted to generate 891 to 1,782 kWh per annum resulting in 20-40% reduction in CO_2 emissions. In the case where the whole 18m^2 roof area is covered by solar PV panel, a 60% reduction in emissions can be achieved which exceeds the mandatory energy requirements for Level 4 of the Code for Sustainable Homes (44% reduction in DER over the TER).

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.

The cost for each percentage increase in carbon reduction has been also calculated in order to identify which is the most cost effective option for this development group. Due to the balance between the capital costs and the nett savings for all PV panel options, the cost per percentage increase in carbon reduction remains the same. However, this will help in identifying the most cost-effective investment when all technologies will be compared at the conclusions section. Factoring grants and financial incentives will potential reduce the payback period to 10 or 15 years.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
2m^2	0.31	297	169	6.7%	£2,000	£10	£0	67	300
3 m^2	0.46	446	253	10.0%	£3,000	£20	£0	75	300
6 m^2	0.92	891	506	20.0%	£6,000	£30	£0	60	300
12 m^2	1.85	1,782	1,012	40.0%	£12,000	£60	£36	51	300

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
18 m^2	2.77	2,673	1,518	60.0%	£18,000	£90	£72	50	300

Table 7.76 Solar PV options for new mid-terrace houses, carbon savings and costs

Solar Thermal

Tables 7.77 and 7.78 below present the savings in carbon emissions resulting from solar flat plate and evacuated tube collectors. It sets out, for the different percentages increase in carbon reduction, the area, system power rating and cost of each option.

It is apparent from the tables that a 20% reduction in CO_2 emissions can be achieved when a 5.8m^2 flat plate or 4.5m^2 evacuated tube thermal collector are installed subject to ideal configuration (south facing roof, 30 deg pitch and un-shaded).

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1.5 m^2	580	126	5%	1,500	£10	75	£300
2.9 m^2	1,200	262	10%	3,100	£20	>100	£300
5.8 m^2	2,320	506	20%	6,000	£30	86	£300

Table 7.77 Flat Plate thermal collector options, carbon savings and costs for mid-terrace houses

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
1 m^2	540	118	5%	1,333	£10	>100	£286
2.3 m^2	1,215	265	10%	3,000	£20	100	£286
4.5 m^2	2,430	530	21%	6,000	£30	75	£286

Table 7.78 Evacuated tube thermal collector options, carbon savings and costs for mid-terrace houses

An installation of 7.2m^2 of flat plate or 5.4m^2 evacuated tube collectors can provide the property with 100% of its domestic hot water requirements, resulting in 25% reduction in CO_2 emissions and at a budget premium cost of £7,200. It is therefore possible to achieve the mandatory Ene1 level of Code Level 3 (25% reduction of DER over TER).

Although all the options shown in the tables are feasible for the specific development type, solar thermal technology does not seem a cost effective option due to the long payback periods. However, factoring grants and other financial incentive packages can reduce the payback period and make this technology more affordable. Despite the two collector types achieve the same emission savings; it is obvious that evacuated tube requires less area and their cost for each percentage increase in carbon reduction is lower than that of the flat plate collector. Therefore it is suggested that evacuated tube collectors are more favourable for this development group.

Ground Source Heat Pumps (GSHP)

An installation of 3.5 kW ground source heat pump is predicted to generate 7MWh, resulting at 779 $kgCO_2$ emissions reduction per annum. The GSHP can provide the total space heating and hot water requirements of this development at a budget premium cost of £5,950.

In order to supply the total space heating and hot water demand of the development, it is predicted that 2 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is insufficient space at the development for GSHP. In addition, the high electricity prices for domestic properties make this investment unviable due to the long payback period.

In case however, there is a garden or parking space which increases the total available floor area, the installation of a 3.5kW could be feasible. It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology. The cost per each percentage increase in carbon reduction is also given in the table below.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3.5 kW	6,928	779	30.82%	£5,950	£30	>100	£193

Table 7.79 GSHP size, carbon savings and costs for new mid-terrace houses

Air Source Heat Pumps (ASHP)

A 3.5 kW ASHP could be installed on the development providing 100% of the house's space heating and hot water requirements. The ASHP will reduce the overall CO_2 emissions by almost 27% at a budget premium cost of £945[49].

Given the payback period of 32 years and the grants or other clean energy cashback schemes, the ASHP seems more favourable for this development group. This option can also be considered as the most cost effective option based on the lowest cost for each percentage increase achieved in carbon reduction.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3.5 kW	6,928	675	26.69%	£945	£5	32	£35

Table 7.80 ASHP size, carbon savings and costs for new mid-terrace houses

Biomass Heating

A 2kW biomass boiler is predicted to reduce the CO_2 emissions associated with the development by almost 55%, at a budget premium cost of £3,000[50]. This boiler can provide 100% of the space heating and 57% of the hot water demand. A requirement for a woodfuel storage and a flue that will terminate above roof level, need to be thoroughly considered prior to the design stage.

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of $0.17m^3$ would be required. Using wood chips, which have a lower energy density, a quarterly delivery of $0.53m^3$ would be required.

[49] Trianco Heating Products Ltd
http://www.airconwarehouse.com/acatalog/Trianco_Activair_Air_Source_Heat_Pumps.html

[50] Budget Price provided by Ecoheat and Power Ltd

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2 kW	5,675	1,388	54.89%	£3,000	£150	-30	£55

Table 7.81 Biomass heating, carbon savings and costs for new mid-terrace houses

The emission savings and costs are detailed in Table 7.81 below. Although biomass is feasible to cover the space heating and hot water demand of the development, the high fuel prices and maintenance cost make it unviable for this development type. Factoring grants and clean energy cashback schemes will potentially make this technology option cost-effective for residential properties.

Wind Turbines

An installation of 1 No. 1.2kW Windsave roof mounted wind turbine is predicted to generate 1250kW per annum resulting in 28.1% reduction in CO_2 emissions. The budget premium cost is £1,898 and the annual ROC savings are £36. The wind turbine can supply 40% of the house's electricity demand.

It seems that wind turbines offer significant savings in both energy and carbon emissions and their payback period is reasonable. They will be therefore supported and encouraged subject to comply with the air quality and noise policies of the Council.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
1.2kW Windsave	1,250	710	28.1%	£1,898	£20	£36	10	£68

Table 7.82 Wind turbines, carbon savings and costs for new mid-terrace houses

The low cost for each percentage increase achieved in carbon reduction make this technology a cost effective option for a mid terrace property.

Conclusions

This section outlines the optimum solution for the mid-terrace house in terms of measure/measures based on physical feasibility and cost effectiveness and the results are presented in table 7.83.

With regards to the energy efficiency scenarios, best fabric standards can be considered the most cost-effective option for this development group as they have the lowest cost per each percentage increase in carbon reduction compared to the other fabric standards. Comparing the feasible renewable technologies, a 3.5kW ASHP seems to be the most cost effective solution for this development; while the roof mounted wind turbine comes third in the cost effectiveness hierarchy.

GSHP, biomass and solar thermal, although identified as feasible for a mid terrace house, due to high fuel costs which result in long payback periods have made them unaffordable and therefore they will not be recommended for similar developments. Furthermore, despite the high cost for each percentage increase in carbon reduction for the hybrid panel installation with 2kWp capacity, it could be considered as an alternative to wind turbine for supplying green electricity and reducing the emissions by 41%. On the other hand, solar thermal was discounted due to the long payback periods. However, various financial incentives and regulation changes will potentially reduce the overall costs of some of the above technologies and make them more affordable options.

If best fabric standards are combined with a 3.5kW ASHP, a reduction of 65% can be achieved which exceeds Level 4 of the Code for Sustainable Homes or 51.5% CO_2 emissions savings when non-regulated have been considered as well. This combination is regarded as the most cost effective option for this development type. Alternatively, best practice with 1.25kW roof mounted wind turbine will result in 66% or 52.5% emission savings when regulated energy use or regulated and non-regulated have been included, respectively. This could be considered as the second optimum solution for a mid terrace property. As a third option, although it might not be considered as a favourable option, is the combination of best fabric standards with the 1.85kWp PV panel. Their combination provides 79% reduction in CO_2 emissions when only regulated energy use has been considered or 65.5% emissions reduction when both regulated and non-regulated energy use have been considered.

Measure		% Emissions Reduction	Cost per %
EEM	Best fabric standards	38%	£87
	Advanced fabric standards	49%	£97
	Good fabric standards	8%	£101
RES /LZC	3.5 kW ASHP	27%	£35
	2kW Biomass	55%	£55
	1.2kW Windsave	28%	£68
	3.5kW GSHP	31%	£193
	4.5m2 evacuated tube thermal collector	21%	£286
	1.85 kWp Solar PV	41%	£300
	5.8m2 flat plate thermal collector	20%	£300

Table 7.83 Feasible and cost effective measures for a new build mid-terrace houses

7.4.1.9 Works to existing / Refurbishment

This section will outline the implications in terms of feasibility and viability of measures for existing properties either converted or refurbished.

Whilst there is greater control and perhaps more obvious opportunities to minimise energy consumed in new buildings, such developments potentially make up a relatively small proportion of the building stock occupied in the future. It is therefore prudent to consider the borough's existing building stock and what options exist to reduce the energy demand. To give this some context the electrical energy demand of new housing built from 2009 onwards will represent only 6.7% of all residential electrical energy demand in 2026**.** It is important to also note however that the role of the planning system in influencing the energy use of existing buildings is limited to those cases where the fabric of the building is changing as a result of a development proposal, for example as part of a change of use or conversion.

Due to diversity of the existing housing stock in the London Borough of Ealing and 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, it is difficult to assess or define a single common CO_2 emission level. Despite the fact that the Building Regulations set limiting U-value standards for existing dwellings, they may vary depending on the particular situation of the refurbishment project. This is mainly due a number of clauses within the Part L document which allow particular requirements to be waived (due to technical or commercial reasons).

Section 7.1.1, which analysed the planning permissions for residential units in the London Borough of Ealing, identified that a significant number of applications constituted conversions (35%), change of use and continued use only constituted about 3% to 4% of the overall planning consents in the period 2008/2009. As it is afore mentioned conversions most commonly involve the refurbishment of an existing house to form several flats and often also involve some for of extension to the property.

It is therefore not practical to define a single target in terms of CO_2 reductions required to be delivered from energy efficiency measures or renewable energy for schemes involving the refurbishment of a house or a flat. It is instead proposed that such schemes will be required to adhere to Building Regulations for existing dwellings and to require the installation of some form of renewable energy where feasible. If during the refurbishment the future inclusion of microgeneration technologies has been already included to the infrastructure costs then the cost of applying these technologies will be considerably less. This may well save costs in the long term and accelerate the future integration of such technologies. Possible actions include: passive house principles, twin-coil hot water cylinder which are normally required for solar thermal systems and do not cost much more than standard cylinders, thermal store which is beneficial for biomass boilers, underfloor heating system which increases the efficiency of GSHP significantly as the delivery temperature drops and boiler position in house next to external wall to allow space for biomass storage hopper, or to facilitate easy connection of ground loops.

It is important to note that all refurbishment projects implemented from 1st October 2010, will need to comply with the new Building Regulations Part L1B 2010[51].

With regards to minor applications involving extensions to single family dwelling houses, which it would constitute a considerable proportion of all planning applications, it is proposed to apply an 'Uttlesford' type condition. In effect this condition requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested although this will be determined on a case by case basis), is earmarked for energy efficiency measures.

Renewable and low carbon technologies which are likely to be feasible for refurbishments include ASHP, solar photovoltaic, solar thermal and GSHP. These technologies will potentially meet only a proportion of the development's demand and their costs will vary from between £1,000 to £10,000. However, it is important to note that the costs of the low carbon and renewable technologies and that of the energy efficiency measures must be considered on a case by case basis.

Although in most instances internal work will not require planning permission, this may not be the case if the property is listed. Where the existing dwelling is of historic or heritage value, it is essential to consult with the Conservation Officers in the London Borough of Ealing and the English Heritage, as to the best way to incorporate energy efficiency measures into the dwelling in a sympathetic way which will not cause long-term damage to its fabric and structure. The proposed works must be considered on a case by case basis.

Energy Efficiency

This section provides an example of the potential for CO_2 reduction when a period mid-terrace, a period end terrace house, with 1970's extension and a 1980 mid-floor flat are entirely refurbished to comply with all the energy efficiency measures described in the approved documents L1B for renovated and replacement elements. In addition, examples of feasible upgraded insulation and other features that go beyond the limited requirements of Building Regulations will also be provided. The examples beyond current Building Regulations have been taken from the Energy

[51] More information about the new Building Regulations on Communities and Local Government website

Saving Trust[52] in Tables 7.84, 7.85 and 7.86 below. It is important to note that emissions savings include both regulated and non-regulated emissions (such as cooking and appliances).

In the case of the construction of a rear extension or loft insulation for all the examples given in the tables below, 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.

In the best case scenario, where a period mid-terrace 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 50-70% from its baseline. Similar CO_2 emissions reduction can be achieved if the same house would be refurbished with typical upgraded fabric features as shown in the table 7.84. A reduction in the energy costs of up to £650 per annum can be achieved.

Building Element	Typical existing features		Building Regs Part L 2010		Typical upgraded fabric features[53]
		W/m^{2}K	W/m^{2}K		W/m^{2}K
			replacements for existing elements	renovation of thermal elements	
Walls	solid walls – 215mm thick brickwork	2.1	0.28	0.30 or 0.55	internal insulation 0.18
Floors	uninsulated suspended timber floor	0.52	0.22	0.25	Insulated replacement concrete floor - 0.11
Roofs	uninsulated	2.3	0.16 or 0.18	0.16 or 0.18	0.1
Windows,roof windows, rooflights & curtain walling	single glazed timber frames	4.8	BWER Band C or better or 1.6W/m2K	BWER Band C or better or 1.6W/m2K	Windows – triple glazed, timber frames 0.80 W/m2K (BFRC g-value of glazing – 0.34 W/m2K)
Doors	unglazed solid timber	3	1.8	1.8	1
Air permeability (m3/m2hr @50Pa)		12	8	8	3
Other features					
Ventilation	Natural		Natural		MVHR 85%
Boiler efficiency	85%		90%		85% (no secondary room heating needed).
Water storage cylinder	140 litre capacity loose jacket on cylinder, pipe insulation.		105 litre capacity, 80mm factory cylinder insulation		110 litre capacity, 80mm factory cylinder insulation, all pipework insulated.
Lighting	Conventional		100% dedicated low energy efficient lighting		100% dedicated low energy efficient lighting

[52] CE309, Sustainable refurbishment – Towards an 80% reduction in CO2 emissions, water efficiency, waste reduction and climate change adaptation.
[53] Figures based on a floor area 85m^2

Table 7.84 U-Values and other energy efficiency standards in period mid-terrace and renovated houses

A reduction of 50-60% in the Dwelling Emission Rate (DER) over the baseline can be achieved in the case where a period end-terrace house with 1970's extension is entirely refurbished in order to comply with the insulation levels and other energy efficiency measures described in the approved documents L1B. A reduction of around 57% in the DER over the TER will be met if the same house would be refurbished with typical upgraded fabric features as shown in the table 7.85. The total energy cost savings per annum can be up to £990.

Building Element	**Typical existing features**		**Building Regs Part L 2010**		**Typical upgraded fabric features**
	W/m^2K		W/m^2K		W/m^2K
Main house			replacements for exisitng elements	renovation of thermal elements	
Walls	Solid walls – 215mm thick brickwork	2.1	0.28	0.30 or 0.55	internal insulation 0.18
Floors	uninsulated suspended timber floor	0.52	0.22	0.25	Insulated suspended timber floor - 0.19
Roofs	Insulated roof – 100mm mineral wool	0.41	0.16 or 0.18	0.16 or 0.18	0.10
Windows,roof windows, rooflights & curtain walling	single glazed timber frames	4.8	BWER Band C or better or 1.6W/m2K	BWER Band C or better or 1.6W/m2K	Windows – double glazed, timber frames BFRC g-value – 0.45 W/m2K
Doors	unglazed solid timber	3	1.8	1.8	insulated panel -1.00
Extension					
Walls	Unfilled brick/brick cavity walls	1.39			Insulated cavity walls – internal insulation - 0.18
Floors	Uninsulated concrete floor	0.52			Insulated concrete floor - 0.19
Roofs	Uninsulated flat roof	2			insulated flat roof - 0.19
Windows,roof windows, rooflights & curtain walling	single glazed timber frames	4.8			Windows – double glazed, timber frames BFRC g-value – 0.45 W/m2K
Doors	half glazed solid timber	3.7			insulated panel -1.00
Air permeability (m3/m2hr @50Pa)		12	8	8	3
Other features					
Ventilation	Natural		Natural		MVHR 85%
Boiler efficiency	68%		90%		91% condensing boiler, programmer, room thermostat and thermostatic radiator values (no secondary room heating needed)

Building Element	Typical existing features	Building Regs Part L 2010	Typical upgraded fabric features
Water storage cylinder	210litre capacity, loose jacket on cylinder, pipe insulation.	110 litre capacity, 80mm factory cylinder insulation	110 litre capacity, 80mm factory cylinder insulation, all pipework insulated
Lighting	Conventional	100% dedicated low energy efficient lighting	100% dedicated low energy efficient lighting
Cooking	Electric cooking	Electric cooking	Electric cooking

Table 7.85 U-Values and other energy efficiency standards in period end-terrace with 1970's extension and renovated houses

In the case where a 1980 mid-floor flat is going to be entirely refurbished, a net CO_2 emissions reduction of approximately 40-50% from its baseline can be achieved if it was refurbished up to the Building Regulations standards or achieving the energy efficiency standards shown in the last column of the table 7.86. An approximate reduction of £520 in the energy costs over a £1,148 baseline can be achieved.

Building Element	Typical existing features		Building Regs Part L 2010		Typical upgraded fabric features
	W/m^{2}K		W/m^{2}K		W/m^{2}K
			replacements for existing elements	renovation of thermal elements	
Walls	Uninsulated brick/block cavity walls	0.6	0.28	0.30 or 0.55	internal insulation 0.20
Floors	uninsulated suspended timber floor	0.52	0.22	0.25	Insulated replacement concrete floor - 0.11
Windows,roof windows, rooflights & curtain walling	single glazing	4.8	BWER Band C or better or 1.6W/m2K	BWER Band C or better or 1.6W/m2K	Windows – triple glazed, timber frames 0.80 W/m2K (BFRC g-value of glazing – 0.34 W/m2K)
Doors	one solid timber one full single-glazed	3.00 4.40	1.8	1.8	insulated panel - 1.00
Air permeability (m3/m2hr @50Pa)	10		8	8	3
Other features					
Ventilation	Natural		Natural		MVHR 85%
Boiler efficiency	Electric convector room heaters+ electric cooking		Electric convector room heaters+ electric cooking		Electric convector room heaters+ electric cooking
Lighting	Conventional		100% dedicated low energy efficient lighting		100% dedicated low energy efficient lighting

Table 7.86 U-Values and other energy efficiency standards in 1980 mid-floor and renovated flat

Installation and provision of feasible renewable technologies

Once the energy efficiency measures have reduced the heat and electricity demand as far as is feasible, renewable and/or low carbon technologies will be asked to further reduce the dwelling's energy use and turn it to an even more energy efficient property(s). It should be expected that the incorporation of these technologies will only replace a proportion of the overall energy demand. Some technologies are better suited in refurbishment projects than others due to the infrastructure required. As it is afore-mentioned refurbishments involving more than 4 units will have to comply with the targets set in section 7.4.1. For refurbishments of up to 4 units, the basic principles, constraints and opportunities for each technology which can be feasibly incorporated are discussed briefly below.

Technology	Size	Potential CO_2 emission savings	Indicative cost (£)	Other characteristics
Solar thermal	4-6m^2	up to 550	£3000 to £5000	1. Panel needs to face east to west through south 2. Oversizing a solar thermal system will affect its lifespan. 3. No or limited shading from other buildings, threes and features of the building
Solar PV	7m^2 (or 1.08kWp)	up to 520	~£6,200	1. The roof should be west to east (through south) facing to maximize solar yields. 2. No or limited shading from other buildings, threes and features of the building. 3. PV panels can be replaced by PV tiles (equivalent yield per surface area and a similar cost)
ASHP	6-10 kW	700- 1400	£6k-10k	1. Very easy to retrofit 2. Can be fitted externally to a wall or placed on the ground. 3. Assumes refurbishment level to conform with at least the current Building Regulations 4. Favourable to well insulated and draught proofed property for the heating system to be effective. 5. They perform better with underfloor heating systems or warm air heating because of the lower water temperatures required.
GSHP	6-10kW	700-1400	£10k - £15k	1. Assumes refurbishment level to conform to at least the current Building Regulations 2. Underfloor/low heat heating system necessary to improve the coefficient of performance of the pump, therefore maximizing the CO2 savings. 3. Favourable to well insulated buildings as reduces the costs, limits the size and the depth of the boreholes 4. Access and sufficient land for drilling a borehole 5. A ground survey must confirm the possibility to drill and the suitability of the ground conditions.
Wind turbines	1-1.5kW	~680	£1,898 or £750/kW	1. Small domestic wind turbines work best in exposed locations, without turbulence caused by obstacles such as trees 2. An average wind speed of no less than 5m/s make the system more effective
Biomass	5-8kW	1500-5000	£3k to £10k	1. Required large dry area close to the boiler to store your wood 2. A flue is required which is specifically designed for wood fuel appliances 3. Make sure it complies with Ealing's air quality policies

Table 7.87 Feasible renewable technologies for refurbishments of up to 4 units.

Technology	Size	Potential CO2 emission savings	CO_2 emissions Reduction period mid terrace	CO_2 emissions Reduction 1980 flat	CO_2 emissions Reduction period end terrace	Indicative cost (£)	Cost per % for period mid terrace	Cost per % for 1980 mid-floor flat	Cost per % for period end terrace
Solar thermal	4-6m2	up to 550	8%	13%	6%	£3000 to £5000	£500	£308	£667
Solar PV	$7m^2$ (or 1.08kWp)	up to 520	8%	12%	6%	~£6,200	£775	£517	£1,033
ASHP	6-10 kW	700- 1400	16%	25%	11%	£6k-10k	£500	£320	£727
GSHP	6-10kW	700-1400	16%	25%	11%	£10k -£15k	£781	£500	£1,136
Wind turbines	1 -1.5kW	~680	10%	16%	7%	£1,898 or £750/kW	£190	£119	£271
Biomass	5-8kW	1500-5000	48%	78%	35%	£3k to £10k	£42	£26	£57

Table 7.88 Feasible and cost effective technologies for refurbishments of up to 4 units[54].

Conclusions

The diversity of the existing housing stock in the London Borough of Ealing and the complexity of establishing a baseline in CO_2 emissions after a refurbishment prevent setting up specific targets in terms of CO_2 emissions reduction resulting from energy efficiency measures and low and zero carbon technologies. However, the Council will 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 examples above, energy efficiency standards can deliver a reduction of up to 70% of the total CO_2 emissions.

With regards to minor applications such as extensions, it is proposed to use the 'Uttlesford' type condition. In effect this condition requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested, although this will be determined on a case by case basis) is earmarked for energy efficiency measures, beyond current building regulations. For refurbishments involving the creation of a new unit(s), the energy efficiency scenarios identified to be the most cost effective for each residential development group will have to be followed.

7.4.2 Non-Residential

New Build

7.4.2.1 Offices

Despite the insignificant change in office proposals in Ealing borough, it was suggested to assess the impact of the different sustainability measures on carbon emissions for this development type.

[54] Cost per % based on baseline emissions

The energy and associated CO_2 emissions of commercial buildings can vary considerably due to a variety of factors, including the energy management of the building, occupancy, human behaviour etc. More specifically, energy use in offices varies considerably based on the type and size of the building. Most office developments generally fall into one of four types: naturally ventilated, cellular & open plan and air-conditioned standard and prestige, as defined in the Energy Consumption Guide 19[55],

The example used for this development group, which can be described as shallow plan side lit building, is believed to be the fairly representative of offices in the London Borough of Ealing. The case study selected for modelling (a 7 storey building of 9,577 sq. m.) can be described as comprising 'various fabrics and glazing, rarely full curtain wall glazing'.

Energy efficiency

The annual energy and CO_2 emissions for the modelled building are given in Table 7.89. It is important to mention that the carbon emisisons reduction for the energy efficiency scenarios against the current Building Regulations Part L (2006) has been derived from both regulated and non-regulated energy use.

Energy Use (kWh/yr)	**Baseline**	**Good Fabric Standards**	**Best Fabric Standards**	**Advanced Fabric Standards**
Space Heating	254,862	238,364	90,271	39,372
Hot Water	43,669	43,638	43,638	43,638
Lighting	211,260	208,197	144,800	142,405
Other	542,133	539,249	517,797	536,567
Total Gas	298,531	282,001	133,909	83,010
Total Electricity	753,392	747,446	662,597	678,973
Grant Total	**753,392**	**747,446**	**662,597**	**678,973**
CO_2 Total ($kgCO_2$/yr)	375,847	370,131	305,594	292,648
Percentage CO_2 reduction	-	**1.52%**	**18.69%**	**22.14%**

Table 7.89 Overall annual energy consumption and CO_2 emissions for the energy efficiency scenarios for offices

It is evident that the savings achieved in space heating, after energy efficiency measures have been implemented into the development, are significant at 65% and 85%. Factoring the Energy Hierarchy's priority for reducing the energy demand through improvements in the building's elements prior to incorporating CHP or renewable technologies, the results clearly demonstrate that by investing in sustainable design can make the building very efficient while reduces the requirement for on-site generation from renewable and/or low carbon energy sources.

Table 7.89 details the percentage improvement in CO_2 emissions when only regulated energy use has been considered. It is obvious that the good fabric standards, which are very similar to the current Building Regulations' requirements (2006), result in only 2.1% carbon savings in comparison with the best and advanced standards. Implementing best practice will result in 25.8% CO_2 emissions savings, while passivhaus standards reduce emissions by 27.2%. It is clear that the savings achieved through the best and advanced practice do not differ considerably. This can be due to the limitations of the iSBEM software, used in this study to ensure compliance with Building Regulations, compared to other accredited softwares that are currently in the market.

[55] Energy Consumption Guide 19, Energy use in offices, Best Practice Programme

The table below also presents the costs required in order to implement each of these measures. Implementing advanced fabric standards in an office will cost almost 39% more than applying the current Building Regulations' minimum requirements, while good and best practice will cost more by 10% and 17%, respectively. In addition, the cost beyond the baseline and the cost for each percentage increase in carbon reduction have been also calculated. For each percentage increase achieved in carbon reduction, a cost of £14,198 would need to be spent, if good fabric standards were being implemented while £2,045 and £6,214 would need to be spent if best and advanced fabric standards were to be applied. Therefore, best fabric standards can be considered the most cost-effective option between the three scenarios tested for offices.

Another way of evaluating which of these scenarios is the most viable for this development type is by factoring the costs below to the overall construction costs. Section 6.2 and 6.3 that are still to be completed, they will clarify the above issues further.

Measure	BER	TER	Percentage CO_2 reduction	Costs	Cost beyond baseline	Cost per %
Baseline	50.69	50.72	0.1%	£267,075	£0.00	£0.00
Good Fabric Standards	49.67	50.72	2.1%	£296,461	£29,386	£14,198
Best Fabric Standards	37.62	50.72	25.8%	£319,894	£52,819	£2,045
Advanced Fabric Standards	36.95	50.72	27.2%	£435,824	£168,749	£6,214

Table 7.90 BER/TER achieved in offices with different levels of energy efficiency

<u>CHP / CCHP/ Decentralised Energy Options</u>

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 onsite 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.

Initial modelling of the energy demand at the development indicates that a 15kWe/29kWth gas fired CHP unit, may be appropriate for the development. It is predicted to generate for 8,956 hours per annum, reducing emissions by 90 tonnes CO_2 at a budget premium cost of £52,000. A summary of the calculations for the CHP unit are shown in table 7.89. The costs outlined have been based on ballpark figures provided by CHP suppliers, EC Power.

System	Hours operation	Heat Generated / % heat demand/ % hot water demand (kWh/yr)	Electricity Generated / % of elec demand (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yrs)	Cost per %
XRGI 15kW	8,956	268,678 / 53% heat / 53% HW	134,339 / 18%	89,697 / 24%	£52,000	£780	2	£22

Table 7.91 CHP for new offices, carbon savings and costs

In addition, the cost for each percentage increase in carbon reduction for the CHP is £22. The high emission savings that CHP achieves as well as the short payback period make this technology option feasible and cost effective for this development type.

<u>Solar Photovoltaics (PV)</u>

The office development assessed for the purposes of this study could accommodate a solar panel area of 395m^2, which is almost half the amount of the roof, to reduce its CO_2 emissions by 9% at a budget premium cost of £395,000. If 100% of the roof space could be used for the solar PV panels a 16% reduction in overall CO_2 emissions would be achieved covering 14% of the development's electricity demand.

Table 7.92 below shows the energy generated by the solar PV panel and the carbon savings as well as the associated costs. It is important to note that the low improvement in carbon emissions is because the electricity consumption has derived from both regulated and non-regulated energy use. The non-regulated energy use (e.g. equipment) counts for the 19% of the overall energy consumption while lighting's contribution to the overall energy reaches 20%. This implies that the overall electricity consumption counts for 72% showing the significance of offsetting carbon emissions by incorporating energy management systems and energy efficient lighting. Changing the occupant behaviour which dictates the energy consumption and is generally difficult to control can play a vital role in minimising the energy. As afore-mentioned in Section 4, passive controls and sensors on lighting and heating can assist in minimising energy use.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
395 m^2	61	58,658	33,317	9%	£395,000	£1,980	£2,074	76	£44,559

Table 7.92 Roof-mounted solar PV panels for offices, carbon savings and costs for new-build offices

Despite roof-mounted panels are the preferred option, new high-rise office developments increasingly incorporate photovoltaic panels on their façades. Table 7.92 indicates the amount of the PV area available to be mounted on the south façade of the building. As most of the new office developments incorporate glass as the main material, the amount of wall that is left for mounting the panels is reduced.

An installation of 128m^2 of solar PV panel mounted on the south façade is predicted to generate 14MWh of electricity per annum, reducing the development associated CO_2 emissions by 2.1%. It is also important to ensure that there is no risk of overshading from neighbouring development. The option of installing a panel on the south façade is clearly not viable for the specific development due to the high payback and therefore is not being recommended.

Both tables indicate that a significant reduction in overall CO_2 emissions will not be possible for this building configuration through photovoltaic panels alone and hence it will need to be combined with other alternative renewable technologies such as CHP, biomass, GSHP etc.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
128 m^2	19.75	14,066	7,989	2.1%	£128,000	£640	£501	>100	60,215

Table 7.93 Solar PV panel at the south façade, carbon savings and costs for new-build offices

For each percentage increase in carbon reduction the hybrid PV panel achieve, a cost of £44,559 will need to be spent. This cost together with the long payback period render the option of providing electricity through the solar technology impractical. However, financial incentives mentioned in Section 6.4 will potentially reduce the capital costs and hence the payback period.

Solar thermal

Offices typically do not consume a large amount energy for hot water heating, as shown in Table 7.88 where CO_2 emissions resulting from hot water heating represent only 2%. Considering that a communal solar thermal system usually provides 50% of the water heating demand, the potential CO_2 reductions through the use of a solar thermal system becomes negligible discounting this technology as feasible.

If, however, a solar thermal collector could be installed on the roof of this building, a 110m^2 flat plate or evacuated tube collector could reduce the emissions by approximately 2.6% while providing 100% of the hot water demand. The results shown in table 7.94 indicate that this technology is not viable for the specific development type due to the long payback periods.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
110m^2 (flat plate)	44,080	9,608	2.56%	114,000	£570	>100	£44,593
100m^2 (evacuated tube)	44,100	9,613	2.56%	147,000	£740	>100	£57,475

Table 7.94 Solar thermal collector options, carbon savings and costs for new-build offices

Ground Source Heat Pumps (GSHP)

Office development could feasibly incorporate a ground source heat pump for both space heating and cooling. An installation of 5 No. 65kW heat pumps would provide heating with a CoP of 4 and cooling with a CoP of 5.5. The savings and costs are described in Table 7.95. However, in order to supply the total space heating and cooling demand of the development, it is predicted that 128 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is not considered to be sufficient space at the development for GSHP to supply the total heat and cooling demand.

Despite the short payback period and the significant emission savings, the above consideration together with potential difficulties for extensive ground works due to surrounding buildings and main roads, render the option of a ground source heat pump as feasible for this development.

System	Heat Generated (kWh/yr)	Electricity Generated (for cooling) (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance cost (£/yr)	Payback (yr)	Cost per %
5x65 kW	397,593	247,138	119,838	31.88%	£552,500	£4,144	7	£17,328

Table 7.95 GSHP size, carbon savings and costs for new-build offices

Air Source Heat Pumps (ASHP)

Air source heat pumps technology is an alternative to GSHP when the latter is not found feasible. Although it is not considered as efficient as GSHP, it can still offer energy and carbon savings and they are definitely more efficient than conventional air conditioning units.

They are not generally considered to be a renewable technology due to the variability of the air temperature and not as efficient as the ground source heat pumps because the efficiency and capacity of the heating mode decrease with decreasing outdoor air temperature and the efficiency and capacity of the cooling mode decrease with increasing outdoor air temperature.

However, since the recent adoption of the Climate and Energy Package by the EU Parliament on the 6th April 2009, the use of Air Source Heat Pumps can now be considered a feasible form of renewable technology. The Climate Energy Package includes the Directive on the Promotion of Energy from Renewable Sources (RES), which covers the use of air, ground and water source heat pumps.

Table 7.96 below indicates that a 3 No. 60kW system could provide 100% of the building's heating and cooling demand with CoP of 3.5 and 4.9, respectively. The costs are also presented in the table below.

System	Energy Generated (kWh/yr)	Electricity Generated (for cooling) (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance cost (£/yr)	Payback (yr)	Cost per %
3x60kW	253,515	248,710	99,662	26.52%	£180,000	£1,350	58	6,788

Table 7.96 ASHP, carbon savings and costs for offices

Biomass Heating

The sizing exercise concludes that 100% of the space heating requirement and 81% of the hot water demand of the modelled building could be provided by a 150kW boiler. The biomass boiler is predicted to reduce the CO_2 emissions associated with the development by 13%, at a budget premium cost of £27,000. The use of a biomass boiler would require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost.

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 (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance cost (£/yr)	Payback (yr)	Cost per %
150 kW	249,585	48,502	12.90%	£27,000	£1,350	-14	£2,092

Table 7.97 Biomass, carbon savings and costs for offices

Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of $10m^3$ would be required. Using wood chips, which have a lower energy density, a quarterly delivery of $31m^3$ would be required.

Based on the costs shown in table 7.97, biomass does not seem viable solution for new office developments. This is mainly due to the high biomass fuel costs which reduce the energy savings leaving the investment without yearly nett savings. On the contrary, the cost for each percentage increase in carbon reduction is much less when compared to the other technologies which implies that it will need to be further explored. Factoring grants and other financial incentives can make this option an affordable solution.

Generally when biomass boilers are recommended, fuel storage and a plant room would be required. For large office blocks like the one tested here, the above requirements will not have a big impact on the overall office space. However, for office developments smaller than the example used, biomass boilers of 8kW in size could be suitable. Which could dramatically reduce the office space where offices of this size would normally have wall mounted combination boilers.

Wind Turbines

Generally office buildings are located in central areas of higher density, where space is often a premium, and is unlikely to be sufficient to accommodate medium scale free standing wind turbines and the proximity to surrounding buildings or residential properties is likely to present a concern. The required distance between the wind turbine's location and the surrounding buildings can ensure the turbine's optimum function.

An initial assessment of the options for wind energy is presented in table 7.98 below. The turbines range from roof-mounted to stand-alone wind turbines generating various amounts of electricity and carbon savings. It is obvious that wind turbine's contribution to the overall CO_2 emissions of the development is negligible and accordingly these are not recommended for similar developments.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
12x1kW Aeroenvironment AVX1000 (@18m agl)	30,348	17,238	4.6%	£70,000	£700	£1,073	24	£15,263
24x1kW Aeroenvironment AVX1000 (@18m agl)	28,800	16,358	4.4%	£90,000	£900	£1,001	35	£20,678
1x6kW vQuiet Revolution	8,500	4,828	1.3%	£60,000	£600	£286	141	£46,708
4x2.5 kW Proven	17,128	9,729	2.6%	£50,400	£500	£608	32	£19,471

Table 7.98 Wind turbine options, carbon savings and costs for office

Conclusions

This section outlines the optimum solution for a new-build office in terms of measures based on physical feasibility and cost effectiveness. The results are presented in table 7.99.

With regards to the energy efficiency scenarios, best fabric standards are clearly the most cost-effective option for this development group as they have the lowest cost for each percentage saved in carbon emissions.

Comparing the feasible renewable technologies, the installation of a 15kWe gas-fired CHP seems to be the most cost effective solution for an office achieving 24% reduction in CO_2 emissions. On the other hand, a 150kW biomass can reduce the office's emissions by 13% with a cost of £2,092 for each percentage reduction achieved in CO_2 emissions. However, as it was shown in table 7.96 above, biomass technology is not a cost effective solution for this development and this might be due to assumptions taken in this study for the price of biomass fuels. The increasing demand for biomass boilers will potentially drop the prices of wood pellets or chips.

ASHP's come third in the cost effectiveness hierarchy. They reduce emissions by 27% which is the highest improvement in comparison with the other feasible technologies but each percentage reduction achieved will cost £6,788. Solar PV technology could be potentially feasible for this development saving approximately 9% of the CO_2 emissions but the extremely high cost that needs to be spent for each percentage increase renders this option as non cost effective.

Measure		% Emissions Reduction	Cost per %
EEM	Best fabric standards	26%	£2,045
	Advanced fabric standards	27%	£6,214
	Good fabric standards	2.1%	£14,198
RES /LZC	15kWe CHP	24%	£22
	150kW Biomass	13%	£2,092
	3x60kW ASHP	27%	£6,788
	61kWp Solar panel	9%	£44,559

Table 7.99 Feasible and cost effective measures for offices

Various financial incentives and regulation changes will potentially reduce the overall costs of some of the above technologies and turn them to affordable solutions for similar developments.

If best fabric standards are to be combined with CHP a reduction of 50% can be achieved. Their combination can be considered as the optimum solution for this development. It is important to note that the emission savings presented in the table below are based on only regulated energy use while both regulated and non-regulated energy use have been considered for the renewable technologies. This implies that CHP can achieve even higher emissions reduction if non-regulated energy was not included in the calculations.

7.4.2.2 Warehousing

Warehouse developments in Ealing vary between storage and distribution centres to self storage with either flexible office space inside the building or associated ancillary office space. Based on the analysis of the planning permissions, a 3,369 m^2 storage facility with associated ancillary office space was used as an example. Due to the nature of the example building, it was suggested to use electric heating system to provide the energy requirements of the office.

Electric heating systems are considered 100% efficient at the point of use, meaning all the electricity used is converted directly into heat, unlike boiler-based systems where energy is wasted through the flue. Electric water heating is an efficient method of heating water directly with electric immersion that are in direct contact with the water, reducing energy losses than can be experienced from pipework, and circulating pumps. If an off-peak electricity supply is provided it allows the water to be heated during the evening or early morning providing a full tank of hot water ready for each day. Despite its high efficiency, electric heating has much higher carbon dioxide emissions due to the fuel factor for electricity[56] and are not generally recommended for other types of buildings.

[56]Building Regulations Part L2A, 2006

The warehouse building will not be heated which means that the three energy efficiency scenarios will only be tested in the office. However, energy efficiency measures such as efficient lighting will be applied to measure the carbon savings. The electric heating for the office also means that the application of the energy efficiency measures will not have a significant effect on the carbon savings normally achieved from the incorporation of such measures.

Energy efficiency

The overall energy and associated CO_2 emissions have been calculated for the baseline and the three energy efficiency scenarios. The baseline energy and CO_2 emissions have been estimated after applying the limiting U-Values of the current Building Regulations Part L (2006) to the whole development, while good, best and advanced fabric standards have been tested only to the office. The results are shown in Table 7.100.

Energy Use (kWh/yr)	**Baseline**	**Good Fabric Standards**	**Best Fabric Standards**	**Advanced Fabric Standards**
Space Heating	8,676	6,575	5,322	2,989
Hot Water	44,380	44,380	44,380	44,380
Lighting	128,331	128,331	117,375	116,364
Other	45,059	45,059	43,592	43,298
Total Electricity	226,445	224,345	210,668	207,032
Grant Total	**226,445**	**224,345**	**210,668**	**207,032**
CO_2 Total ($kgCO_2/yr$)	95,560	94,674	88,902	87,367
Percentage CO_2 reduction	-	**0.93%**	**6.97%**	**8.57%**

Table 7.100 Overall annual energy consumption and CO_2 emissions savings for warehouses

While table 7.100 above presents the energy and CO_2 emission savings calculated based on both regulated and non-regulated energy use, table 7.101 below shows the BER against the TER for the whole development for the four scenarios (regulated energy only). It is apparent that the application of the energy efficiency measures to a building of this use does not provide significant carbon dioxide emissions savings.

The SBEM modelling includes the predicted demand for hot water; however it employs a very high benchmark for water demand within the warehouse and office development that it is considered to be in excess of what can be reasonably expected for a building of this type. Use of the BRE water calculator tool suggests a DHW demand for the building of about half that currently predicted by SBEM. This can have a significant effect on the modelling of viability for low and zero carbon technologies; however SBEM predictions have been used for the analysis.

To build a warehouse with ancillary office to current Building Regulations costs approximately £141,000. This is based on suppliers' information for insulation and windows. Door costs have been assumed due to lack of precise information from suppliers[57]. As it is afore-mentioned, the energy efficiency measures were tested only to the office and their costs range between £60,000 to £80,000.

[57] £1,000/door for baseline and good fabric standards, £1,500/door and £2,000/door for best and advanced fabric standards. Further information regarding the costs of the doors is required.

Measure	BER	TER	Percentage CO_2 reduction	Costs	Cost beyond baseline	Cost per %
Baseline	23.27	23.28	0.0%	£141,297	£0.00	£0.00
Good Fabric Standards	23.01	23.28	1.2%	£61,567	£79,729	£68,744
Best Fabric Standards	21.3	23.28	8.5%	£71,500	£69,797	£8,206
Advanced Fabric Standards	20.84	23.28	10.5%	£80,743	£60,554	£5,777

Table 7.101 BER /TER achieved for warehouses and costs

The table above indicates that the cost of implementing the energy efficiency measures increase relative to improvement. The cost beyond the baseline and the cost for each percentage increase in carbon reduction are also presented in the table above demonstrating that advanced or passivhaus standards are the most cost-effective option.

CHP / CCHP/ Decentralised Energy Options

Detailed calculations to determine the possible carbon savings and financial viability of CHP on this development group have not been undertaken given that there is small heat demand from the office and reception areas and therefore insufficient loads to make such an option technically or economically viable.

Solar Photovoltaics (PV)

Solar PV technology is generally considered a favourable technology for warehouses as it supplies the development with free and zero carbon electricity. Table 7.102 details the savings in carbon emissions resulting from the different PV panel options. It sets out, for each suggested percentage increase in carbon reduction, the area, system power rating and cost for each option. It also shows that in order to achieve the maximum savings in CO_2 emissions, 680m^2 is needed using hybrid modules. The costs outlined have been based on ballpark figures provided by PV suppliers.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yrs)	ROC Income (£/yr)	Payback (yrs)	Cost per %
57 m^2	9	8,465	4,808	5%	£57,000	£290	296	68	11,329
113 m^2	17	16,781	9,531	10%	£113,000	£570	592	68	11,329
227 m^2	35	33,710	19,147	20%	£227,000	£1,140	1,221	67	11,329
453 m^2	70	67,271	38,210	40%	£453,000	£2,270	2,479	67	11,329
680 m^2	105	100,980	57,357	60%	£680,000	£3,400	3,700	67	11,329

Table 7.102 Solar PV options for warehouses, carbon savings and costs

Despite the high capital costs and payback periods, financial incentives such as the Renewables Obligation Certificates, feed-in-tariffs, will potentially reduce the capital and operational expenditure and payback by half.

The cost for each percentage increase in carbon reduction has been also calculated in order to assist in identifying which is the most cost effective solution for this development group. Due to the balance between the capital costs and the net savings for all PV panel options, the cost per percentage increase in carbon reduction remains the same.

Solar Thermal

Solar hot water technology is ideally suited to houses and other buildings which have a high demand for domestic hot water. They are particularly well suited to houses as each typically has its own independent heating system with separate hot water cylinder.

However, given the hot water demand within the office building of this development, this technology can potentially offer significant CO_2 emission savings. Tables 7.103 and 7.104 present the carbon emissions savings achieved from solar flat plate and evacuated tube collectors for a warehouse development. It sets out, for the different percentages increase in carbon reduction, the area, system power rating and cost of each option.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yrs)	Payback (yr)	Cost per %
55 m^2	22,040	4,804	5%	57,000	£290	>100	£11,338
110 m^2	44,080	9,608	10%	114,000	£570	>100	£11,338
220 m^2	88,160	19,217	20%	228,000	£1,140	>100	£11,338
438 m^2	175,160	38,181	40%	453,000	£2,270	>100	£11,338

Table 7.103 Flat Plate solar collectors, carbon savings and costs for warehouses

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yrs)	Payback (yr)	Cost per %
41 m^2	21,870	4,767	5%	54,000	£270	>100	£10,825
81 m^2	43,740	9,534	10%	108,000	£540	>100	£10,825
162 m^2	87,480	19,069	20%	216,000	£1,080	>100	£10,825
326 m^2	176,175	38,402	40%	435,000	£2,180	>100	£10,825

Table 7.104 Evacuated tube collectors, carbon savings and costs for warehouses

Comparing the two standard types of collectors, it is obvious that in order to achieve the maximum in carbon savings, e.g. 40%, the evacuated tube collectors require less roof area while generate almost the same amount of energy, it cost less by 4% and the investment is repaid within a 9 years period.

The costs shown in the tables above indicate that none of the solar thermal collector types are currently cost effective for the specific development due to the long payback period. However, various future changes in market conditions and policies as well as financial incentives will reduce the costs and therefore the payback period and will potentially make this technology a more affordable investment.

<u>Ground Source Heat Pumps (GSHP)</u>

A 20 kW ground source heat pump could be used to provide the development with space heating and hot water. In order to supply the total space heating and hot water demand of the development, it is predicted that 10 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is sufficient space at the development for GSHP to supply 100% of the development's space heating and hot water requirements, resulting in a 17.6% emission saving at a budget premium cost of £28,000.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yrs)	Payback (yr)	Cost per %
20 kW	53,061	16,794	17.57%	£28,000	£210	7	£1,593

Table 7.105 GSHP size, carbon savings and costs for warehouses

It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology. The cost per each percentage increase in carbon reduction is also shown in table 7.105. Given the short payback period, this technology is therefore a cost effective solution for this development group.

Air Source Heat Pumps (ASHP)

Air sourced heat pumps operate using the same reverse refrigeration cycle as ground source heat pumps. However the initial heat energy is extracted from the external air, rather than from the ground. These heat pumps can be reversed to provide cooling to an area, although this reduces the coefficient of performance of the pump.

Air sourced pumps may be suitable to address areas likely to suffer from local overheating, such as within the office building. However natural ventilation, shading and reduction of internal loads are normally the priority to reduce the risk of overheating.

An installation of 20kW air-sourced heat pump system is predicted to provide a net reduction in annual energy consumption of 53 MWh and reduce annual associated CO_2 emissions by 16 tonnes or 17% of the overall carbon emissions. The budget additional cost of introducing an air sourced heat pump system is £5,000 with a payback period of 1 year.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yrs)	Payback (yr)	Cost per %
20 kW	53,061	15,994	17%	£5,000	£40	1	£299

Table 7.106 ASHP, its carbon savings and costs for warehouses

The cost per each percentage increase in carbon reduction is also given in table 7.106. It is apparent that the short payback period, the low annual maintenance cost and the cost for each percentage increase in carbon reduction, make this technology a cost effective solution for this development group.

Biomass Heating

Biomass would not be considered feasible or viable for this type of development. This is mainly because the building is all-electric and therefore the space heating and hot water requirements are supplied by electric heating and water system. In the case, however, that a warehouse is run on conventional gas fired boilers, biomass heating would be an option to consider for offsetting the carbon emissions and provide the building with its space heating and hot water requirements. As the example assessed in this study is electric and not gas heated, biomass has not been considered further.

Wind Turbines

Generally warehouses are located in industrial areas where the possibility of having sufficient land to place the wind turbines is greater while the proximity to surrounding buildings or residential properties might be lower. The required distance between the wind turbine's location and the surrounding buildings can ensure its optimum function.

An initial assessment of the options for wind energy is presented in table 7.107 below. The turbines range from roof-mounted to stand-alone wind turbines generating various amounts of electricity and carbon savings.

The maximum feasible number of 1kW Aeroenvironment turbines for this development group is 54 supplying almost 65MWh per annum of electricity (37% of electricity demand) while reducing the CO_2 emissions by 38.5%. The 54 wind turbines would require a roof space of approximately 108m in total. The capital cost of the 54 Aeroenvironment wind turbines is £300,000 while for each year the nett savings are almost £6,000 and the income receiving from ROCs is approximately £2,300. The payback period is a bit high but with the regulations constantly changing and more incentives for investing in renewables, it might get reduced.

The 2 No. 6kW Quiet Revolution and 7 No. 2.5 Proven wind turbines are of small to middle scale and they can be installed on the ground and on the roof, respectively, subject to the building structure is strong in order to avoid vibration due to forces transferred from the turbine in strong winds. They can generate 17 and 30 MWh of electricity per annum resulting in 10% and 18% reducing in CO_2 emissions with a budget premium cost of £20,000 and £40,000, respectively. It is clear from the table below that the payback periods for both of them are very similar and therefore the installation of 7 No. 2.5 kW Proven wind turbines would be more favourable as it generates higher amounts of electricity and achieves higher carbon and financial savings.

Stand-alone wind turbines have been also assessed for this development group subject to land availability. A 20kW Westwind turbine is predicting to supply the development with 22.7MWh of electricity, resulting in a CO_2 emission saving of almost 13 tonnes per annum at a capital cost of £10,000 with a payback period of 22 years.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yrs)	ROC Income (£/yr)	Payback	Cost per %
6x1kW Aeroenvironment AVX1000 (@40m agl)	10,098	5,736	6.0%	£30,000	£300	£370	29	£4,998
12x1kW Aeroenvironment AVX1000 (@18m agl)	14,400	8,179	8.6%	£50,000	£500	£518	35	£5,842
24x1kW Aeroenvironment AVX1000 (@18m agl)	28,800	16,358	17.1%	£140,000	£1,400	£1,036	57	£8,178
54x1kW Aeroenvironment AVX1000 (@18m agl)	64,800	36,806	38.5%	£300,000	£3,000	£2,368	53	£7,789
1x6kW vQuiet Revolution	8,500	4,828	5.1%	£25,000	£250	£296	29	£4,948
2x6kW vQuiet Revolution	17,000	9,656	10.1%	£50,000	£500	£629	28	£4,948
2x2.5 kW Proven	8,564	4,864	5.1%	£25,200	£250	£296	29	£4,951
7x2.5 kW Proven	29,974	17,025	17.8%	£88,200	£880	£1,073	28	£4,951
1x20kW Westwind	22,660	12,871	13.5%	£55,000	£550	£814	22	£4,083

Table 7.107 Wind turbine options for warehouses, carbon savings and costs

The cost for each percentage increase in carbon reduction is also presented in the table above. The 20kW Westwind free standing wind turbine has the lowest cost for each percentage reduction achieved in CO_2 emissions while results in 13.5% emissions improvement over the baseline. However, due to land availability issues, this size of wind turbine might not be suitable for other similar proposals. It was therefore suggested that the renewable contribution of the 54 No. 1kW or the 7 No. 2.5kW roof mounted wind turbines is greater compared to the other options despite of the higher cost per percentage reduction.

Conclusions

This section outlines the optimum solution for new-build warehouses in terms of measures based on physical feasibility and cost effectiveness. The results are presented in table 7.108.

With regards to the energy efficiency scenarios, advanced fabric standards can be considered the most cost-effective option for this development group as they have the lowest cost per each percentage increase in carbon reduction and achieve the highest emission savings compared to the other scenarios. However, due to the nature of the development, a reduction of 10% in CO_2 emissions might not always be possible to be achieved. This implies that this type of developments will potentially focus on renewable technologies to achieve the required targets from on-site low carbon technologies, rather than energy efficiency measures. In any case, a minimum improvement over the Building Regulations Part L will be always sought for such proposed developments.

Comparing the feasible renewable technologies, ASHP seems to be the most cost effective solution for the warehouse, while GSHP comes next to the cost effectiveness hierarchy. Roof mounted wind turbines are following reducing the emissions by 18% and 39% depending on the turbine's series and the type. It is suggested however that the installation of 54 No. 1kW turbines can offer greater emission savings, despite the higher cost for each percentage increase in carbon reduction.

If advanced fabric standards are combined with ASHP a reduction of 27.5% in CO_2 emissions can be achieved. This could be considered as the optimum solution for this development group. The combination of GSHP or 7 No. 2.5kW roof mounted wind turbines with advanced fabric standards results in similar emissions reduction as those of the ASHP but with higher costs spent for each percentage increase in carbon reduction.

On the other hand, advanced fabric standards combined with 54 No. 1kW roof mounted wind turbines provides the greatest emission savings with almost 50%.

Although solar technologies are feasible for this development group, they do not seem to be cost effective based on the costs shown below. It is obvious from the table that a solar PV panel with 105kWp capacity can reduce the emissions by 60% but proved to be the second highest in terms of the costs that need to be spent per each percentage increase in carbon reduction. Various financial incentives and regulation changes will potentially reduce the overall costs of the solar technologies and make them an affordable investment for similar developments.

It is important to mention that the renewable technologies shown in Table 7.102 have been assessed based on both regulated and non-regulated energy use which implies that most of them can achieve even higher emissions reduction if non-regulated energy was not included in the calculations.

	Measure	% Emissions Reduction	Cost per %
EEM	Advanced fabric standards	10.5%	£5,777
	Best fabric standards	8.5%	£8,206

	Measure	% Emissions Reduction	Cost per %
	Good fabric standards	1.2%	£68,744
RES /LZC	20kW ASHP	17%	£299
	20kW GSHP	18%	£1,593
	7x2.5 kW Proven	18%	£4,951
	54x1kW Aeroenvironment AVX1000 (@18m agl)	39%	£7,789
	326m2 evacuated tube thermal collector	40%	£10,825
	105kWp Solar PV	60%	£11,329
	438m2 flat plate thermal collector	40%	£11,338

Table 7.108 Feasible and cost effective measures for new-build warehouses

7.4.2.3 Schools

School developments in Ealing can range from extensive 2 storey primary schools to 3 to 4 storey secondary schools. Based on the analysis of the planning application files, a 4,178 m^2 3-storey school was used as an example.

Energy Efficiency Measures

The annual overall energy demand and associated CO_2 emissions for the school were estimated using the National Calculation Methodology, iSBEM. Table 7.109 shows clearly that the space heating demand will change significantly depending on the different levels of energy efficiency and the same happens with the carbon savings. It should be noted that the percentage improvement has been calculated based on regulated and un-regulated energy use. The 'other' energy use shown in the table below includes the consumption of cooling, auxiliary and equipment. Whistle the energy from the equipment remains the same throughout the three scenarios of energy efficiency, lighting shows an improvement of 11% to 22% and auxiliary 4% when more efficient fan systems were applied.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Space Heating	187,030	147,601	88,054	48,724
Hot Water	23,233	23,233	23,233	21,866
Lighting	94,553	94,553	84,136	73,512
Other	203,640	206,129	197,447	201,423
Total Gas	210,263	170,834	111,288	70,590
Total Electricity	298,193	300,682	281,583	274,935
Grant Total	**508,456**	**471,516**	**392,871**	**345,525**
CO_2 Total ($kgCO_2$/yr)	166,629	160,030	140,418	129,717
Percentage CO_2 reduction	-	**3.96%**	**15.73%**	**22.15%**

Table 7.109 Breakdown of annual energy requirements and associated carbon emissions

Table 7.110 details the percentage reduction in BER over TER which varies from approximately 5% to 25% depending on the level of insulation and other efficiency measures. The table also shows the costs for achieving the three energy efficiency scenarios. The percentage improvement of the BER against the TER regards only regulated emissions. Comparing the percentage improvements presented in tables 7.109 and 7.110, it is apparent that the carbon savings do not differ significantly. This implies that the un-regulated energy use does not have a significant contribution in schools' energy consumption and carbon emissions compared to residential properties or offices.

The cost beyond the baseline and the cost for each percentage increase in carbon reduction have also been calculated in order to assist in understanding which of these scenarios is the most cost-effective option for this development. For each percentage increase achieved in carbon reduction, a cost of £10,806 would need to be spent, if good fabric standards were to be implemented while £5,265 and £6,260 would need to be spent if best and advanced fabric standards were to be applied, respectively. Based on the above considerations, best fabric standards are considered to be the most cost effective solution in terms of energy efficiency measures.

Measure	BER	TER	Percentage CO_2 reduction (ENE1)	Costs	Cost beyond baseline	Cost per %
Baseline	34.21	34.24	0.1%	£255,438	£0.00	£0.00
Good Fabric Standards	32.63	34.24	4.7%	£306,250	£50,813	£10,806
Best Fabric Standards	27.94	34.24	18.4%	£352,315	£96,878	£5,265
Advanced Fabric Standards	25.37	34.24	25.9%	£417,600	£162,163	£6,260

Table 7.110 BER/TER achieved in a new-build school with different levels of energy efficiency and costs

CHP / CCHP/ Decentralised Energy Options

In order for the use of CHP to be economically viable and provide the maximum environmental benefits, it is essential to run for as many hours as possible with high and simultaneous demands for electricity and heat throughout the year.

Introducing combined heat and power generation into schools might be feasible. But to be efficient, it has to be limited to a size where the heat output can be utilised, with the only summer load being the daily domestic hot water demand. These considerations render the option of installing a CHP system at schools impractical.

A recent guidance on the design and construction of sustainable, low carbon school buildings published by Target Zero[58] indicates that the most cost-effective route to providing directly-connected heat is a district CHP plant. A number of CHP variants were modelled and a district CHP system powered by either a gas turbine or a fuel cell was predicted to be the most cost-effective route to achieving both a 44% and 70% reduction below the current requirements of Part L 2006, although these targets will have to include a contribution from energy efficiency. However not all schools will be in an area where district schemes are viable and a more detailed feasibility study will need to be conducted to identify high enough heat demand density to make district CHP viable.

Solar Photovoltaic (PV)

In order to avoid overshading, and ensure access for maintenance, it is recommended that the panels do not occupy more than half of the available roof space. The available roof space of this specific example is 1,038 m^2 and therefore the following options for PV panels are presented in table 7.111. An installation of 192m^2 to 767m^2 of inclined, south facing, hybrid PV panels is predicted to generate approximately 28MWh to 113MWh of electricity per annum, reducing the

[58] http://www.targetzero.info/guidance_reports/view/school/

development associated CO_2 emissions by 10% to 39%. It is also important to ensure that there is no risk of overshading from neighbouring development. Factoring grants except the ROC income in to the overall costs makes solar PV technology an affordable solution for schools.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
95 m^2	15	14,108	8,013	5%	£95,000	£480	£518	67	£19,755
192 m^2	30	28,512	16,195	10%	£192,000	£960	£1,036	67	£19,755
384 m^2	59	57,024	32,390	19%	£384,000	£1,920	£2,108	66	£19,755
767 m^2	118	113,900	64,695	39%	£767,000	£3,840	£4,180	67	£19,755

Table 7.111 Solar PV options for schools, carbon savings and costs for new-build schools

The Government's target is that from 2016, all new school buildings in England will produce zero carbon emissions from their day-to-day use. It is therefore evident that PV technology will not be able to reduce emissions by ≥100% and hence it will need to be combined with another renewable technology such as wind, biomass, GSHP or even CHP to achieve a zero carbon school.

The costs related to this technology are also presented in the table above. The cost for each percentage increase in carbon reduction has been also calculated in order to identify which of the energy efficiency scenarios is the most cost effective solution for this development group. Due to the balance between the capital costs and the nett savings for all PV panel options, the cost per percentage increase in carbon reduction remains the same.

Solar Thermal

Solar hot water 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.

Ground Source Heat Pumps (GSHP)

An installation of 3 No. 45kW ground source heat pumps could be used to provide the development with space heating. In order to supply the total space heating and hot water demand of the development, it is predicted that 68 boreholes, each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is insufficient space at the development for GSHP.

Generally new build schools have dedicated areas for parking and other external areas with various uses e.g. playing fields, cycle storage spaces etc. which increase the overall footprint of the building making it possible for a GSHP to be installed. The technology could supply 100% of the development's space heating requirements, resulting in a 9.41% emission savings at a budget premium cost of £229,500.

It is important to note that the costs do not include ground testing, drilling or testing where it will be a subject of further investigation for applicants recommending this technology. The cost for each percentage increase in carbon reduction is also given in the table below. The current electricity prices do not offer significant nett savings which in turn result in a long payback period. The above considerations render the option of the GSHP unviable for the specific development.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3x45 kW	139,453	15,685	9.41%	£229,500	£3,440	>100	£24,381

Table 7.112 GSHP size, carbon emissions and costs for schools

Air Source Heat Pumps (ASHP)

An installation of 3 No. 45kW ASHP is predicted to supply the total space heating requirement for the school, reducing total development emissions by 8.2%, at a budget premium cost of £135,000. Table 7.113 below indicates the size of the ASHP's with CoP of 3.5, their contribution to carbon savings as well as the cost and annual nett savings.

The costs for implementing this technology are also presented in the table below. Given the low CO_2 emissions reduction achieved and the high cost per each percentage increase in carbon reduction, ASHP is not considered an affordable investment for schools.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
3x45 kW	139,453	13,584	8.2%	£135,000	£680	>100	£16,560

Table 7.113 ASHP, carbon savings and costs for schools

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 150kW biomass boiler is predicted to reduce the CO_2 emissions associated with the development by 23%, at a budget premium cost of £26,000. This boiler can provide 100% of the space heating and 42% of the hot water demand. A fuel pellet delivery of 8m^3 would be required every two weeks during the main heating season with less frequent deliveries throughout the remainder of the year.

The costs are detailed in Table 7.114 below. The use of a biomass boiler would require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost. It is obvious from the table below that although biomass is feasible to cover both the space heating and hot water requirements of the development, the high fuel and maintenance costs reduce the energy savings leaving the investment without significant yearly nett savings. The cost for each percentage achieved in carbon reduction has been also estimated to be £1,133 for this technology.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
150 kW	196,686	38,222	22.94%	£26,000	£1,300	-15	£1,133

Table 7.114 Biomass heating and costs for schools

Factoring grants and other financial incentives can potentially reduced biomass fuels prices and make biomass heating an affordable solution for schools.

Wind Turbines

Wind turbines are not generally recommended in urban environment due to the adverse effect that surrounding buildings generally have on the wind flow and the insufficient land. As a rule of thumb, wind turbines need to be at least 150m from surrounding buildings to avoid issues of noise and flicker which is rarely possible, to have at least doubled the length of the chosen mast or 10m distance between them. The actual distance however will depend upon a number of factors, including the local terrain, trees and the background noise in the area. Available land is an important factor to consider when middle or large scale wind turbines are recommended.

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 purposes. Table 7.115 below compares different options of wind turbines that could be installed either on the roof of the school or the playground.

The initial feasibility indicated that a series of 24 No. 1kW Aeroenvironment roof mounted wind turbines, normally sold in units of 6, reduce the overall emissions by 9.8% covering 10% of the electricity demand. The 24 turbines will require around 48 metres of space alongside the roof facing west or south west. Despite the high cost estimated for each percentage increase achieved in carbon reduction, the higher emission savings provided render this option feasible and cost effective.

On the other hand, an installation of 2 No. 2.5kW Quiet Revolution vertical axis wind turbines achieve a reduction of almost 6% in CO_2 emissions while it has the second lowest cost for each percentage increase in carbon reduction. An area of approximately 20m around the wind turbines will be required.

The small output and contribution to total emissions provided by the other wind turbine options means that they will not be cost-effective for the specific development.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
6x1kW Aeroenvironment AVX1000 (@40m agl)	10,098	5,736	3.44%	£30,000	£500	£370	29	£8,715
12x1kW Aeroenvironment AVX1000 (@18m agl)	20,196	11,471	6.88%	£50,000	£900	£740	23	£7,263
24x1kW Aeroenvironment AVX1000 (@18m agl)	28,800	16,358	9.82%	£90,000	£1,800	£1,036	31	£9,168
2x6kW vQuiet Revolution	17,000	9,656	5.79%	£10,000	£100	£629	5	£1,726
2x2.5 kW Proven	8,564	4,864	3%	10,000	£100	£296	10	£3,426
1x20kW Westwind	22,660	12,871	8%	10,000	£100	£814	4	£1,295

Table 7.115 Wind turbine options for schools, carbon savings & costs

Although, it may be desirable to install one large or medium wind turbine near a school for educational reasons, the installation of more than one turbine may not be suitable. Other renewable energy sources like PV, biomass or GSHP are therefore needed to achieve high CO_2 reductions.

Conclusions

This section outlines the optimum solution for new-build schools in terms of measures based on physical feasibility and cost effectiveness.

Table 7.116 below demonstrates that best fabric standards are the most cost effective option for schools achieving 18% improvement in CO_2 emissions with the lowest cost per percentage saved of carbon emissions.

With regards to the feasible renewable technologies for this development, the 150kW biomass boiler seems to be the most affordable solution compared to the other technologies reducing the baseline emissions by 23% with £1,133 for each percentage reduction achieved. However, table 7.114 above indicated high fuel costs prevent this technology from being currently cost effective. The forthcoming Renewable Heat Incentive programme which is due to come in force in April 2011 and is designed to offer financial incentives to those who are switching from using fossil fuels to renewable technologies, may reduce the financial payback while increasing the annual energy savings (£/year).

On the other hand, a series of 24 No. 1kW roof mounted wind turbines are coming second in the cost effectiveness hierarchy. Although feasible for school developments, it will need to be combined with other renewable technologies to achieve greater emissions reduction. An ASHP system is following reducing the emissions by 9% with a cost of £16,560 for each percentage reduction achieved. As with biomass, table 7.112 showed a long payback period, and for this reason when this technology is compared with the solar PV panel with 59kWp capacity, it is obvious that the solar panel option will offer double emission savings at a difference of approximately £3000. GSHP offer the same emission savings with a long payback period. The £24,381 cost for each percentage increase in carbon reduction achieved makes this option impractical for this development group.

As it is afore-mentioned, various financial incentives and regulation changes will potentially reduce the overall costs of some of the above technologies such as biomass and GSHP's and make them cost effective for schools.

If best fabric standards will be combined with biomass heating a reduction of 41% can be achieved while if combined with roof mounted wind turbines the overall CO_2 emissions will be reduced by 28%. It is therefore suggested that the most optimum solution is the combination of best fabric standards with biomass boiler.

Measure		% Emissions Reduction	Cost per %
EEM	Best fabric standards	18%	£5,265
	Advanced fabric standards	26%	£6,260
	Good fabric standards	4.7%	£10,806
RES /LZC	150kW biomass	23%	£1,133
	24x1kW Aeroenvironment AVX1000 (@18m agl)	10%	£9,168
	3x45kW ASHP	9%	£16,560
	59kWp Solar PV	19%	£19,755
	3x45kW GSHP	9%	£24,381

Table 7.116 Feasible and cost effective measures for schools

7.4.2.4 Hotels

Hotel developments in Ealing vary between small hotels to high-rise hotels of 1 to 5 storeys. Based on the analysis of the planning application files which showed an increase in proposals for hotel developments, a 1,855 m^2 5-storey hotel was used as an example.

Energy efficiency

The overall energy and associated CO_2 emissions have been calculated for the baseline and the 3 fabric standard scenarios. The baseline energy and CO_2 emissions have been estimated after applying the limiting U-Values of the current Building Regulations Part L (2006) to the whole development.

Table 7.117 presents the overall annual energy consumption and CO_2 emissions as well as the percentage improvement in CO_2 emissions after the implementation of the energy efficiency scenarios against the baseline.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Space Heating	90,648	92,350	35,626	20,268
Hot Water	286,811	286,811	286,811	250,764
Lighting	39,776	35,690	28,984	27,908
Other	178,723	173,159	155,986	155,487
Total Gas	377,459	379,161	322,437	271,032
Total Electricity	218,499	208,849	184,969	183,395
Grant Total	**595,958**	**588,010**	**507,407**	**454,427**
CO_2 Total ($kgCO_2$/yr)	165,434	161,692	140,610	129,973
Percentage CO_2 reduction	-	**2.26%**	**15.01%**	**21.43%**

Table 7.117 Overall annual energy consumption and CO_2 emissions savings for new-build hotels

The energy efficiency modelling carried out for hotels showed that a 61% and 78% reduction in the space heating energy demand could be achieved when best and advanced fabric standards are applied, respectively. An overall reduction of 15% or 24% in energy consumption and a 15% or 21.4% reduction in the overall CO_2 emissions of the building can be achieved when implementing the energy efficiency measures explained in Section 4.

Whistle table 7.117 above presents the energy and CO_2 emission savings calculated based on both regulated and non-regulated energy use, table 7.118 below shows the BER against the TER for the whole development for the four scenarios (regulated energy only). It is apparent that the application of the energy efficiency measures to the building of this use provides significant carbon dioxide emissions savings. While good fabric standards do not offer significant savings with only 2.8% over the baseline, best and advanced standards increase the CO_2 savings up to 18% and 26%.

The table below also details the costs to meet the different energy efficiency measures standards which increase proportionally as these get improved. The cost beyond the baseline and the cost for each percentage increase in carbon reduction have also been calculated and will help to identify the most cost-effective option for this development. For each percentage increase achieved in carbon reduction, a cost of £2,746 would need to be spent, if good fabric standards were being implemented, while £730 and £839 would need to be spent if best and advanced fabric standards were to be applied, respectively.

To build a hotel for complying with the current Building Regulations (2006) costs approximately £34,400 while costs to apply better insulation and other higher efficiency standards can range approximately from £7,500 to £21,900.

Measure	BER	TER	Percentage CO_2 reduction	Costs	Cost beyond baseline	Cost per %
Baseline	73.20	73.21	0.0%	£34,416	£0.00	£0.00
Good Fabric Standards	71.18	73.21	2.8%	£42,030	£7,615	£2,746
Best Fabric Standards	59.82	73.21	18.3%	£47,764	£13,349	£730
Advanced Fabric Standards	54.08	73.21	26.1%	£56,350	£21,934	£839

Table 7.118 BER /TER achieved for hotels and costs

<u>CHP/CCHP/ Decentralised Energy Options</u>

Well-designed CHP can have efficiencies approaching 75%, as opposed to the 45% of the UK's most efficient central power stations. This is due to the utilisation of heat from electricity generation and the avoidance of transmission losses because electricity is generated onsite. The result is that more work is carried out for the same CO_2 emissions, providing electricity and heat to occupiers and owners at competitive costs and with enhanced security of supply.

While CHP installations reduce energy costs there is a high initial investment required in the plant. To be economically viable, CHP needs to run for as many hours as possible with high demands for electricity and heat. The best schemes are installed in developments where there is a high baseload heat demand throughout the year, and this often applies at hotels, especially those with swimming pools and leisure facilities.

Our initial analysis of the energy demand predicts that the optimum CHP unit for the development would be a 33kWe/55kWth CHP unit. Operating for 80% load would reduce annual CO_2 emissions by 58 tonnes. The unit is expected to generate annual energy cost savings of approximately £28,000. The analysis also indicates that there is sufficient heat demand at the development for the unit to operate throughout the summer months, and its operation would not be restricted to the winter heating season. The long operating hours for the CHP result in a low pay back period, and CHP is considered to be suitable for this development.

System	Hours operation	Heat Generated / % heat demand/ % hot water demand (kWh/yr)	Electricity Generated / % of elec demand (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	Capital Cost (£)	Maintenance Cost (£/yr)	Payback	Cost per %
33kW	5,490	301,967 / 83% heat / 83% HW	181,180 / 83%	57,960 / 35%	£75,000	£1,125	3	£21

Table 7.119 CHP, carbon savings and costs for hotels

A cost of £21 will need to be spent for each percentage reduction achieved through the CHP application. The significant savings achieved through the CHP unit as well as the short payback period make this technology feasible and cost effective for this development type.

Solar Photovoltaics (PV)

The roof area of the proposed development could be used for the installation of inclined, south facing, PV panels. An installation of 197m^2 of hybrid PV panels is predicted to generate 29 MWh of electricity per annum and reduce development emissions by 16.6 tonnes CO_2 (10%). The installation has a budget premium cost of £197,000. If the whole roof was covered by solar PV panels subject to there was no overshadowing of neighbouring buildings, a 288m^2 of panel area with a capacity of 44kWp could be installed providing almost 43MWh of electricity and reducing the CO_2 emissions by 15% or 24 tonnes of CO_2 emissions per annum.

Photovoltaic cladding is not recommended for the South or West elevations of the proposed hotel due to the lower efficiency of the photovoltaic panels in these orientations and the greater risk of overshadowing from future developments in the area.

Table 7.120 below shows the savings in carbon emissions resulting from the different PV panel feasible options. It sets out, for each suggested percentage increase in carbon reduction, the area, system power rating and cost for each option. It is obvious, however, that solar PV technology cannot achieve higher emission savings and hence it would need to be combined with other renewable technologies to increase the emission savings from the low and zero carbon technologies such as CHP, solar thermal.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
99 m^2	15	14,702	8,350	5.0%	£99,000	£500	£501	69	19,613
197 m^2	30	29,255	16,617	10.0%	£197,000	£990	£1,037	68	19,613

Table 7.120 Solar PV options, carbon savings and costs for hotels

Despite the high capital costs and payback periods, financial incentives that will be or already are in force, such as the Renewables Obligation Certificates, feed-in-tariffs, can reduce the expenditure and payback down to even 50%. The cost per each percentage increase in carbon reduction is also shown in the table above.

Solar Thermal

An area of 191m^2 flat plate roof mounted thermal panels used to heat the domestic hot water is predicted to reduce the demand on the boilers by 77 MWh/annum (27% of the hot water demand). As hotels typically have a large demand for hot water, this can be an appropriate solution for much of the year. The installation of 191m^2 panels is predicted to reduce the development emissions by 10%. The thermal panels have a budget premium cost of £198,000. This solution will utilise most of the available roof space, possibly restricting the opportunity for green or brown roofs.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
96 m^2	38,280	8,344	5%	£99,000	£500	>100	£19,628
191 m^2	76,560	16,688	10%	£198,000	£990	>100	£19,628

Table 7.121 Flat plate solar collectors, carbon savings and costs for hotels

Alternatively, 142m^2 of evacuated tube solar thermal collectors could be installed on the roof generating 16.6MWh of energy and reducing the CO_2 emissions by 10% at a budget premium cost of £189,000.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
70 m^2	37,665	8,210	5%	£93,000	£470	>100	£18,739
142 m^2	76,545	16,685	10%	£189,000	£950	>100	£18,739

Table 7.122 Evacuated tube solar collector, carbon savings and costs for hotels

It is apparent from the tables above that while evacuated tube collectors produce the same amount of energy resulting in the same CO_2 emissions reduction, they require less area to be installed and are cheaper. This clearly makes them more favourable for the specific development.

Because of the limited roof space and the panels being unable to supply higher emission reductions, they need to be combined with other feasible renewable or low carbon technologies in order to increase their contribution. In addition, despite the long payback period, potential savings can be achieved from various grants and the Renewable Heat Incentive which will come in force early next year.

The costs shown in the tables above indicate that none of these solar thermal collector types are currently cost effective for the specific development due to the long payback period. However, various future changes in market conditions and policies as well as financial incentives will reduce the costs and therefore the payback period and will potentially make this technology a more affordable investment.

Ground Source Heat Pumps (GSHP)

Most of the hotels proposed within the London Borough of Ealing are located in central areas where they normally have very little external area and a relatively small footprint. An initial analysis predicted that a total of 50 boreholes each 100m deep, would be required. With a minimum separation between boreholes of 6-9 meters, there is insufficient space at the development for GSHP to supply 100% of the development's space heating and hot water requirements.

As GSHPs operate most efficiently when supplying heat at low temperatures, they are not typically suitable to contribute to the hotel's domestic hot water requirements, and integration with high temperature heating systems can be difficult.

Air Source Heat Pumps (ASHP)

Air source heat pumps technology is an alternative to GSHP. Although it is not considered as efficient as GSHP, it can still offer energy and carbon savings and they are definitely more efficient than conventional air conditioning units.

They are not generally considered to be a renewable technology due to the variability of the air temperature and not as efficient as the ground source heat pumps because the efficiency and capacity of the heating mode decrease with decreasing outdoor air temperature and the efficiency and capacity of the cooling mode decrease with increasing outdoor air temperature.

A 50kW air-air heat pump providing the total space heating and cooling requirements of the development are predicted to reduce development emissions by 14 tonnes CO_2 per annum (9%). The budget premium cost for the heat pump is £50,000. Table 7.123 below indicates the size of the ASHP with CoP of 3.5 and 4.5 for heating and cooling, respectively, their contribution to carbon savings as well as the capital and maintenance costs. The payback and the cost for each percentage increase in carbon reduction are also shown below.

System	Heat Generated (kWh/yr)	Electricity Generated (for cooling) (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
50kW	90,965	55,910	14,104	9%	£50,000	£380	9	5,865

Table 7.123 ASHP, carbon savings and costs for hotels

Biomass Heating

A 100 kW biomass pellet boiler is predicted to produce 344 MWh of heat, and reduce development emissions by 94 tonnes per annum. This equates to 57.11% of the development's predicted emissions. A biomass boiler of this size has a premium budget cost of £15,000, although the cost of fuel to the boiler is greater than a traditional gas boiler, resulting in a predicted annual cost increase of approximately £2,000. The biomass boiler has a typical space requirement of 1.5m x 4.5m.

A fuel pellet delivery of $8m^3$ would be required every two weeks during the main heating season with less frequent deliveries throughout the remainder of the year. Using wood chips, which have a lower energy density, a quarterly delivery of $25m^3$ would be required. It is important to ensure that the biomass boiler and storage is placed in an appropriate location to ensure that the pellets can be delivered. It will be necessary to provide additional gas boilers to meet peak heating requirements at times of the year.

A requirement for a woodfuel storage, a plant room and a flue that will terminate above roof level, need to be thoroughly considered prior to the design stage as they might dramatically reduce the hotel space, especially in smaller scale hotels that this one used as an example.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
100 kW	343,746	94,478	57.11%	£15,000	£750	-9	£263

Table 7.124 Biomass heating, carbon savings and costs for hotels

The costs for the biomass boiler are also shown in the table above. It is important to note that a biomass boiler would require a community heating system to distribute the heat throughout the building, and the cost of this pipework is not included in the budget cost. In addition the annual fuel costs are higher than the energy savings for this technology leaving the investment without significant yearly nett savings. The cost for each percentage achieved in carbon reduction has been also estimated to be £263 for this technology.

Wind Turbines

Generally hotels are located in central areas in the borough where there is no sufficient land and the available external areas are mostly utilised for car parking, loading areas and pathways. Most areas of the available external spaces would not provide the required distance between the wind turbine and buildings to ensure the optimum function of the turbine. In addition, hotels like the one used in this study, are located nearby residential units and therefore noise and visual impacts might be an issue. These considerations render the option of free standing wind turbines as impractical for this type of developments.

Assuming that the roof mounted turbines recommended are complying with Ealing's air quality and noise policies, they can potentially be a feasible option for providing a proportion of the development's electricity demand.

An initial assessment of the options for wind energy is presented in table 7.125 below. A series of 24 No. 1kW building mounted turbines, installed on the South or West elevations of the proposed hotel are predicted to supply 29MWh of electricity per annum (13% of electricity demand) at a budget premium cost of £90,000. This will provide an emission saving of 16 tonnes per annum, equivalent to 9.9% of the development's emissions. The turbines would increase the overall height of the building by approximately 2 meters.

The 4 No. 2.5kW Proven wind turbines can generate 17 MWh of electricity per annum resulting in 5.9% reduction in CO_2 emissions with a budget premium cost of £50,400.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2/yr$)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
6x1kW Aeroenvironment AVX1000 (@40m agl)	10,098	5,736	3.5%	£30,000	£300	£358	29	£8,653
12x1kW Aeroenvironment AVX1000 (@18m agl)	14,400	8,179	4.9%	£50,000	£500	£501	36	£10,113
24x1kW Aeroenvironment AVX1000 (@18m agl)	28,800	16,358	9.9%	£90,000	£900	£1,001	31	£9,102
4x2.5 kW Proven	17,128	9,729	5.9%	£50,400	£500	£608	29	£8,570

Table 7.125 Wind turbine options, carbon savings and costs for hotels

It is obvious that the wind turbines assessed will require to be combined with other renewable energy sources, such as biomass, solar PV, solar thermal, GSHP to increase their contribution to the overall development's emissions.

Conclusions

This section outlines the optimum solution for hotels in terms of measure/measures based on physical feasibility and cost effectiveness. The results are presented in table 7.126.

With regards to the energy efficiency scenarios, best fabric standards can be considered the most cost-effective option for hotel developments as they have the lowest cost per each percentage increase in carbon reduction compared to the other energy efficiency scenarios.

Comparing the feasible renewable technologies, a 33kWe gas-fired CHP reduces the baseline emissions by 35% with a cost of £21 per percentage saved in CO_2. Second on the cost effectiveness hierarchy is the 100kW biomass boiler which offsets the development's emissions by 57% with a cost of £263 per percentage saved in CO_2 emissions. As a third option a 50kW ASHP can provide both heating and cooling but reduces the baseline emissions by only 10%. Slightly lower or identical CO_2 reductions are achieved by the remaining feasible technologies presented in table 7.126; however they will need to be combined with compatible low carbon technologies to increase their contribution to the overall emissions reduction.

If best fabric standards are combined with CHP, a reduction of approximately 53% could be achieved making this option of the most cost effective solutions. On the other hand, the combination of biomass heating with best practice can achieve a reduction of around 75%. Although CHP with best practice can be considered as the most feasible and cost effective solution for this development, biomass boiler offers an additional reduction in CO_2 emissions by 22%. It was afore mentioned that due to the current high biomass fuel costs, biomass technology has been rendered as unaffordable. The forthcoming Renewable Heat Incentive programme which is due to come in force in April 2011 and is designed to offer financial incentives to those who are switching from using fossil fuels to renewable technologies, may reduce the financial payback while increasing the annual energy savings (£/year).

It is important to mention that the renewable technologies shown in Table 7.126 have been assessed based on both regulated and non-regulated energy use. This implies that both CHP and biomass heating can achieve even higher emissions reduction if non-regulated energy has not been included in the calculations.

	Measure	% Emissions Reduction	Cost per %
EEM	Best fabric standards	18%	£730
	Advanced fabric standards	26%	£839
	Good fabric standards	2.8%	£2,746
RES /LZC	33kWe CHP	35%	£21
	100kW Biomass	57%	£263
	50kW ASHP	9%	£5,865
	4x2.5 kW Proven	6%	£8,570
	24x1kW Aeroenvironment AVX1000 (@18m agl)	10%	£9,102
	142m^2 evacuated tube collector	10%	£18,739
	30kWp Solar panel	10%	£19,613
	191 m^2 flat plate collector	10%	£19,628

Table 7.126 Feasible and cost effective measures for hotels

7.4.2.5 Retail/ Supermarket

Retail developments in the London Borough of Ealing vary from small garment boutiques to shopping centres or large supermarkets. However, most of the retail proposals received within April '07 to March '08 showed an increase in medium to large supermarkets in the borough. The supermarket used as an example is a large 2-storey building with a total area of 12,631 m^2.

Energy Efficiency

This section presents the overall energy consumption and associated CO_2 emissions of the development for the baseline and the energy efficiency scenarios considered for the purposes of this study. The baseline energy consumption was modelled to comply with the current Building Regulations Part L (2006).

It is evident from the table 7.127 the significant supermarket's requirements for cooling, refrigeration and lighting and the impact that the energy efficiency scenarios have on the CO_2 emissions.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Space Heating	497,132	406,196	176,431	118,594
Hot Water	9,730	9,730	9,730	9,492
Lighting	767,563	773,526	661,658	657,699
Other	1,085,764	1,058,585	1,023,555	904,635
Total Gas	506,861	415,926	186,161	128,086
Total Electricity	1,853,326	1,832,110	1,685,213	1,562,334
Grant Total	**2,360,188**	**2,248,036**	**1,871,374**	**1,690,420**
CO_2 Total ($kgCO_2/yr$)	880,435	853,840	747,275	684,154
Percentage CO_2 reduction	-	**3.02%**	**15.12%**	**22.29%**

Table 7.127 Overall annual energy consumption and associated CO_2 emissions savings for new-build supermarkets

Table 7.128 below presents the BER and TER achieved after the energy efficiency scenarios were tested in the example building. Best and advanced fabric standards can reduce the overall emissions of the development by 19.2% and 28.3%, respectively, when only regulated energy use has been considered in the calculations. When non-regulated energy use was included, these percentage savings get slightly reduced by 4.1% and 6.01%, respectively (see Table 7.127).

The table below also details the costs required in order to implement each of these scenarios. Implementing advanced fabric standards in a supermarket of this scale will cost almost 39% more than applying the current Building Regulations' minimum requirements, while good and best practice will cost more by 20% and 30%, respectively.

However, as the development must comply with the Building Regulations Part L, the cost of £364,535 can be considered as the baseline which against the additional costs of applying the energy efficiency scenarios will have to be compared. Therefore, it was suggested to measure the cost beyond the baseline and the cost for each percentage increase in carbon reduction. These two costs will assist in understanding which of these measures is the most cost-effective option for this development. It is evident that best practice standards scenario is the most cost effective option with a cost of £8,196 for each percentage reduction achieved in CO_2 emissions, while a cost of £8,280 will need to be spent for advanced practice. Whistle, best practice achieves 19.2%, advanced measures achieve almost a further 10% in emission savings with only £80 more. For this reason, it was suggested to consider advanced efficiency measures as the most cost effective option for new build supermarkets.

Factoring the costs below to the overall construction costs will be another way to determine which of these scenarios is more cost effective to this development group. Section 6.2 and 6.3 that are still to be completed, they will clarify the above issues further.

Measure	BER	TER	Percentage CO_2 reduction	Costs	Cost beyond baseline	Cost per %
Baseline	55.00	55.01	0.0%	£364,535	£0.00	£0.00
Good Fabric Standards	52.90	55.01	3.8%	£455,079	£90,544	£23,600
Best Fabric Standards	44.46	55.01	19.2%	£521,684	£157,149	£8,196
Advanced Fabric Standards	39.46	55.01	28.3%	£598,515	£233,980	£8,280

Table 7.128 BER/TER achieved, carbon savings and costs for supermarkets

CHP / CCHP/ Decentralised Energy Options

An initial assessment has been carried out to identify the feasibility of a CHP system for the development. CHP systems perform well and can offer substantial carbon and cost savings when correctly matched to the site electricity and heat load profiles of a site. The best sites for CHP have a significant continuous or base load heat demand. Ideally a system would have high run-hours e.g. 4,500 hours or more per year for a fast return investment. Because sites usually have a greater demand for electricity than for heat, it is the heat demand that, in most cases, determines the CHP unit's size. As a result, most CHP units produce less electricity than the electrical base load demand of the site they serve.

Initial modelling of the energy demand at the development indicates that a 70kWe/104kWth CHP unit, with an operational load factor of 90%, may be appropriate for the development. It is predicted to generate for 4,968 hours per annum, reducing emissions by 98.12 tonnes CO_2 at a budget premium cost of £75,000. A summary of the calculations for the CHP unit are shown in table 7.129. Biomass can be also used to run the CHP unit but there are currently no biomass CHP units of this scale in the market.

System	Hours operation	Heat Generated / % heat demand/ % hot water demand (kWh/yr)	Electricity Generated / % of elec demand (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yrs)	Cost per %
70kWe	4,968	512,557 / 52% heat / 52% HW	347,780 / 19%	98,122 / 11%	£75,000	£27,485	3	£6,818

Table 7.129 CHP size, carbon savings and costs for a supermarket

In addition, the payback period, maintenance cost and the cost for each percentage increase in carbon reduction are also presented in the table above. A cost of £6,818 will need to be spent for each percentage reduction achieved through the CHP application. Due to the relatively low emission savings achieved, the CHP will need to be combined with compatible renewable technologies such as solar PV, in order to increase its emission reduction contribution.

Generally, a site with a large and continuous cooling demand, like the example used in this study, and perhaps a declining demand for heat, may consider replacing a conventional electricity-based cooling system with absorption cooling – a system that uses heat instead of electricity for the cooling process. When a prime mover provides electricity, heat and cooling via an absorption chiller it is often referred to as trigeneration. Replacing conventional electricity-based cooling system with absorption cooling can save up to 30% in CO_2 emissions.

Solar Photovoltaics (PV)

Half of the roof area of the proposed development could be used for the installation of inclined, south facing, PV panels. An installation of either 593m^2 or 1185m^2 of hybrid PV panels is predicted to generate 88 or 176 MWh of electricity per annum and reduce the development's emissions by 50 or 100 tonnes CO_2.

Table 7.130 shows the energy generated by the solar PV panels, the carbon reduction achieved together with their associated costs. It is obvious that the second option of solar PV panel is not currently cost effective while it achieves only 11% reduction in CO_2 emissions and therefore it will not be considered further in this study.

Given the only option is the installation of a $593m^2$ panel which reduces the overall emissions by only a 5.7%, this technology will need to be combined with another renewable or low carbon energy source to increase their contribution towards overall CO_2 emissions reduction.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	Capital Cost (£)	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
$593m^2$	91	88,061	50,018	5.7%	£593,000	£2,970	£3,256	69	104,381
$1185m^2$	182	175,973	99,952	11%	£1,185,000	£5,930	6,475	69	104,381

Table 7.130 Solar PV options, carbon savings and costs for supermarkets

The cost for each percentage increase in carbon reduction has been also calculated and presented in the table above together with the maintenance cost, the ROC income and the payback period. Due to the balance between the capital costs and the nett savings for both PV panel options, the cost per percentage increase in carbon reduction remains the same. However, this will help in identifying the most cost-effective investment when all technologies will be compared at the conclusions section.

Solar Thermal

An initial analysis indicated that the installation of $23m^2$ flat plate or $25m^2$ evacuated tube collectors can provide 100% of the development's domestic hot water requirement. Considering, however, the negligible CO_2 emissions savings they provide to the development, this technology is rendered as impractical for this development group.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
$23m^2$ flat plate	9,280	2,023	0.23%	24,000	£120	>100	£104,460
25 m^2 evacuated tube	9,900	2,158	0.25%	33,000	£170	>100	£134,637

Table 7.131 Flat plate and evacuated tube thermal collector options, carbon savings and costs for supermarkets

Ground Source Heat Pumps (GSHP)

A ground source heat pump could provide the retail use with space heating and cooling. An installation of 2 No. 100kW GSHP could provide heating with a CoP of 4 and cooling with a CoP of 5.5. The savings and costs are described in the table below. The system is predicted to reduce the CO_2 emissions associated with the development by 148 tonnes per annum (16.8%) at a budget premium cost of £340,000.

A total of 100 boreholes each 100m deep, would be required, with a minimum separation between boreholes of 6-9 meters for an installation of this size.

It is important to note that the costs do not include ground testing or drilling. These will be a subject of further investigation for applicants recommending this technology. The cost for each percentage increase in carbon reduction is also given in the table below.

System	Heat Generated (kWh/yr)	Electricity Generated (for cooling)(kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2x100 kW	487,920	467,094	148,195	16.83%	£340,000	£2,550	9	£20,200

Table 7.132 GSHP size, carbon savings and costs for supermarkets

Air Source Heat Pumps (ASHP)

An installation of 2 No. 100kW air-to-air heat pumps can provide the total space heating and cooling requirements of the development. They are predicted to reduce development emissions by 140 tonnes CO_2 per annum (16%). The budget premium cost for the heat pump is £200,000. Table 7.133 below indicates the size of the ASHP with CoP of 3.5 and 4.5 for heating and cooling, respectively, their contribution to carbon savings as well as the capital and maintenance costs. The payback and the cost for each percentage increase in carbon reduction are also shown below.

System	Heat Generated (kWh/yr)	Electricity Generated (for cooling)(kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
2x100kW	487,920	467,094	140,841	16.00%	£200,000	£1,500	32	£12,503

Table 7.133 ASHP size, carbon savings and costs for supermarkets

Biomass Heating

The sizing exercise concludes that a biomass boiler of 200kW can provide space heating to the modelled building. The biomass boiler is predicted to reduce the CO_2 emissions associated with the development by 10%, at a budget premium cost of £26,000.

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. Using wood pellets, which is the wood fuel type with the highest energy density, a quarterly delivery of $15m^3$ would be required. Using wood chips, which have a lower energy density, a quarterly delivery of $46m^3$ would be required.

Based on the costs shown in table 7.134, biomass is not a cost effective solution and this is mainly due to the current high biomass fuel costs which reduce the annual energy savings leaving the investment without yearly nett savings. On the contrary, the cost for each percentage increase in carbon reduction is lower when compared to the other technologies. Factoring grants and other financial incentives can make this option an affordable solution.

Generally when biomass boilers are recommended, fuel storage and a plant room would be required. For large retailers like the one tested here, the above requirements will not have a big impact on the overall space. However, for retail developments smaller than the example used, e.g. $\leq 1500m^2$, biomass boilers of 8-40kW in size could be suitable.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
200 kW	480,078	89,644	10.18%	£26,000	£1,300	-39	£2,554

Table 7.134 Biomass heating, carbon savings and costs for new-build supermarkets

Wind Turbines

The predicted output of turbines for the site has been determined using the BERR wind speed database and manufacturer information. The income from the sale of ROC certificates has been included in the financial calculations for the turbines. Furthermore the maintenance cost and the cost needs to be spent for each percentage increase in carbon reduction are also presented in the table below.

A series of 48 No. 1kW building mounted wind turbines, positioned along the South West face of the building, are predicted to generate 32.7 tonnes of CO_2 emission savings per annum. This will reduce emissions by 3.7%, at a premium budget cost of £180,000; whistle it will provide 3% of the development's energy requirements, with a predicted payback of 32 years. The 48 roof mounted turbines will require an area of 96m alongside the roof.

A further 230 No. 1kW wind turbines on the South West boundary of the site are predicted to generate a 175.8 tonnes of CO_2 emissions saving, corresponding to a 20% reduction. The turbines have a premium budget cost of £960,000. These turbines will provide 17% of the development's energy requirements, with a predicted payback of 31 years. The required space along the roof for the 230 roof mounted turbines is 516m.

It is obvious that the contribution of the remaining wind turbines in reducing the overall site's emissions are negligible and therefore they will require to be combined with other renewable technologies to increase their contribution such as GSHP, ASHP, CHP, biomass. This however, does not exclude them from being considered as feasible for the specific development type.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback (yrs)	Cost per %
48x1kW Aeroenvironment AVX1000 (@18m agl)	57,600	32,717	3.7%	£180,000	£1,800	£2,109	32	£48,439
130x1kW Aeroenvironment AVX1000 (@18m agl)	156,000	88,608	10.1%	£490,000	£4,900	£5,772	32	£48,688
258x1kW Aeroenvironment AVX1000 (@18m agl)	309,600	175,853	20.0%	£960,000	£9,600	£11,433	31	£48,064
3x6kW vQuiet Revolution	25,500	14,484	1.6%	£75,000	£750	£925	30	£45,590
10x2.5 kW Proven	42,820	24,322	2.8%	£126,000	£1,260	£1,554	29	£45,611
1x20kW Westwind	22,660	12,871	1.5%	£55,000	£550	£814	23	£37,623

Table 7.135 Wind turbine options, carbon savings and costs for retails

Conclusions

This section outlines the optimum solution for new-build supermarkets in terms of measures based on physical feasibility and cost effectiveness and the results are presented in table 7.136.

With regards to the energy efficiency scenarios, best practice standards scenario is the most cost effective option with a cost of £8,196 for each percentage saved achieved in CO_2 emissions, while a cost of £8,280 will need to be spent for advanced practice. Whistle, best practice achieves 19.2%, advanced measures achieve almost a further 10% in emission savings with only £80 more. It was decided, however, to assume best practice standards are the optimum solution in terms of energy efficiency measures.

Comparing the feasible renewable technologies, biomass heating seems to be the most cost effective solution for the development based on the percentage saved in CO_2 emissions. However, table 7.134 above indicated high fuel costs prevent this technology from being currently cost effective. This can be explained by the assumed fuel prices for biomass fuels used in this study. The forthcoming Renewable Heat Incentive programme which is due to come in force in April 2011 and is designed to offer financial incentives to those who are switching from using fossil fuels to renewable technologies, may reduce the financial payback while increasing the annual energy savings (£/year).

A 70kWe CHP unit comes next in terms of cost effectiveness achieving similar emissions reduction with the 200kW biomass boiler. ASHP technology is following reducing the emissions by 16% with a cost of £12,503 for each percentage reduction achieved. A reduction of 17% in CO_2 emissions is achieved through the GSHP application but with a cost of £20,200 which is almost double the cost of the ASHP. Therefore between the two heat pump technologies, the ASHP is more cost effective.

It should be noted however, that as the development becomes more energy efficient, some of the technologies shown in table 7.136 might not be feasible any more or offer the same savings, such as CHP.

Wind and solar PV technologies although feasible for this development group, they are not cost effective due to the lower emissions savings achieved and the higher cost per percentage saved in CO_2 emissions when compared with the other technologies.

It is important to mention that the renewable technologies shown in table 7.136 have been assessed based on both regulated and non-regulated energy use which implies that the CHP and the ASHP can achieve even higher emissions reduction if non-regulated energy was not included in the calculations.

As it is afore-mentioned, various financial incentives and regulation changes will potentially reduce the overall costs of the above technologies and make them more cost effective.

	Measure	% Emissions Reduction	Cost per %
EEM	Best fabric standards	19%	8,196
	Advanced fabric standards	28%	8,280
	Good fabric standards	3.8%	23,600
RES /LZC	200kW Biomass	10%	2,554
	70kWe CHP	11%	6,818
	2x100 ASHP	16%	12,503
	2x100 GSHP	17%	20,200

Measure		% Emissions Reduction	Cost per %
	1x20kW Westwind	1%	37,623
	130x1kW Aeroenvironment AVX1000 (@18m agl)	10%	48,688
	91kWp Solar PV	6%	104,381

Table 7.136 Feasible and cost effective measures for new build retail spaces

7.4.2.6 Restaurant

Planning permissions analysed for restaurants showed the majority of proposals were for small restaurants café, hot food and takeaway. Most of these types of restaurants are smaller than 1000m^2 and are part of mixed-use developments located on the ground floor in central areas in the borough. It was therefore suggested for this development group a typical 105m^2 restaurant to be modelled to assess the different energy efficiency measures and renewable and low carbon technologies.

Energy Efficiency

The annual energy and CO_2 emissions for the modelled building are given in Table 7.137. It is important to mention that the carbon emisisons reduction for the energy efficiency scenarios against the current Building Regulations Part L (2006) has been derived from both regulated and non-regulated energy use.

Energy Use (kWh/yr)	Baseline	Good Fabric Standards	Best Fabric Standards	Advanced Fabric Standards
Space Heating	7,118	7,064	5,797	1,070
Hot Water	10,839	10,839	9,476	9,476
Lighting	7,733	6,431	5,610	5,548
Other	23,904	24,004	23,754	23,304
Total Gas	17,957	17,903	15,273	10,546
Total Electricity	31,637	30,435	29,364	28,851
Grant Total	**49,594**	**48,338**	**44,637**	**39,397**
CO_2 Total ($kgCO_2$/yr)	16,834	16,317	15,355	14,221
Percentage CO_2 reduction	-	**3.08%**	**8.79%**	**15.52%**

Table 7.137 Overall annual energy consumption and CO_2 emissions savings for restaurants

The example used for this development group is located on the ground floor of a mixed-use development and it has only two main external walls which implies that the implementation of the energy efficiency scenarios will not have a significant impact in the overall carbon savings as it can be seen in table 7.137. It should be noted that the example building has a ceiling and not a roof and therefore it has not been included in the calculations as there is no heat loss.

Generally the whole energy consumption has shown an improvement with the most important that of space heating; 19% and 85% heating reduction after the best and advanced fabric standards were tested.

Table 7.138 details the percentage reduction in BER over TER (only regulated energy use) which varies from approximately 0.2% to 25% depending on the level of insulation and other measures mentioned in Section 4. The table also shows the costs for achieving the different levels of energy efficiency scenarios.

Comparing the percentage improvements presented in tables 7.137 and 7.138, it can be seen that the carbon savings achieved after the implementation of the energy efficiency measures differ significantly. This implies that the energy coming from appliances and other equipment has a significant in the overall energy consumption of the building. A-rated appliances can help reduce the un-regulated energy use. The costs for implementing the different scenarios are also presented in the table below.

Measure	BER	TER	Percentage CO_2 reduction	Costs	Cost beyond baseline	Cost per %
Baseline	99.22	99.34	0.1%	£5,083	£0.00	£0.00
Good Fabric Standards	99.18	99.34	0.2%	£5,745	£662	£4,108
Best Fabric Standards	85.00	99.34	14.4%	£6,657	£1,574	£109
Advanced Fabric Standards	74.13	99.34	25.4%	£8,618	£3,535	£139

Table 7.138 BER/TER achieved in a new-build restaurant with different levels of energy efficiency and costs

CHP / CCHP/ Decentralised Energy Options

Well-designed CHP can have efficiencies approaching 75%, as opposed to the 45% of the UK's most efficient central power stations. The result is that more work is carried out for the same CO_2 emissions, providing electricity and heat to occupiers at competitive costs and with enhanced security of supply.

To be economically viable, CHP needs to run for as many hours as possible with high demands for electricity and heat. The best schemes are installed in developments where there is a high baseload heat demand throughout the year.

Detailed calculations to determine the possible carbon savings and financial viability of CHP on this development group showed that there is a small heat demand and therefore insufficient loads to make a CHP options technically or economically viable.

Solar Photovoltaics (PV)

In new build mixed use developments the layout of the development is thoroughly designed in order both residential and commercial parts to benefit from renewable and low carbon technologies. It is then easier for solar technologies to be incorporated and provide savings in the commercial part of the development.

This would not be the case for refurbishments where restaurants normally are based on the ground floor of an existing building with no available roof space.

In our case because the example building is a new build, it was assumed that solar PV panels could be installed on the roof to provide electricity to the restaurant. Table 7.139 presents the options for PV panels, the energy generated, the carbon savings and the costs.

Assuming that the whole development has a roof area of 700 m^2, an installation of 120m^2 hybrid photovoltaic panels on the roof, which utilises less than half of the roof area, is predicted to reduce CO_2 emissions by 60%, at a budget premium cost of £120,000. The panels have a predicted payback of 68 years. Smaller areas of PV panels could be also installed providing less energy and carbon savings but apparently with similar payback periods which makes the option of the 120m^2 hybrid panels more favourable compared to the other options.

System	Capacity (kWp)	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
10 m^2	2	1,485	843	5%	£10,000	£50	£37	73	1,996
20 m^2	3	2,970	1,687	10%	£20,000	£100	£74	76	1,996
40 m^2	6	5,940	3,374	20%	£40,000	£200	£185	70	1,996
80 m^2	12	11,880	6,748	40%	£80,000	£400	£407	68	1,996
120 m^2	18	17,820	10,122	60%	£120,000	£600	£629	68	1,996

Table 7.139 Solar PV options for the restaurant, carbon savings and costs

Solar Thermal

An area of 194m^2 flat plate roof mounted thermal panels is predicted to reduce CO_2 emissions by 100% at a budget premium cost of £201,000. Smaller areas of solar collectors can also contribute in reducing the CO_2 emissions of the development. As restaurants have typically a yearly demand for hot water, this can be a feasible solution.

Both solar thermal and photovoltaic panels operate most efficiently when kept clean and unobstructed. While rain will assist with keeping the panels clear, and there will be measures in place to control dust at the development, it may be necessary to periodically clean the panels manually.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
7 m^2	2,900	632	4%	7,500	£40	>100	£1,997
15 m^2	5,800	1,264	8%	15,000	£80	>100	£1,997
29 m^2	11,600	2,529	15%	30,000	£150	>100	£1,997
78 m^2	31,320	6,827	41%	81,000	£410	>100	£1,997
116 m^2	46,400	10,114	60%	120,000	£600	>100	£1,997
194 m^2	77,720	16,941	101%	201,000	£1,010	>100	£1,997

Table 7.140 Flat plate solar collectors' options for restaurants

Alternatively, an installation of 144m2 of evacuated tube solar thermal collectors could be installed on the roof generating approximately 78MWh of heat to warm the hot water and reducing the CO_2 emissions by 100% at a budget premium cost of £192,000.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
7 m^2	3,645	795	5%	9,000	£50	>100	£1,907
16 m^2	8,505	1,854	11%	21,000	£110	>100	£1,907
29 m^2	15,795	3,443	20%	39,000	£200	>100	£1,907
59 m^2	31,590	6,886	41%	78,000	£390	>100	£1,907
86 m^2	46,170	10,064	60%	114,000	£570	>100	£1,907
144 m^2	77,760	16,950	101%	192,000	£960	>100	£1,907

Table 7.141 Evacuated tube solar collectors' options for restaurants

It is apparent from the tables above that while evacuated tube collectors produce similar amounts of energy and resulting in the same CO_2 emissions reduction, they require less area to be installed and are cheaper. The cost for each percentage increase in carbon reduction is also given for both collector types in the tables above.

However, both types of collectors have a long payback period which makes them currently unaffordable for the specific development group.

Ground Source Heat Pumps (GSHP)

GSHP can be used to provide the total space heat and hot water demand of the development. A 10 kW heat pump installation is predicted to generate 18MWh of heat and hot water per annum for the development. The system is predicted to reduce the CO_2 emissions associated with the development by 2 tonnes per annum.

A horizontal heat exchanger of 230m^2 will typically be required for an installation of this size. Alternatively, a total of 5 boreholes each 100m deep, would be required, with a minimum separation between boreholes of 6-9 meters. The GSHP system has a budget premium cost of £17,000.

In this instance, the horizontal heat exchanger or boreholes could be installed within the development's car park if available.

In case of refurbishment, ground source heat pumps would not however be feasible for a development of this type due to insufficient space.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
10 kW	17,957	2,156	12.81%	£17,000	£128	43	£1,327

Table 7.142 GSHP size, carbon savings and costs for restaurants

Air Source Heat Pumps (ASHP)

Air-sourced heat pumps could be used to provide the heating and cooling for the development. The system could be mounted onto the wall blowing warm air into the building and when reversed it can provide cool air.

An air-sourced heat pump system is predicted to provide a net reduction in annual heating and cooling consumption of approximately 7MWh and 5MWh respectively and reduce annual associated CO_2 emissions by 1.9 tonnes. The budget additional cost of introducing an air sourced heat pump system is £6,500. The associated costs to this technology are shown in table 7.143.

System	Heat Generated (kWh/yr)	Electricity Generated (for cooling) (£/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
6kW	7,183	5,211	1,951	11.59%	£6,500	£50	17	£561

Table 7.143 ASHP size, carbon savings and costs for restaurants

Additionally, ASHP's are considered an easy technology to retrofit in existing developments and hence they could be advantageous in refurbishment projects.

Biomass Heating

The use of a 5kW wood pellet boiler is predicted to generate 15.8MWh of heat for the development, although an additional gas fired boiler would be required for peak winter demand. A biomass boiler is predicted to deliver 31% of the development's energy requirements with an associated CO_2 emission saving of 3 tonnes per annum (17.5%).

Biomass boilers typically have a low capital cost, but the cost of the biomass fuel itself is currently more expensive than the cost for gas. The budget premium cost for a boiler of this size is £1,750.

In order to provide storage for two week's peak winter pellet fuel requirement, a 1m^3 fuel store would be required for the development. The plant room would also have to be enlarged to cater for the additional boiler and there would be a requirement for a flue. This means that the space of the restaurant will be reduced due to the above requirements.

The additional operational burden associated with fuel costs, additional maintenance, ordering of fuel and ash disposal make biomass an unattractive option for this retail development.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	Payback (yr)	Cost per %
5 kW	15,812	2,953	17.54%	£1,750	£88	-14	£100

Table 7.144 Biomass heating, carbon savings and costs for restaurants

Wind Turbines

For this technology the assumptions made were the same as those for the solar technologies. A series of 12 No. 1kW building mounted wind turbines, positioned along the South West face of the building, are predicted to generate 8 tonnes of CO_2 emission savings per annum. This will reduce emissions by 48.6%, at a premium budget cost of £50,000; whistle it will provide 46% of the development's energy requirements, with a predicted payback of 35 years.

On the other hand, the installation of 1 No. 6kW wind turbine on the South West boundary of the site are predicted to generate a 4.8 tonnes of CO_2 emissions saving, corresponding to a 28.7% reduction. The turbines have a premium budget cost of £50,000. These turbines will provide 27% of the development's energy requirements, with a predicted payback of 29 years.

Three No. 2.5kW roof mounted wind turbines is predicted to generate 13MWh of energy providing 41% of the development's energy requirements with an annual CO_2 emissions reduction of 43.3%. The turbines have a premium budget cost of £37,800 with a predicted payback period of 29 years.

The predicted output of turbines for the site has been determined using the BERR wind speed database and manufacturer information. The income from the sale of ROC certificates has been included in the financial calculations for the turbines. Furthermore the maintenance cost and the cost needs to be spent for each percentage increase in carbon reduction are also presented in the table below.

System	Energy Generated (kWh/yr)	CO_2 Savings ($kgCO_2$/yr)	CO_2 Reduction	Capital Cost (£)	Maintenance Cost (£/yr)	ROC Income (£/yr)	Payback	Cost per %
6x1kW Aeroenvironment AVX1000(@18m agl)	10,098	5,736	34.1%	£30,000	£300	£370	29	£881
12x1kW Aeroenvironment AVX1000 (@18m agl)	14,400	8,179	48.6%	£50,000	£500	£518	35	£1,029
1x6kW vQuiet Revolution	8,500	4,828	28.7%	£25,000	£250	£296	29	£872
2x6kW vQuiet Revolution	17,000	9,656	57.4%	£50,000	£500	£629	28	£872
2x2.5 kW Proven	8,564	4,864	28.9%	£25,200	£200	£296	29	£872
3x2.5 kW Proven	12,846	7,297	43.3%	£37,800	£380	£444	29	£872

Table 7.145 Wind turbine options, carbon savings and costs for restaurants

Conclusions

This section outlines the optimum solution for a restaurant which is part of a mixed-use development proposal in terms of measures based on physical feasibility and cost effectiveness and the results are presented in table 7.146.

With regards to the energy efficiency scenarios, best fabric standards can be considered the most cost-effective option for this development. However, with £30 more for each percentage reduction in CO_2 emissions, advanced fabric standards achieve an additional 10% in emission savings.

Comparing the feasible renewable technologies, it is obvious that there is a variety of options which could be feasible for similar developments. A 5kW biomass boiler seems to be the most cost effective solution, while a 10kW ASHP comes second with a cost of £561 per percentage saved achieved in CO_2 emissions. Whilst, table 7.144 above indicated high fuel costs prevent this technology from being currently cost effective, the introduction of the forthcoming Renewable Heat Incentive programme, due to come in April 2011, is designed to offer financial incentives to those who are switching from using fossil fuels to heat producing low carbon technologies, may reduce the financial payback while increasing the annual energy savings (£/year).

In case there is an available land at the development and there are not buildings in a close proximity, then a 6kW Quiet Revolution wind turbine could be installed reducing the overall restaurant's emissions by 29% with a cost of £872 per percentage saved in carbon reduction. This turbine will require an approximate area of 18m for its installation. At the same cost though, there is the option of 3 No. 2.5kW Proven roof mounted wind turbines. These wind turbines will require an approximate space alongside the roof of 30m and can achieve a reduction in CO_2 emissions of 43%.

Although the remaining technologies have been proved to be feasible for this development group, their costs are higher and therefore are not considered as cost effective as the biomass, or the ASHP. It is important to note that the 144m^2 evacuated tube or the 194m^2 flat plate thermal collector can reduce the overall restaurants' emissions by 100% with a cost of £1,907 or £1,997 for each percentage CO_2 emissions reduction, respectively.

If best fabric standards are combined with biomass heating a reduction of around 32% can be achieved. This combination of energy efficiency and renewable technology can be considered as the most cost effective and feasible option for the restaurant. On the other hand, the series of 12 No 1kW roof mounted wind turbines which require a roof space of about 24m, although slightly more expensive than the afore mentioned technologies, it can achieve 49% of emission savings while when combined with energy efficiency it can reduce the baseline emissions by approximately 63%. In addition, if there is available roof area without overshadowing where an area of 144m^2 of evacuated tube collector could be installed providing energy only for the restaurant, a reduction of 100% in CO_2 emissions can be achieved.

Based on the above considerations, it can be assumed that a 5kW biomass boiler with best fabric standards is the most optimum solution for similar developments.

It is important to mention that the renewable technologies shown in Table 7.146 have been assessed based on both regulated and non-regulated energy use which implies that all the technologies can achieve even higher emissions reduction if non-regulated energy was not included in the calculations.

	Measure	% Emissions Reduction	Cost per %
EEM	Best fabric standards	14%	£109
	Advanced fabric standards	25%	£139
	Good fabric standards	0.2%	£4,108
RES /LZC	5kW Biomass	18%	£100
	10kW ASHP	12%	£561
	1x6kW vQuiet Revolution	29%	£872
	3x2.5 kW Proven	43%	£872
	12x1kW Aeroenvironment AVX1000 (@18m agl)	49%	£1,029
	10kW GSHP	13%	£1,327
	144m^2 evacuated tube collector	101%	£1,907
	59m^2 evacuated tube collector	41%	£1,907
	12kWp Solar panel	40%	£1,996
	194m^2 flat plate collector	101%	£1,997
	78m^2 flat plate collector	41%	£1,997

Table 7.146 Feasible and cost effective measures for restaurants

7.4.2.7 Work to existing non-residential buildings/ Refurbishment

This section outlines the implications in terms of feasibility and viability of measures for existing buildings either converted or refurbished.

The nature and the condition of a building, its location and potential position in the market, economic conditions and the investment timescale of the developer will determine the extent of its possible refurbishment. As in existing dwellings, it is difficult to assess and establish a single common CO_2 emission level due to variation of the construction methodology. For this reason, it is suggested that no specific target of CO_2 emissions reduction will be defined from energy efficiency measures and low and zero carbon technologies that should be applied to schemes involving the refurbishment of a commercial building.

It is instead proposed that any refurbishment in existing buildings other than dwellings below 1000m^2 to follow the Building Regulations and install some form of low and zero carbon technology where feasible and viable. If during the refurbishment the future inclusion of low and zero carbon technologies have been already included to the infrastructure costs then the cost of applying these technologies will be considerably less. It is important to note that all refurbishment projects planned to go through the planning process from 1st October 2010, they will need to comply with the new Building Regulations Part L1B 2010.

In addition to the above suggestion, for applications involving the extension or conversion of a commercial building, it is proposed to use the 'Uttlesford' type condition. In effect this condition requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested although this will be determined on a case by case basis) is earmarked for energy efficiency measures.

Renewable and low carbon technologies which are likely to be feasible for refurbishments are ASHP, solar photovoltaic, gas fired CHP and wind turbines. These technologies will potentially meet only a proportion of the development's demand and their costs can vary significantly depending on the scale of the refurbishment from £20,000 to several thousand pounds. However, it is important to note that the costs of the low carbon and renewable technologies and that of the energy efficiency measures must be considered on a case by case basis.

For refurbishments in commercial buildings which are listed or situated in a conservation area, is of historic or heritage value, it is essential to consult with the Conservation Officers in the London Borough of Ealing and the English Heritage, as to the best way to incorporate energy efficiency measures into the building without having a detrimental effect on the building's original features. The permitted undertaken works must be considered on a case by case basis.

Applications regarding extension or conversion of either equal or above $1000m^2$ will need to comply with the CO_2 emission reduction targets established through this study.

<u>Conclusions</u>

The Council should therefore require the following steps to be undertaken for all commercial applications involving either extension or conversion below $1000m^2$.

As a first step, refurbishments should comply with the Building Regulations for existing buildings other than dwellings dealing with the conservation of energy and fuel (AD L2B). Use of the 'Uttlesford' type condition which requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested, although this will be determined on a case by case basis) is earmarked for energy efficiency measures.

Secondly, refurbishments are expected to install one or more of the low and zero carbon technologies. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective.

For refurbishments $\geq 1000m^2$, the energy efficiency scenarios and renewable and low carbon technologies identified to be the most cost effective for each development group will have to be followed.

8 Recommendations for Policy content / target setting

This section presents the options in terms of carbon emission saving targets, and makes recommendations based on the findings of the technical feasibility and financial methodology employed. It also draws out implications for the development of policies in the emerging LDF documents.

8.1 Technical and Cost Overview

Table 8.1 presents the findings from the technical and financial feasibility analysis for each development group tested. The findings are following the Energy Hierarchy and are based on Buildings Regulations energy use (regulated) first and then on both regulated and non-regulated energy use. The London Borough of Ealing's aim is to establish minimum and best advisory targets in terms of carbon emission savings from a) energy efficiency measures, b) combined heat and power and c) on-site renewables for the development groups tested.

The third column of the table 8.1 called '*Overall % CO_2 emission savings from the combination of the most feasible & cost effective measures*' indicates the overall CO_2 emission targets that can be achieved when the optimum energy efficiency measures are combined with the optimum low and zero carbon technologies for each development group tested following the Energy Hierarchy. The CO_2 emission targets in the following columns show the carbon emission savings based on both regulated and unregulated energy use and calculated based on the original baseline (Building Regulations 2006). These have been calculated separately for each measure and related back to the original baseline.

It should also be noted that the combination of measures is a major factor which can impact on the efficiency of the systems and the emission savings achieved. For those development groups where biomass heating has been recommended after CHP, it is assumed that it will act as back-up/top-up boiler and not as the leading technology. It is generally accepted that CHP is not suitable to be combined with biomass heating as both technologies produce the same elements of energy, heat and hot water, while solar PV is more likely to be combined with CHP systems as it tops up the electricity produced by the system.

Whilst there is greater control and perhaps more obvious opportunities to minimise energy consumed in new buildings, these will potentially make up a relatively small proportion of the occupied buildings in the future. It is therefore prudent to consider the borough's existing building stock and what options exist to reduce the energy demand. For this reason, it was suggested to provide specific policy advice and guidance in residential and commercial refurbishments as distinct from new-build. The results are also presented in table 8.1 below.

8.1.1 Residential

The results for residential blocks show great CO_2 emissions savings achieved through advanced energy efficiency measures. It is generally the case that for flats the more cost effective route to the CO_2 target is via the use of renewable technologies rather than fabric improvements. However, the results shown in table 8.1 showed that this is not the case regardless the amount of wall that a flat presents to the outside and the limited effect of reducing heat loss through it. The application of passivhaus standards is the most cost effective solution. Therefore, a reduction in CO_2 from energy efficiency measures of at least 20% should be required in all residential blocks. In regards to CHP, residential blocks of 50 units or more show a 30% to 40% CO_2 reduction, while biomass achieves 34% improvement. It is therefore obvious that residential developments can achieve an overall emission reduction of at least 55% which exceeds Code Level 4 of the Code for Sustainable Homes.

Residential houses show that best practice is the most cost effective option from energy efficiency measures. As for residential blocks this is due to the greater surface area where energy efficient measures can be applied to, and be effective. A reduction of at least 24% from energy efficiency measures should be required from all residential houses. CHP would not be recommended in individual properties but significant emissions can be achieved from renewable technologies. The results indicated that ASHP is the most cost effective option while reduces the baseline emissions by an average of 27%. An overall reduction of at least 50% in CO_2 emissions reduction should be required for residential houses which exceed Level 4 of the Code for Sustainable Homes.

As in applications involving commercial refurbishments, it is not easy to define a specific target for CO_2 emissions from residential refurbishments. This is due to the condition of the existing housing stock and the variation of construction methodology, which results in large variations of the U-Values of thermal elements and dwelling air tightness. Therefore, given the constraints mentioned in the commercial refurbishments above, it was suggested to follow similar steps but slightly amended for proposals involving the refurbishment of up to 4 residential units:

1. As a first step, refurbishments should comply with the Building Regulations for existing dwellings dealing with the conservation of energy and fuel (AD L1B). Use of the 'Uttlesford' type condition which requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested, although this will be determined on a case by case basis) is earmarked for energy efficiency measures.

2. Secondly, refurbishments are expected to install one or more of the low and zero carbon technologies. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective.

3. Where the existing dwelling is of historic or heritage value, it is essential to consult with the Conservation Officers in the London Borough of Ealing and the English Heritage, as to the best way to incorporate energy efficiency measures into the dwelling in a sympathetic way which will not cause long-term damage to its fabric and structure. The permitted undertaken works must be considered on a case by case basis.

The results from section 7.4.9.1 indicated that reduction of up to 70% can be achieved through energy efficiency measures and a 35% or more in CO_2 can be reduced from biomass technology. Biomass was the first in cost effectiveness; however it is unlikely to be generally adopted for individual dwellings because the minimum size of automated biomass boiler is too large for an energy efficient house. This is likely to affect not only refurbishments but also new build minor developments. In the case where biomass is recommended air quality impact of small biomass boilers need to be considered. However it is possible that small scale distribution systems may be increasingly adopted in the future as a strategy to achieve low and zero carbon houses.

It is understood that there will be a degree of flexibility in the above requirements given that most refurbishments will be quite different.

8.1.2 Commercial

The results for the retail development group (A1/A2/A3-5) indicated a number of technical constraints. Whilst, higher emission savings are achieved through the energy efficiency measures for the supermarket, the restaurant struggles to meet similar carbon reduction targets. The restaurant development group, assumed to be part of a mixed-use development, had less external surface area compared to that of the supermarket which results in lower heat losses and make the application of energy efficiency measures not so effective. A reduction of at least 15% should be achieved from energy efficiency measures for both development types when only regulated energy use is considered. With regards to the non-regulated CO_2 emissions, it is difficult to compare the two retail developments due to the difference in their equipment's energy loads. It is also evident that a reduction of at least 10% can be achieved from low carbon technologies. However, while CHP is feasible to a supermarket, its application to individual small scale restaurants is not. It is important to note that the measures have been tested against the baseline energy demand of the restaurant only and not of the whole mixed-use development. This implies that a CHP can be feasible to mix-use developments as it can provide electricity and heat to both development's elements. In any case, CHP systems can reduce the baseline emissions by up to 11% for these class uses. Biomass heating and ASHP found to be feasible offering at least a 10% CO_2 reduction. However, although the price of buying and installing biomass boilers are more cost effective than the other technologies, the current biomass fuel prices prevent it from being a cost effective solution. An overall reduction of at least 20% in CO_2 emissions should be achieved for this class use (regulated and non-regulated energy use).

With regards to the office and warehouse development groups (B1/B2/B8), it is obvious that offices can achieve greater emission savings from energy efficiency measures compared to warehouses, despite their unique demand profiles, which require a lot less hot water and heating in comparison to electricity. The results from the warehouse show that energy efficiency measures have less of an effect as they mostly reduce heat demand. Therefore, warehouses require significantly more renewably-supplied electricity to reach the targets. As the warehouse case tested was all-electric, the most suitable solution would be to be replaced with either air source or ground source heat pumps. The results show that the most cost effective solution for this type of development is ASHP. Offices, on the other hand, have a potential to reduce their emissions through a combined heat and power system reducing CO_2 by 24%. The CHP application will potentially allow offices to investigate opportunities for developing a decentralised energy network if the right mix of uses is in a reasonable proximity, e.g. residential blocks which can be provided by a proportion of the excess heat the CHP system will produce throughout the year. In regards to the renewable technologies, the results indicated biomass for offices as the most cost effective option offering a reduction of 13% in CO_2. However, the current high prices of biomass fuel resulted in negative yearly savings. The feasible and cost effective options for offices cannot however be combined as CHP systems are not compatible with biomass but are more suitable with solar PV or wind. Solar PV and wind turbines can both reduce the electricity which is much higher grade of energy than heat but their renewable contribution to emission savings is negligible and costly. Because of the variation in the energy load between the two development groups, it was suggested to split the overall CO_2 targets. Therefore, for offices and warehouses CO_2 reduction targets of at least 18% and 8%, respectively, should be achieved from energy efficiency measures considering both regulated and non-regulated energy use. An overall reduction target of at least 30% and 25% for offices and warehouses, respectively, should be achieved when regulated and non-regulated energy use has been considered. This implies that the emissions savings from only regulated emissions should be much higher considering the non-regulated energy load that the results showed for both class uses as shown in table 8.1.

The results for class use C1/C2, a hotel show that energy efficiency measures have great potential when used in hotels. This is likely due to the increased demand for hot water that can be supplied from biomass boilers or CHP. An overall target of at least 45% in CO_2 emissions reduction should be required for new-build hotels.

The results for schools (D1/D2) show that a reduction of at least 15% in CO_2 can be achieved after having incorporated best practice efficiency measures. While low carbon technologies are not feasible for this type of developments, significant savings can be met through renewable energy sources such as biomass and wind turbines. Biomass showed a 23% CO_2 reduction while wind turbines only a 10% over the baseline. Biomass heating can play a vital role in reducing CO_2 emissions from schools but the current high prices of fuels discount it from being cost effective. A recent guidance on the design and construction of sustainable, low carbon school buildings published by Target Zero indicates that the most cost-effective route to providing directly-connected heat is a district CHP plant. It will be therefore required for new school developments to investigate the potential to either connect or future proof their energy system for potential connection to a decentralised energy network. An overall target of at least 30% in CO_2 emissions, considering both regulated and non-regulated, should therefore be required for all new build school developments.

As it is afore-mentioned, it is difficult to define a single level of CO_2 emissions for refurbishments as there are technical and cost constraints due to their building fabric. Applying energy efficiency measures and particularly increase the insulation levels on this type of projects will be much more costly due to the difficulty of installation, and subsequent increase in cost of labour. The existing energy demand and the energy efficiency performance are depending on the fabric of the building and the costs of improvement vary greatly depending on the type and condition of the existing stock. Despite of the cost of applying energy efficiency measures in refurbishments, many of these are necessary in any case to make a building more energy efficient and reduce its energy use. Internal insulation, though expensive, renews the condition of the walls and makes the rooms airtight. Some of the target fabric U values, such as floor or walls, may not be practicable, and airtightness and thermal bridging standards may be difficult to achieve. On the other hand some of the extra cost will be similar to new build. The windows are likely to be requiring replacement in any case, and the increased cost of going to a high standard of energy efficiency is less significant than the replacement cost of the window itself. Therefore, given the constraints mentioned above it was suggested that commercial refurbishments below $1000m^2$ should follow the next steps:

1. As a first step, refurbishments should comply with the Building Regulations for existing buildings other than dwellings dealing with the conservation of energy and fuel (AD L2B). Use of the 'Uttlesford' type condition which requires applicants to demonstrate that a certain percentage of the development costs (e.g. 10% is suggested, although this will be determined on a case by case basis) is earmarked for energy efficiency measures.

2. Secondly, refurbishments are expected to install one or more of the low and zero carbon technologies. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective.

3. Where the existing dwelling is of historic or heritage value, it is essential to consult with the Conservation Officers in the London Borough of Ealing and the English Heritage, as to the best way to incorporate energy efficiency measures into the dwelling in a sympathetic way which will not cause long-term damage to its fabric and structure. The permitted undertaken works must be considered on a case by case basis.

However, it is understood that there will be a degree of flexibility in the above requirements given that most refurbishments will be quite different.

Table 8.1 below presents the optimum targets that can be achieved for each development group based on the findings from the technical and financial feasibility analysis.

Class Use	Development Group	Overall % CO_2 emission savings from the combination of the most feasible & cost effective measures	Energy Efficiency Measures (EEM)	Combined Heat & Power (CHP)	Renewable Energy Sources (RES)
			(Regulated & Regulated +Non-Regulated CO_2 reduction)	(Regulated +Non-Regulated CO_2 reduction)	(Regulated +Non-Regulated CO_2 reduction)
A1: Shops A2: Finance/Professions A3-5 Food & drink	Supermarket	CHP after EEM: Not feasible Biomass after EEM: a) 15% (regulated) b) 11% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 19% Regulated + Non-Regulated: 15%	11%	Biomass Heating: 10%
	Restaurant	Biomass after EEM: a) 32% (regulated) b) 18% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 14.4% Regulated + Non-Regulated: 9%	Not feasible	Biomass Heating:18%
B1/B2/B8: Business General Industry Storage and distribution	Office	CHP after EEM: a)10% (regulated) b) 7% (regulated + Non-regulated) Biomass Heating after CHP + EEM:: a) 15% (regulated) b) 10% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 26% Regulated + Non-Regulated: 19%	24%	Biomass Heating: 13%
	Warehouse	ASHP after EEM: a) 20% (regulated) b) 16% (regulated + Non-regulated)	Advanced Fabric Standards Regulated Emission Savings: 11% Regulated + Non-Regulated: 9%	Not feasible	ASHP: 17%
C1 /C2 : Hotels, guest houses and boarding houses/ Residential institutions	Hotel	CHP after EEM: a) 55% (regulated) b) 44% (regulated + Non-regulated) Biomass Heating after EEM+CHP: a) 12% (regulated) b) 4.4% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 18% Regulated + Non-Regulated: 15%	35%	Biomass Heating:57%
D1/D2: Non-residential institutions/ Assembly & leisure	School	Biomass Heating after EEM: a) 22% (regulated) b) 15% (regulated + Non-regulated) Wind after EEM: a) 14% (regulated) b) 12% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 18.4% Regulated + Non-Regulated: 16%	Not feasible	Biomass Heating: 23% Roof mounted wind turbines: 10%

Class Use	Development Group	Overall % CO_2 emission savings from the combination of the most feasible & cost effective measures	Energy Efficiency Measures (EEM)	Combined Heat & Power (CHP)	Renewable Energy Sources (RES)
			(Regulated & Regulated +Non-Regulated CO_2 reduction)	(Regulated +Non-Regulated CO_2 reduction)	(Regulated +Non-Regulated CO_2 reduction)
All commercial class uses	Refurbishments	EEM: Min 15%	**Below 1000m²**: Compliance with Building Regulations Part L2B and demonstration of at least 10% of the development costs for energy efficiency measures **Equal or above 1000m²**: Compliance with targets achieved from this study	**Below 1000m²**: Installation of one or more of the low and zero carbon technologies, where feasible. **Equal or above 1000m²**: Compliance with targets achieved from this study	
C3: Dwellings	Flats (1-5 units)	Biomass after EEM: 86% (regulated- exceeds Code Level 4) 32% (regulated + Non-regulated)	Advanced Fabric Standards Regulated Emission Savings: 44% Regulated + Non-Regulated: 24%	Not feasible	Biomass Heating: 34%
	Flats (6-10 units)	Biomass after EEM: 86% (regulated- exceeds Code Level 4) 32% (regulated + Non-regulated)	Advanced Fabric Standards Regulated Emission Savings: 44% Regulated + Non-Regulated: 27%	Not feasible	Biomass Heating: 34%
	Flats (11-50 units)	CHP after EEM: a)83% (regulated- exceeds Code Level 4) b) 30% (regulated + Non-regulated) Biomass Heating after EEM+CHP:: a) 64% (regulated) b) 32% (regulated + Non-regulated)	Advanced Fabric Standards Regulated Emission Savings: 44% Regulated + Non-Regulated: 27%	41%	Biomass Heating: 34%
	Flats (51+ units)	CHP after EEM: a)69% (regulated- exceeds Code Level 4) b) 27% (regulated + Non-regulated) Biomass Heating after EEM+CHP: a) 66% (regulated) b) 26% (regulated + Non-regulated)	Advanced Fabric Standards Regulated Emission Savings: 43.7% Regulated + Non-Regulated: 27%	31%	Biomass Heating: 34%
	Detached	ASHP after EEM: a)49% (regulated- exceeds Code Level 4) b) 28% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 39% Regulated + Non-Regulated: 27%	Not feasible	ASHP: 28%

Class Use	Development Group	Overall % CO_2 emission savings from the combination of the most feasible & cost effective measures	Energy Efficiency Measures (EEM)	Combined Heat & Power (CHP)	Renewable Energy Sources (RES)
			(Regulated & Regulated +Non-Regulated CO_2 reduction)	(Regulated +Non-Regulated CO_2 reduction)	(Regulated +Non-Regulated CO_2 reduction)
	Semi-detached	ASHP after EEM: a)48% (regulated- exceeds Code Level 4) b) 24% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 39.4% Regulated + Non-Regulated: 27 %	Not feasible	ASHP: 26%
	End-Terrace	ASHP after EEM: a)52% (regulated- exceeds Code Level 4) b) 25% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 39% Regulated + Non-Regulated: 26%	Not feasible	ASHP: 29%
	Mid-Terrace	ASHP after EEM: a)51% (regulated- exceeds Code Level 4) b) 24% (regulated + Non-regulated)	Best Fabric Standards Regulated Emission Savings: 38% Regulated + Non-Regulated: 25%	Not feasible	ASHP: 27%
	Refurbishments		**Maximum:** 70% **Up to 4 units**: Compliance with Building Regulations Part L1B and demonstration of at least 10% of the development costs for energy efficiency measures **More than 4 units**: Compliance with targets concluded from this study.	**Up to 4 units**: Installation of one or more of the low and zero carbon technologies, where feasible. **More than 4 units**: Compliance with targets concluded from this study.	

Table 8.1 Carbon emission reduction options for the development groups

Overall, the key finding from the technical analysis is that achievement of 25%, 30%, 45% and, in many cases, 50-60% CO_2 reduction targets are technically feasible for all of the development types tested, with the exception of the retail, warehouse and school developments. These targets relate to the overall CO_2 emission reduction targets achieved through the combination of the optimum measures for each development group. Therefore the key limiting factor is likely to be financial viability. For those developments where the overall CO_2 emission targets did not exceed the minimum carbon emission savings established in Policy 5.2 of the Draft Replacement London Plan, the Council will encourage applicants to demonstrate that they have fully considered measures to satisfy the London Plan policy.

It is generally evident that best practice standards appeared to be feasible and the most cost effective option for most of the development groups (see table 8.1) achieving reduction of 15-26% with the exception of the restaurant and the warehouse. With regards to technologies, CHP seems to be feasible and viable in larger scale developments while ASHP and biomass show a significant reduction in emissions specifically when assessed against the Building Regulations 2006 baseline. In particular biomass heating, although for most of the development groups it did not offer significant energy savings due to the assumptions made for the biomass fuel prices, it seems that it is the most cost-effective solution in terms of the cost per percentage savings in carbon emissions.

In regards to solar technologies, the high fuel prices, the high capital cost and the relatively low yearly nett savings render these technologies as non cost effective.

Should biomass not be an option, for example because of air quality concerns, uncertainty of fuel delivery etc, the applicant would need to revert to using higher cost options. In most cases, this will make the achievement of the targets more expensive, particularly for smaller schemes. Removing biomass as an option will also be likely to increase the numbers of examples where the targets are not achievable.

In the absence of biomass as an option, and in the likely case that community networks are unavailable to connect to, at least in the near term, the remaining options become fewer and therefore there is a higher risk that targets may be undeliverable. Remaining options include gas CHP and heat pumps to provide for heat demand, supplemented by PV and wind for electricity.

Under specific circumstances, where the targets cannot be met due to a variety of technical and financial constraints and the applicant has demonstrated the constraints, it is expected that the targets will be relaxed.

It is likely that the clean cashback schemes, such as the Feed-in-Tariffs (FIT) and the Renewable Heat Incentive (RHI) will have a positive impact on the uptake of the technologies identified not to be cost effective, which will be a step in the right direction towards lowering the carbon emissions from the Borough.

8.1.3 Mixed-Use Developments

In respect of mixed use schemes, it is proposed that the targets defined for each development type will be applied to each relevant section of the development.

8.2 Decentralised energy

All developers will be required to investigate the potential to connect to an existing heat network, to make provision to connect to a future network, to commit to discuss connection if they are approached by a DE service provider in the future, or even establish new networks. Developers should use either the London Heat Map tool or the London Heat Map Study for the London Borough of Ealing. The Council will require developers to prioritise connection to existing or planned decentralised energy networks where feasible.

It is considered important for all development, regardless of its scale, to be captured under the carbon reduction targets proposed. Whilst smaller developments may contribute low net additional carbon dioxide emissions, the incremental increase from a small scale developments across the borough could have a significant impact across the borough.

Where a link to a district heating system is not possible, except for a few specific examples, the lowest cost route involves the use of biomass boilers for heating and hot water.

Further information is provided in the Heat Mapping Study which can be found on the London Borough of Ealing's website.

8.3 Implications of CO_2 reduction standards on the Code for Sustainable Homes and BREEAM

Based on the findings set out above, at the very least in respect of the energy component of the Code, achieving Level 4[59] of the Code for Sustainable Homes between now and 2013 would be reasonable. However, this standard is anticipated to increase to Code Level 5 in 2012 as a mandatory requirement for social rented developments. Accordingly, target setting in terms of code levels will need to be periodically reviewed. In the interim code Level 4 will be the minimum requirement for all applications either private housing or socially funded. Code Level 4, in respect of the energy component at least, is also comparable with the overall CO2 emission saving targets established in Policy 5.2 of the draft consultation London Plan for the years 2010 to 2013. In addition to endorsing the minimum overall carbon emission targets in Policy 5.2, the Council will also expect developers to demonstrate consideration of measures to achieve the higher level advisory targets for each measure in table 8.1.

In addition to setting targets in respect of energy and CO2 emissions, the Code for sustainable homes, specifies a whole range of criteria for other aspects of the buildings design and management. The Code for example sets mandatory targets for the following categories: potable water consumption, Materials, Water surface runoff 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 – a) Ensure that the peak rate of runoff into watercourses is no greater for the developed site than it was for the predevelopment site. b) 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 nonpotable 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 wellbeing
- Management
- Ecology

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

[59] Credit Ene1: Dwelling Emission Rate measures CO_2 emissions reductions as a percentage reduction of emissions regulated under Building Regulations Part L 2006.

The Code assessments are normally carried out in two stages:

- Design Stage (DS), leading to an Interim certificate. This interim certificate is provided for information only and cannot be used to represent the performance of a completed dwelling.
- Post Construction Stage (PCS), leading to a Final certificate. This final certificate is carried out after construction and completion and represents the final Code Certificate given to each dwelling.

For commercial developments, the BRE Environmental Assessment Method (BREEAM) is used to assess their environmental performance. Whilst no mandatory targets are set at the national and regional level in terms of BREEAM or other assessment tools for non-residential buildings, based on the findings of this report, and from previous experience of its application, it is considered reasonable and achievable to require non-residential proposals to satisfy a BREEAM rating of 'Very Good'. As with the Code and the other energy policy targets, this standard will need to be reviewed overtime. In respect of carbon emissions, commercial buildings will nonetheless still need to comply with Policy 5.2 of the London Plan.

8.4 Final Conclusions

Drawing upon the technical and financial modelling undertaken as part of this study, the analysis and qualitative assessment of the future changes in market conditions, and likely legislative changes in policy, the following section sets out key recommendations for the formulation of policy in the emerging LDf documents.

In order to provide the basis and context for more detailed policies on CO_2 reduction and sustainable design and construction, it is proposed that there is an overriding objective in the Development Strategy promoting climate change mitigation and adaptation. In addition it is recommended that the strategy adopts the overall carbon emissions target saving target (60% till 2025) as proposed in the Draft Replacement London Plan (policy 5.1), and the minimum carbon emission savings for major developments as established in Policy 5.2.

With regard to the emerging Development Management DPD, it is recommended that this document endorse all of the policies in the draft London Plan with regard to energy and climate change mitigation/adaptation. In fact the emerging draft of this document repeats the planning decisions component of the draft London Plan. Whilst it is considered that the policies in the draft London Plan are fairly comprehensive, the findings of this study have identified scope to go further in terms of target setting. In this regard there are a number of policy areas which could be supplemented with local policy. For example, whilst the Council endorses and seeks to adopt the requirements set out in policy 5.2B of the replacement London Plan, it does however recognise that the scope of this policy is limited in that it would only be triggered by major development, i.e. residential schemes of 10 or more units and commercial schemes of ~~a~~ 1,000 sq. m. or more. Moreover the targets relate to regulated energy demand only. It is therefore recommended to set minimum standards for minor residential developments involving the creation of 1 or more units (through new build). For minor commercial schemes, i.e. developments constituting less than a 1000 sq. m. (including extensions up to this size), it is proposed that policies are set to require applicants to comply with 2010 Building Regulations (ADL2A). In addition applicants are required to achieve energy efficiency savings (beyond building regs) as established in table 8.1 and to demonstrate full consideration of the use of CHP and renewable energy technologies, and incorporate these where feasible and viable.

For all major developments it is also proposed that preferred best practice targets for each use class, are established, which are further broken down in terms of savings achieved from a) energy efficiency measures, b) combined heat and power, c) on-site renewables. These are designed to ensure general adherence to the Mayor's Energy Hierarchy. Whilst these are intended to be advisory, applicants will nonetheless need to demonstrate that they have fully considered measures to satisfy these higher exemplary standards. The targets will apply until the end of 2012, at which time they will be reviewed and revised. It should be noted that these targets should be calculated on the basis of the total energy demand (both regulated and unregulated), as distinct from the London Plan targets which are measured in terms of regulated demand only. These targets may also provide a useful guide for some minor developments too, although some flexibility will need to be adopted in their application. These targets have been set through modelling the potential performance of new builds, and some flexibility will need to be applied in relation to refurbishment schemes (i.e. change of use/conversions), as it is likely to be more challenging and costly to apply such measures to existing buildings as distinct from new build.

Refurbishments will be expected to install one or more of the low and zero carbon technologies. Where not feasible, it should be demonstrated that the installation of such technology would either not be cost effective. This is intended to recognise the unique challenges that exist in respect of employing such measures in existing buildings. This is proposed to be achieved either by requiring an energy or sustainability statement with the planning application which will specify how the developer intends to reduce the CO_2 emissions of the building through the use of the Energy Hierarchy or by requiring a 'very good' standard under BRE's EcoHomes for refurbishment standard. The establishment of such policy advice and criteria will supplement the policies of the consultation London Plan and especially policy 5.4 Retrofitting.

With regards to minor applications involving extensions to single family dwellinghouses, which constitute a considerable proportion of all planning applications, it is proposed to apply an 'Uttlesford' type condition. In effect this condition requires applicants to demonstrate that a certain percentage of the development costs (eg 10% is suggested although this will be determined on a case by case basis), is earmarked for energy efficiency measures.

Where the existing dwelling is of historic or heritage value, it is essential to consult with the Conservation Officers in the London Borough of Ealing and the English Heritage, as to the best way to incorporate energy efficiency measures into the dwelling in a sympathetic way which will not cause long-term damage to its fabric and structure. The permitted works undertaken must be considered on a case by case basis.

Overall, the key finding from the technical analysis is that achievement of 30%, 45% and, in many cases, 50% CO_2 reduction targets are technically feasible for all of the new build development types tested, with the exception of the retail and warehouse developments. The financial analysis has shown that the costs associated with the increased levels of CO_2 reductions should not be prohibitive to development. In addition, future decreases in costs of technologies and improved financial incentives for these may also increase the viability of any target over time.

It is recommended that the final targets adopted are phased over the lifetime of the LDF documents. One way to implement this would be in line with the revised levels of the Building Regulations updates expected in 2013/16/19, however demonstrating viability of future targets may prove problematic. In setting future targets further consideration would need to be given to how targets would be applied in relation to the broader objective of achieving a district energy network. For example where schemes connect to or contribute to a future network, targets in respect of CHP and renewable installations may need to be relaxed. Further guidance should be provided as part of the Development Management DPD.

When considering the targets in terms of CO_2 emissions, it will be necessary to consider the viability data provided in this study and the need to take a flexible approach to certain kinds of development, with the onus on the developer to demonstrate why a target cannot be met.

As discussed previously the following targets are recommended for new build developments;

Class Use	Development Group	Energy Hierarchy	Individual CO_2 Targets - Both Regulated & Non-regulated**	Overall CO_2 Target- Both Regulated & Non-Regulated
A1/A2/A3-5	Retail	EEM	15%	15%*
		CHP	10%	
		RES	10%	
B1/B2	Office	EEM	18%	25%
		CHP	24%	
		RES	13%	
B8	Warehouse	EEM	8%	16%
		CHP	not feasible	
		RES	17%	
C1/C2	Hotel	EEM	15%	56%
		CHP	35%	
		RES	57%	
D1/D2	School	EEM	16%	15%
		CHP	not feasible	
		RES	23%	
C3	Residential Block 1-5 units	EEM	24%	32%
		CHP	not feasible	
		RES	34%	
C3	Residential Block 6-10 units	EEM	27%	32%
		CHP	not feasible	
		RES	34%	
C3	Residential Block 11-50 units	EEM	27%	64%
		CHP	41%	
		RES	34%	
C3	Residential Block 51+ units	EEM	27%	48%
		CHP	31%	
		RES	34%	
C3	Houses	EEM	26%	26%
		CHP	not feasible	
		RES	27%	

* Approximate average target from both supermarket and restaurant

** Percentages are based on both regulated and unregulated energy use and have been calculated based on the original baseline (Building Regulations 2006). These have been calculated separately for each measure and related back to the original baseline. In practice, however, through the application the percentage contribution for each measure would be calculated at each stage following a revision of baseline, according with the methodology outlined in Appendix D of the supplementary Planning Guidance on Sustainable Design and Construction.

The Core Strategy covers the period up to 2025 and needs to remain robust and relevant over that period. As it afore mentioned, within this period there will be many changes that are likely to influence the market and the costs of the technologies. However, important changes are likely to be expected in policies and regulations in the coming year that may require the eventual policy wording or methodology to be reviewed. *Building Regulations Part L 2010/13, SAP 2009 and Zero Carbon* are the forthcoming policy changes which are expected as a minimum to come through over the next few years.

The impact of these policy changes will need to be reviewed once the full methodology of these policies is understood. As it is aforementioned several times in this report, the CO_2 emissions have been assessed against the Building Regulations Part L 2006. However, as the new regulations will come forward and start being implemented, developers will have to begin to submit energy strategy assessment reports using the 2010 regulations as the baseline to demonstrate building regulations compliance. However developers would still need to demonstrate compliance with the 2006 regulations for planning policy. The policy will eventually be eclipsed by the CLG/ Building Regulations, unless the policy for Zero Carbon Homes by 2016 is changed. However the current recommendations should allow for the development of a policy that is robust, viable for the majority of developments, and importantly likely to become increasingly viable over time.

Appendix A

Biomass Suppliers at South East of England[60]

Berkshire

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Forever Fuels Maidenhead	Ian Armstrong	Tel: 01628 509690 Mobile: 07766 314264 iana@forever-fuels.com www.forever-fuels.com			Yes	
GV Recycling Reading	Geoff Edwards	Mobile: 07899 906201 vikkiedwards2000@aol.com www.gvrecycling.co.uk				Yes
Hampshire Wood Chip Hungerford	William Hamer	Tel: 01488 658356 william.hamer@hampshirewoodchip.co.uk www.hampshirewoodchip.com				Yes
Thames Valley Bioenergy Newbury	Anthony Whitton	Tel: 01635 817420 woodfuel@tvenergy.org www.tvbioenergy.co.uk				Yes
Wessex Woodland Management Hungerford	David Hunt	Tel: 01488 685007 david@wessexwoodland.com www.wessexwoodland.com				Yes

Buckinghamshire

[60] Wood Fuel Suppliers in UK, Source: Biomass Energy Centre

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
AM & MJ Harper Milton Keynes	Jeremy Harper	Tel: 01908 66522 Mobile: 07932 014459 amandmjharper@btinternet.com				Yes

East Sussex

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
AHS Energy Northiam	Paul Davenport	Tel: 01797 252728 Mobile: 07721 884636 paul.davenport@ahs-ltd.co.uk www.ahsenergy.co.uk				Yes
South East Woodfuels Ltd Laughton	Julian Morgan-Jones	Tel: 0845 869 3775 info@sewf.co.uk www.sewf.co.uk				Yes
The Natural Heat Company Rye	Mark Knight	Tel: 01797 227943 rye@thenaturalheatco.co.uk www.thenaturalheatco.co.uk			Yes	

Hampshire

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Hampshire Wood Chip Hungerford	William Hamer	Tel: 01488 658356 william.hamer@hampshirewoodchip.co.uk www.hampshirewoodchip.com				Yes

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Sustainability Centre (Wood4Heat) Petersfield	John Bushby	Tel: 01730 823167 Mobile: 07736 947785 john@wood4heat.co.uk www.wood4heat.co.uk				Yes
UPM Tilhill Alton	Iain Sutherland	Tel: 01420 562197 iain.sutherland@upm-kymmene.com www.upm-tilhill.com		Yes		Yes
UK Wood Pellets Basingstoke	Dean Bulleid	Tel: 01256 411394 Mobile: 07792 535581 info@ukwoodpellets.eu www.ukwoodpellets.eu	Yes		Yes	
Wesnet Services Ltd. Waterlooville	John Westcott	Tel: 02392 595147 forestry@wesnetservices.co.uk www.wesnetservices.co.uk			Yes	Yes

Isle of Wight

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Wight Heat Ventnor	Joanna Richards	Tel: 01983 551 748 Mobile: 07854 676 987 info@wightheat.co.uk www.wightheat.co.uk	Yes			

Kent

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Godinton Park Ashford	Nick Sandford	Tel: 01233 632652 ghpt@godinton.fsnet.co.uk www.godinton-house-gardens.co.uk				Yes
Home Counties Woodfuel Ltd. Tunbridge Wells	John Bee	Tel: 01892 750766 admin@nevilleestate.co.uk				Yes
South East Wood Pellets	William	Mobile: 07973 848365 william@southeastwoodpellets.co.uk www.southeastwoodpellets.co.uk			Yes	
The Natural Heat Company Sellindge	Mark Knight	Tel: 01303 813999 info@thenaturalheatco.co.uk www.thenaturalheatco.co.uk			Yes	
Torry Hill Sittingbourne	John Leigh-Pemberton	Tel: 01795 830245 Mobile: 07768 351275 jlp@torryhill.co.uk www.torryhill.co.uk				Yes
C.E. Murch Canterbury	John Atkins	Tel: 01227 471 774 Mobile: 07870 250 000 ja@amerycourt.co.uk www.bleanwood.co.uk	Yes	Yes		Ye

Oxfordshire

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Goodwood Recycling Ltd. Faringdon	Debbie Bradford	Tel: 01367 810208 Mobile: 07971 624646 enquiries@goodwoodrecycling.co.uk www.goodwoodrecycling.co.uk				Yes

Surrey

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Harvest Woodfuels Farnham	James Little	Tel: 01252 794958 jameslittle@harvestwoodfuels.co.uk www.harvestwoodfuels.co.uk			Yes	
L C Energy ltd Guildford	Mark Lebus	Mobile: 07834 496696 mark@lcenergy.co.uk www.lcenergy.co.uk				Yes
Mark Howard Farnham	Mark Howard	Tel: 01252 850791 Mobile: 07702 152529 markkit@btinternet.com		Yes		
South East Wood Pellets	William	Mobile: 07973 848365 william@southeastwoodpellets.co.uk www.southeastwoodpellets.co.uk			Yes	

West Sussex

Supplier	Contact	Contact details	Supplies			
			Briquettes	Logs	Pellets	Wood chips
Balcombe Estate Balcombe	Jamie Kirkman	Tel: 01444 811233 jamie.woodcutter@virgin.net www.balcombeestate.co.uk				Yes
Eurogreen Worthing	David McIntyre	Tel: 01903 700678 admin@eurogreenuk.com				Yes
Home Grown Timber Horsham	Tony Saunders	Tel: 01293 852700 mail@homegrowntimber.com www.homegrowntimber.com				Yes
Wiston Estate Worthing	William Trinick	Tel: 01903 812129 Mobile: 07979 503440 wtrinick@wistonestate.co.uk				Yes

Sources :

1. Wood Fuel Suppliers in UK <http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,241182&_dad=portal&_schema=PORTAL>

2. Forever Fuels <http://www.forever-fuels.com/content/price-calculator>

3. Biomass: Delivery and Storage <http://www.cen.org.uk/biomass/logistics.asp>