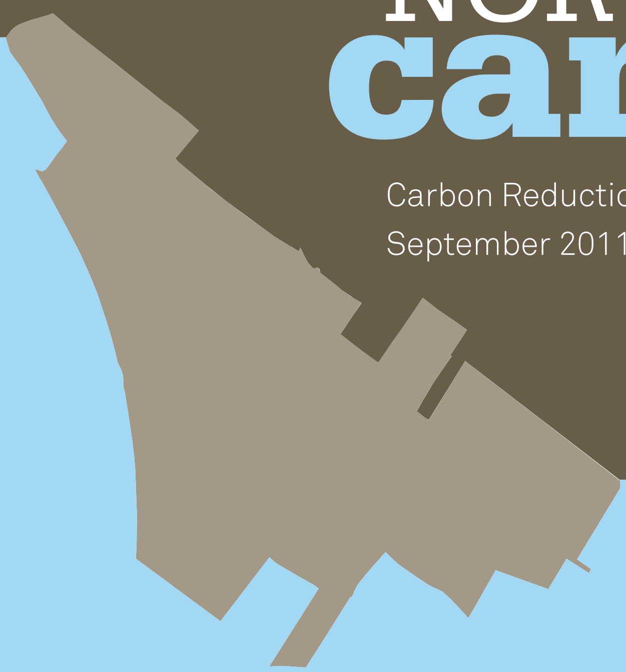

NORTH WEST cambridge

Carbon Reduction Strategy

September 2011

North West Cambridge: Carbon Reduction Strategy

Part A: Energy Strategy

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Executive Summary

Introduction

The North West Cambridge Development ("the Application Site") ("the Proposed Development") proposed by the University of Cambridge ("the Applicant") is a strategic extension to the City of Cambridge. The Application Site has a prominent position with around 150 hectares of land in a triangle between Madingley Road, Huntingdon Road, and the M11 motorway. The scale of the proposal is major for Cambridge and this, combined with the Application Site's geographical spread over Cambridge City Council and South Cambridgeshire District Council has led to the development of an Area Action Plan (AAP) document. The AAP sets out a number of requirements for providing sustainable energy and reducing CO_2 emissions from the Application Site. This, in combination with future developments in Part L of the building regulations (notably a move towards zero carbon homes in 2016 and non-domestic buildings in 2019), means that the Proposed Development must be an exemplar of low carbon design.

This document, Part A of the Carbon Reduction Strategy, analyses a number of energy strategy options leading to the development of a preferred option for submission as part of the outline planning application.

This energy statement is structured into 4 sections:

- Section 1 describes the Proposed Development and defines the minimum targets and standards which apply following a review of relevant policy and legislation.
- Section 2 summarises the technical analysis conducted which ranges from an assessment of the baseline conditions through to a feasibility assessment of a range of measures and technologies aiming to reduce CO_2 emissions.
- Section 3 discusses how these measures may be used to meet the specific policy requirements and form a strategy for the development.
- Section 4 summarises the preferred approach to the energy strategy and proposes how this strategy might evolve in the long-term.

The future building regulations and planning requirements outlined above lead to a number of challenging energy standards for the Application Site. In summary:

A. Buildings should be built to a high level of energy efficiency, potentially to higher standards than required under national regulation. This includes the consideration of passive solar design.

B. Most phases will be required to meet significant CO_2 reductions overall, leading to net zero carbon from 2016 for domestic and 2019 for non-domestic.

C. All dwellings approved on or after 1 April 2013 (and before 2013 if over 50 dwellings) will probably be required to provide at least a 70% CO_2 reduction in regulated loads using on-site technologies (assuming the Code definition aligns with predicted national building regulations and that 70% is selected as the carbon compliance level).

D. Additional CO_2 savings will be required (up to net zero carbon which includes non-regulated loads) either on-site or offsite through Allowable Solutions.

E. A certain element of renewable energy will be required to meet the percentage targets.

Energy efficiency

Baseline (i.e. business as usual) carbon emissions would average just over 23,000 tonnes per year up to 2026 (when the development is forecast to be complete) were there to be no energy targets for the Proposed Development.

High levels of energy efficiency are proposed however such that energy demand will be significantly reduced from this baseline. Dwellings will be built to at least the minimum energy efficiency standard (FEES) proposed in the Government's definition of zero carbon. Passive means of ventilating and cooling non-domestic buildings will be prioritised. In particular, conventional office and academic accommodation will, where practicable, be naturally ventilated, making use of thermal mass and appropriate orientation and shading to minimise overheating. Plan depths will also, where practicable, be kept to a minimum so that occupants are generally close enough to a window to receive natural light and air. Deep plan buildings will generally be restricted to a single storey where roof lights can provide natural light and ventilation or require the inclusion of design features such as atria where similar benefits of daylight and natural ventilation can be achieved.

It is expected that the application of these higher energy efficiency standards will result in demand-side reductions of 18% leading to average carbon emissions of just over 19,000 tonnes per year.

Renewable and low carbon technologies

On the supply side it is acknowledged that reliance on fossil fuels at the Application Site should be minimised. This document examines the appropriateness of a large number of low and zero carbon sources of energy for the Proposed Development. These are summarised in the following table:

Summary of potential renewable and low-carbon energy technologies for the Proposed Development.

Technology	Suitability for the Proposed Development	Comments
Community gas CHP	Suitable for all areas connected to a district heating network.	Gas CHP combines a mature technology with large CO_2 reductions and is capable of meeting the regulated CO_2 limits with small amounts of additional PV where required.
Community biomass boilers	Technically suitable for connection to a DH network	Whilst technically suitable, there are high risks surrounding future availability and cost of fuel. This could be offset by the Renewable Heat Incentive. Greater CO_2 reductions could also be made from biomass using a CHP based technology.
Biomass CHP	Technically suitable for complete development but with phasing difficulties.	Biomass CHP can deliver large CO_2 reductions, but delivering the technology to meet the relatively small heat demand during the early phases will incur higher costs and efficiency penalties. The technology at the scale for the Proposed Development is currently considered to be immature / pre commercial, and there are significant concerns over the availability and future cost of fuel.
Anaerobic digestion	Large scale - not suitable due to waste requirements. Small scale – potentially suitable as part of water treatment.	Large scale AD is not considered suitable for the Proposed Development based on the large feedstock requirements (up to 50,000 tonnes per year) and the nature of the technology for a residential development. [Discussions with suppliers have suggested an AD scheme has marginal viability in this area.] A small scale scheme based around water treatment could be viable if on-site water treatment is proposed. At present, the intention is for all water-treatment to take

		place off-site at the local treatment works.
Large scale wind	Not suitable	Large scale wind is not considered suitable for the Proposed Development due to the requirements for buffer zones and potential visual impact.
Small scale wind	Technically suitable	There could be opportunities for incorporating small scale wind turbines on some parts of the Application Site. However the performance is likely to be poor due to the urban nature of the Application Site, and the contribution to CO_2 savings negligible, even with a large number of turbines.
Photovoltaics	Suitable for all buildings	PV has very few limitations and could be installed on the roofs of all buildings. The maturity of the technology means this is a relatively low risk solution. Maximum contribution is obtained if roof slopes can be designed to be predominantly south facing. Financial support available through the Feed-in-Tariff at least until 2012.
Solar thermal	Suitable for buildings not connected to a heat network.	Solar thermal conflicts with CHP technologies, but could be provided in those buildings with a sufficient hot water demand which are not connected to a heat network. The maturity of the technology means this is a relatively low risk solution.
Heat pumps	Suitable for later-phase commercial buildings.	Heat pumps are not predicted to save much (if any) CO_2 under the current grid mix. However with decarbonisation of the grid, they may be more suitable for later phases of the development. Balancing cooling and heating loads in the non-domestic buildings may help improve the overall efficiency of a ground connected heat pump system. A cooling network could enable centralised chillers to be used to provide additional waste heat.
Micro CHP	Not suitable at this stage	Micro CHP is not currently considered suitable due to the maturity of the technology. However this technology may become suitable (in particular fuel cell) as the technology matures, particularly in areas not connected to a heat network.
Biomass heating	Not suitable	Biomass boilers are not considered suitable for individual buildings due to air quality concerns, lack of heat load diversification, and plant space requirements (including fuel storage) for each building. In general, a large centralised biomass scheme is preferred over small individual installations. Concerns around the future availability and cost of biomass fuel also remain.

The table highlights a number of technologies that are most suitable to the Proposed Development; in particular combined heat and power (CHP), photovoltaic and solar thermal panels and, in the event that the grid decarbonises quickly, heat pumps.

The exact choice of Low and Zero Carbon technologies will be left to the designers of individual buildings at detailed planning, however the widespread use of combined heat and power is predicted on a commitment to the installation of district heating at a site scale. For this reason the Proposed Development includes an energy centre and district heating. Again, the precise technology to be installed in the energy centre will be left to detailed design at phase 1 when the energy centre is proposed to be built however it is envisaged at this stage that gas-fired CHP will be the day-one energy technology. District cooling may feature as well, however the business case for this technology has yet to be established fully.

The North West Cambridge Area Action Plan contains a requirement for non domestic development on the Application Site to achieve a 20% reduction in carbon emissions through the use of renewables should biomass CHP not be proposed:

Whilst not renewable gas fired CHP is estimated to result in carbon savings of 18% in all non-domestic buildings across the Proposed Development. A *further* 20% saving will then be made through the application of, predominantly, PV, solar thermal and heat pumps when aggregated across all buildings. This means that some buildings will achieve more than 20% renewables and some less.

As a rough rule of thumb approximately 50% of the roof area of dwellings will be covered in PV meaning that roofs will have to be appropriately orientated.

The application of all low and zero carbon technologies (domestic and non-domestic) will result in final CO_2 emissions averaging 11,500 tonnes per year. This represents a total saving from the baseline, including energy efficiency, of around 50%.

Conclusions

The following possible approach to the Energy Strategy for the Application Site would be compliant both with National and AAP policy. This represents likely scenarios given current thinking about quantum of development and phasing but must be considered provisional pending detailed design.

From day one all homes will be built to high fabric energy efficiency standards meaning that they will have improved U-values and air-tightness over current Building Regulations. Passive means of ventilating and cooling non-domestic buildings will be used wherever constraints (such as noise) permit this type of approach.

The majority of the Applicant’s residential buildings, including key worker accommodation, will be heated from a district heating main to be routed around the Proposed Development (exceptions may be made where the Applicant’s buildings are planned far from the route of the scheme). Some private residential accommodation will be heated using standalone gas boilers, however plots that are close to the routing of the district heating main will be encouraged to connect to it.

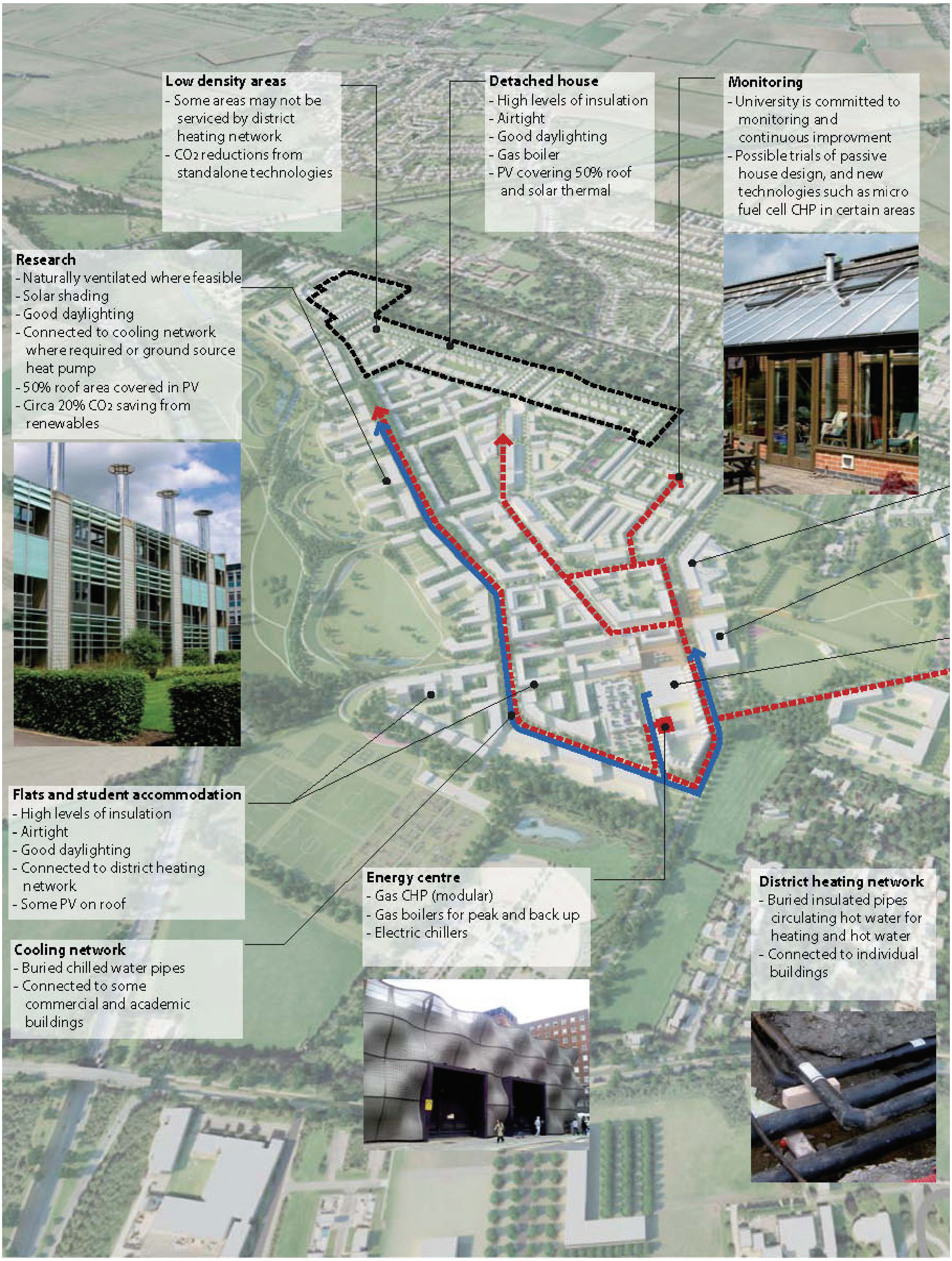
An energy centre will be built within the neighbourhood centre within a few years of the start of the project to generate heat for the district heating main. Initially, the majority of the heat will be produced by a succession of modular gas-fired combined heat and power plants with back-up heating provided by gas-fired boilers. Some heat could be provided from heat rejection from a centralised cooling system (including large amounts of heat from the supermarket refrigeration which may be covenanted to provide it).

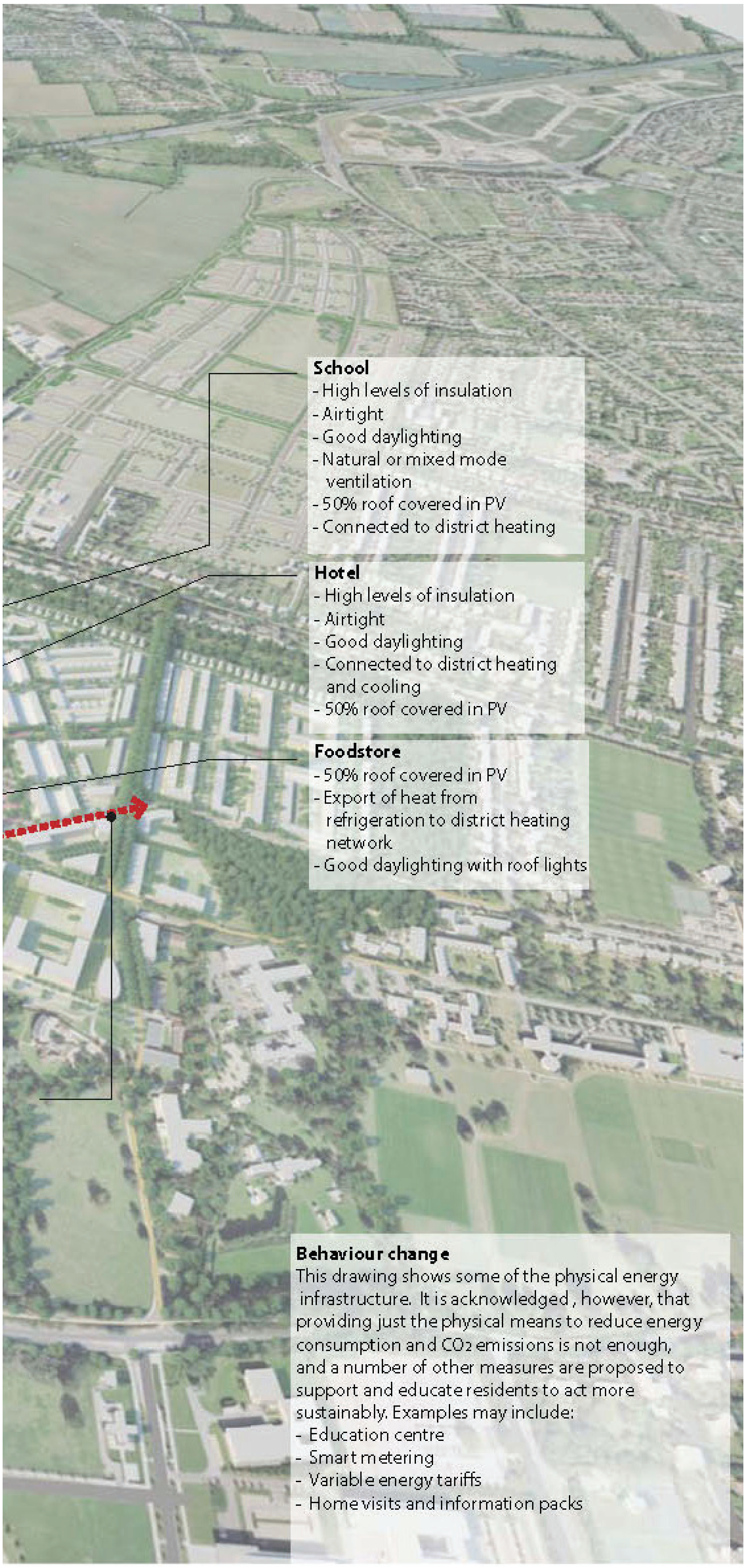
Over time it can be expected that the heat source will change as technologies improve and as fossil fuels (such as gas) become scarcer or more expensive due to climate change legislation. Centralising the heat source and distributing through a district heating system allows the heating technology to be more easily altered than would be the case if gas boilers were distributed across the Proposed Development.

Energy efficiency and gas-fired combined heat and power will produce more than two-thirds of the carbon savings required to meet the Code for Sustainable Homes level 5. The remaining CO_2 reductions are planned to be met with an extensive installation of photovoltaic panels across the roofs of the development. The recent introduction of the Feed-in-tariff makes PV attractive as a producer of on-site renewable electricity.

A large number of non-domestic buildings across the Proposed Development will be heated and cooled using ground source heat pumps, possibly networked using a low temperature district heating system. Whilst the carbon saving potential of this technology is currently limited by the fossil-fuelled power stations that supply the grid (since heat pumps are powered by grid electricity) it is anticipated that emissions from the grid will drop after 2020 as the UK moves to cleaner, high-efficiency gas power stations (possibly with carbon capture), nuclear and large scale wind. At this point heat pumps will become more favourable than gas-fired boilers. The majority of non-domestic buildings are proposed to be built after 2020 so this approach is aligned with the proposed phasing.

Low carbon lifestyles will be promoted through the management of the estate. The proposed energy centre may feature an educational facility to teach residents and visitors about the sustainable technologies employed across the Proposed Development.


Low density areas
- Some areas may not be serviced by district heating network
- CO_2 reductions from standalone technologies
Detached house
- High levels of insulation
- Airtight
- Good daylighting
- Gas boiler
- PV covering 50% roof and solar thermal
Monitoring
- University is committed to monitoring and continuous improvment
- Possible trials of passive house design, and new technologies such as micro fuel cell CHP in certain areas
Research
- Naturally ventilated where feasible
- Solar shading
- Good daylighting
- Connected to cooling network where required or ground source heat pump
- 50% roof area covered in PV
- Circa 20% CO_2 saving from renewables
Flats and student accommodation
- High levels of insulation
- Airtight
- Good daylighting
- Connected to district heating network
- Some PV on roof
Energy centre
- Gas CHP (modular)
- Gas boilers for peak and back up
- Electric chillers
District heating network
- Buried insulated pipes circulating hot water for heating and hot water
- Connected to individual buildings
Cooling network
- Buried chilled water pipes
- Connected to some commercial and academic buildings



Due to the mix of building types and uses on the proposed development, the energy strategy will vary across the site.

This indicative illustration shows examples of how the low carbon aspirations can be met for different areas of the Application Site.

Future Thinking

The energy strategy developed for this planning application will result in a development with significant levels of renewable and low carbon energy generation. The Proposed Development meets current and future (as currently known and defined) building regulations Part L, Code for Sustainable Homes level 5 (and level 6 CO_2 standards from 2016), and local planning policy from the AAP.

The scheme is based around technologies which are currently available and proven, and which can be integrated into the Application Site in a phased approach, such that all phases of the Proposed Development can meet the CO_2 targets. In addition, the proposed scheme presents an acceptable level of risk, both in terms of the technology (all of which have a proven track record), but also in terms of fuel supply.

It is likely that during the lifetime of the Proposed Development, new technologies and fuels will become available which offer advantages over the current options. An important factor to consider is the phased construction. Once the site is complete, alternative forms of energy generation may become viable. As outlined in this report, an important technology category which may become more mature in this timeframe, and more technically viable on the complete development is biomass CHP (using either wood or waste). In light of this, a one hectare site has been set aside in the development for a potential future energy centre (biomass CHP plant).

Structure of the Document

This energy statement is structured into 4 sections:

Section 1 describes the Proposed Development and defines the minimum targets and standards which apply following a review of relevant policy and legislation.

Section 2 summarises the technical analysis conducted which ranges from an assessment of the baseline conditions through to a feasibility assessment of a range of measures and technologies aiming to reduce CO_2 emissions.

Section 3 discusses how these measures may be used to meet the specific policy requirements and form a strategy for the development.

Section 4 summarises the preferred approach to the energy strategy and proposes how this strategy might evolve in the long-term.

Section 1: Background

Section 1 of the Carbon Reduction Strategy Part A describes the development, and defines the minimum targets and standards which apply following a review of relevant policy and legislation. It is split into the following chapters:

1.1 Introduction

1.2 Policy review

1.3 Defining minimum targets and standards

1.1 Introduction

The North West Cambridge Development (“the Application Site”) (“the Proposed Development”) proposed by the University of Cambridge (“the Applicant”) is a strategic extension to the City of Cambridge. The Application Site has a prominent position with circa 150 hectares of land in a triangle between Madingley Road, Huntingdon Road, and the M11 motorway. The scale of the Proposed Development is major for Cambridge and this, combined with the Application Site’s geographical spread over Cambridge City Council and South Cambridgeshire District Council has led to the development of an Area Action Plan (AAP) document. The AAP sets out a number of requirements for providing sustainable energy and reducing CO_2 emissions from the Application Site. This in combination with future developments in Part L of the building regulations means that the definition of an energy and carbon reduction strategy for the Application Site is not only challenging but also vital to the success of the scheme.

This document, Part A of the Carbon Reduction Strategy, analyses a number of energy strategy options leading to the development of a preferred option for submission as part of the planning application. This is in response to the Area Action Plan which states that:

> *A Carbon Reduction Strategy which will set out the broad strategy for the site as a whole will need to be submitted and approved alongside the Masterplan and further detail will be required alongside subsequent planning applications.*

The calculations in this report pertain to one way in which the site could develop based on the application proposals.

1.2 Policy review

Introduction

There is now a comprehensive range of legislation and policy at various governmental levels which supports the development and implementation of low carbon and renewable energy investments.

At the international level, the Kyoto Protocol is currently being updated with the latest United Nations Climate Change Conference (COP 16) held at Cancun in Mexico in December 2010. The 'Bali Roadmap', an output from the Climate Change Conference in Bali (December 2007) set out a two year process to finalise a new legally binding international treaty at the United Nations Climate Change Conference in Copenhagen in December 2009 (COP15).. However COP15 did not produce a legally binding treaty. Politicians from the 192 participating countries recognised - through the Copenhagen Accord - the scientific view that the temperature increase should be held below a 2°C rise, and promised financial aid to developing countries to help them adapt to climate change.

The Cancun meeting in December 2010 established for the first time, an international commitment to 'deep cuts in global greenhouse gas emissions' to hold the increase in global average temperature below 2 degrees Celsius. This includes processes for adopting targets for peaking emissions as soon as possible, and substantially reducing them by 2050.

The conference also adopted decisions to develop systems for measuring, reporting and verifying emission reductions and actions in line with countries' commitments.

The Cancun conference agreed the framework for 'REDD plus': reducing emissions from deforestation and forest degradation, through which developing countries will be paid for keeping trees standing rather than logging them.

The conference also agreed the establishment of a Green Climate Fund to support policies and activities in developing countries. The Fund will be governed by a board with equal representation from developed and developing countries, and its finances will be managed by the World Bank. A transitional committee will be established to design the institutions and operations of the Fund. The conference endorsed the commitment made by developed countries at Copenhagen to mobilise at least $100 billion per year by 2020 to address the needs of developing countries.

The conference did not settle the future of the Kyoto Protocol, and nor did it adopt a new and more comprehensive treaty incorporating all countries. More work is needed to reach this point, but all countries with the exception of Bolivia signed up to the commitments made at Cancun.

The UK is already committed to meeting European CO_2 and energy targets, agreed between the European Commission and the Member States. The European Union has agreed to reduce CO_2 emissions by 20% on 1990 levels by 2020, with an intention to increase this target to 30% if international agreement is reached which commits other developed countries and the more advanced developing nations to comparable reductions.

This section describes the national and local policy which impacts development in the UK and Cambridge, resulting from the international commitments to reduce CO_2 emissions. As this document will make clear, many policies and regulations are under review at the moment, including Building Regulations Part L for 2013 and 2016, Government incentives (e.g., CRC, Green Deal, renewable heat incentive) and The Code for Sustainable Homes. This policy review will therefore be subject to revisions over the development process. The energy strategy set out in this work aim to make use of the best forecasts of future policy direction but also to be flexible to potential variations.

It is important to note that with the change in Government in May 2010, the long term status of many of the national policy documents discussed below is unknown. However at the point of writing, these are the most recent and applicable policy documents available.

National Climate Change and Energy Legislation and Policy

The Climate Change Act (2008)

The Climate Change Act sets a legally binding target for reducing UK carbon dioxide (CO_2) by at least 80% by 2050. It also provides for a Committee on Climate Change which sets out carbon budgets binding on the Government for 5 year periods. In Budget 2009 the first three carbon budgets were announced which set out a binding 34% CO_2 reduction by 2020. The CCC also produces annual reports to monitor progress in meeting these carbon budgets. As a result of the Climate Change Act, a range of policy at national and local level has been developed aimed at reducing carbon emissions. An important impact of this is targets for the development of renewable electricity which will influence the energy strategy selected for the Proposed Development.

Carbon Budgets (2011)

The Committee on Climate Change is an independent body established under the Climate Change Act (2008). The Committee has been tasked with advising the UK Government on preparing for Climate Change, and in particular, developing recommendations on future carbon budgets, effectively legally enforceable CO_2 reduction targets. Four budgets have now been published for 5 year timescales between 2008 and 2027. The Committee published their recommendations on the fourth carbon budget (covering 2023 – 2027) in December 2010, and following an impact assessment, the target was set at a 50% CO_2 reduction from 1990 levels in May 2011, and adopted as law under the Climate Change Act in June 2011. This legally binding target will help drive the development of future UK policy and regulation aimed at reducing CO_2 emissions.

Annual Energy Statement (2010)

The new coalition Government has committed to publishing an Annual Energy Statement (AES) with the aim of providing market direction and setting strategic energy policy. The first AES was published in July 2010 and sets out 32 actions the government proposes to take covering the following areas:

- Saving energy through the Green Deal and supporting vulnerable consumers
- Delivering secure energy on the way to a low carbon energy future
- Managing our energy legacy responsibly and cost-effectively
- Driving ambitious action on climate change at home and abroad

The AES refers to the 2050 pathways analysis conducted by DECC which examines potential energy mix options in 2050 looking at both supply and demand scenarios. This will lead to the development of roadmaps for technologies so that more strategic decisions can be made for the investment of technology and infrastructure.

Comprehensive Spending Review (2010)

The Comprehensive Spending Review (CSR) published in October 2010 is the new Coalition Governments response to the current economic downturn, examining methods by which national Government spending can be reduced, or made more efficient. The following announcements were made in relation to energy:

- Review of Feed in Tariffs (FITs). The CSR announced that the overall level of FITs will be reviewed, with the expectation that the tariffs set for some technologies may be reduced.
- Commitment to the Renewable Heat Incentive (RHI). The government has still not published the final proposals for the RHI, but has committed to introducing a scheme. However there is still no indication of the potential levels which will be set.
- Review of the Carbon Reduction Commitment (CRC). The CSR announces that CRC funds will not be recycled, and that the CRC will therefore operate more as a tax than a market incentive scheme. This means that the costs for all participants are likely to be higher overall.

UK Low Carbon Transition Plan (2009)

The previous Government launched the UK Low Carbon Transition Plan on 15th July 2009. The Plan includes the Renewable Energy Strategy[1] (white paper) and Low Carbon Industrial Strategy. The UK Low Carbon Transition Plan is a Government white paper that sets out policies required to ensure that the UK meets its binding commitment (set legally under the Climate Change Act by the Committee on Climate Change) to reduce carbon emissions by 34% by 2020. The principal policies set out in the document include:

- Getting 40% of our electrical energy from low and zero carbon sources by 2020?
- Rolling out smart meters in every home by 2020.
- Opening a competition for 15 towns, cities and villages to be at the forefront of pioneering green innovation.

UK Renewable Energy Strategy (July 2009)

The Renewable Energy Strategy is a companion document to the UK Low Carbon Transition Plan and describes the measures needed to deliver the UK's target of generating 15% of its total energy from renewable sources by 2020, towards its contribution to the EU's 20% target. It identifies planning, along with other factors, as a potential barrier and proposes changes comparable with the current policy framework for housing delivery. These changes include:

- A rigorous assessment of the local potential for renewable energy;
- Disaggregating local authority specific targets from the regional level;
- Ensuring sufficient allocation of sites or areas to secure the achievement of the target;
- Greater clarity on the available land resource;
- Identifying renewable energy 'growth points'; and
- It also proposes establishing a renewables advisory body.

The Renewable Energy Strategy confirms that a Renewable Heat Incentive will be implemented from April 2011. Tariffs will be payable to energy users generating their own renewable heat. All common forms of renewable energy generation are likely to be included. The RHI consultation was published in Spring 2010 with potential tariff levels which have been included in this analysis. The final proposals for the RHI are still awaited.

Consultation on Renewable Electricity Financial Incentives 2009

This companion document to the UK Low Carbon Transition Plan seeks views on two mechanisms to provide financial incentives for the generation of low carbon and renewable electricity:

- the Renewables Obligation (RO); and
- Feed-In Tariffs (FITs).

Tariff levels have been set for FITs and the scheme started operation in April 2010. However whilst there is commitment to FITs from the Government, the levels may alter (see "Comprehensive Spending Review"). The consultation on the RHI has now closed, but due to the change of Government, final proposals have not been set.

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[1] The Renewable Energy Strategy, DECC, July 2009

Household Energy Management Strategy (2010)

The Household Energy Management Strategy sets out plans for reducing CO_2 emissions from the residential sector by 29% by 2020. Proposed mechanisms included extensive retrofits of energy efficiency measures to 7 million existing homes, and a focus on developing district heating networks and decentralised energy by supporting Local Authorities. Financing models including "Pay as you save" are discussed where homeowners are provided with retrofits free of capital and pay back over a number of years.

Definition of Zero Carbon Homes and Zero Carbon Non-Domestic Buildings Consultation (2008)

The Definition of Zero Carbon Homes and Non-Domestic Buildings consultation sought to clarify the definition of zero carbon that will be applied to new homes and, to a lesser extent, all other buildings through the building regulations. This followed work by the Green Building Council on the Definition of Zero Carbon which identified that the majority of new developments cannot achieve carbon neutrality on-site. The definition of zero carbon in both domestic and non-domestic buildings will therefore include a percentage of off-site low carbon investment termed "Allowable Solutions". The consultation sought agreement on the level of on-site carbon mitigation required to meet a Zero Carbon Standard.

A ministerial statement from the Rt. Honourable John Healy on 16 July 2009 announced that the preferred level of "carbon compliance" (i.e., on-site carbon mitigation) would be set at 70% with reference to 2006 Building Regulations. This means that all homes built after 2016 will have to meet this level of on-site carbon mitigation either through energy efficiency or low and zero carbon technologies such as wind, solar or district energy and CHP.

In Budget 2008, the Government also announced its ambition that all new non-domestic buildings should be zero carbon from 2019 (with earlier targets for schools and other public buildings).

Note; a more detailed discussion on the Definition of Zero Carbon follows this section. The latest position on zero carbon is being developed by the Zero Carbon Hub, supported by AECOM.

National Planning Legislation and Policy

PPS: Planning and Climate Change – Supplement to PPS1: Delivering Sustainable Development (2007)

The Climate Change Planning Policy Statement requires regional planning bodies to:

- Consider how the spatial strategy will support any regional targets on climate change (paragraph 12);
- Consider the potential to build more efficient energy supply and increasing contributions from renewable and low carbon energy sources into new and existing development (paragraph 13);
- Provide a framework for sub-regional and local planning to focus substantial new development on locations where energy can be gained from decentralised energy supply systems, or where there is clear potential for this to be realised (paragraph 13); and
- Ensure opportunities for renewable and low carbon sources of energy supply and supporting infrastructure, including decentralised energy supply systems, are maximised (paragraph 13).

Consultation on Planning Policy Statement: Planning for a Low Carbon Future in a Changing Climate (2010)

Published on 9 March 2010, the consultation document reviews and consolidates the Planning Policy Statement (PPS) 1 Supplement on planning and climate change and PPS22: Renewable Energy. The consultation, which closed on 1st June 2010, encourages councils to plan for low carbon and renewable energy on a strategic level via the development of planning policies that encourage the introduction of decentralised energy systems where proven viable. The document states that:

- Regional strategies should plan for new development in locations that provide for decentralised energy and particularly decentralised heat.

- Local authorities should design their policies to “support and not unreasonably restrict renewable and low carbon energy developments”.
- Local authorities are instructed to "ensure that their development management does not prevent, delay or inhibit proposals for renewable and low-carbon energy" and recognise “that small-scale projects provide a valuable contribution to cutting greenhouse gas emissions”.

The Planning and Energy Act (2008)

The Planning and Energy Act came into force on 13th November 2008 and enables local planning authorities to set requirements for energy use and energy efficiency in local plans. While adding little to the provisions of the Climate Change PPS, the Act sets in statute the role of planning bodies in setting energy targets.

The Recent Planning Acts (1990, 1991, 2004 and 2008) and other more recent policy

Planning and Compulsory Purchase Act 2004 places sustainable development at the heart of the planning system. Implementation of the Act is guided by Planning Policy Statements (PPS) covering a range of issues. In addition to the Climate Change PPS outlined above, those of particular relevance are:

- PPS3 (housing) sets out policies on increasing housing supply and density.
- PPS11 (Regional Spatial Strategies).
- PPS12 (Local Spatial Planning)
- PPS22 (Renewable Energy)
- The Localism Bill
- The Draft National Planning Policy Framework (July 2011)

More recently, the Planning Act 2008 received Royal Assent on 26th November 2008. This has introduced a new planning approval process for “nationally significant infrastructure projects”, which for energy projects would mean schemes over 50MW. The initial aim was that such projects will be required to obtain development consent from the new “Infrastructure Planning Commission” (IPC), but will be exempt from the current requirements to obtain planning permission and other statutory approvals defined by section 33(1) of the Planning Act. Policy for the purposes of the Planning Act is set out in National Policy Statements (section 5 (1-2)). However the new coalition Government will scrap the IPC in the November 2010 Decentralisation and Localism Bill as part of its review of planning policy and the replacement mechanism will be the Major Infrastructure Planning Unit.

Projects within the existing scope of “nationally significant infrastructure project” are defined in section 14 and include the construction of or extension of a generation station (section 14(1) (a)) and the installation of electricity lines above ground (section 14(1) (b)). District heating networks are not currently within this scope although other types of pipeline are included.

The Act also introduced the Community Infrastructure Levy (CIL). Section 205(2) of the Act details that the overall purpose of CIL is to ensure that costs incurred in providing infrastructure to support the development of an area can be funded (wholly or partly) by owners or developers of land.

The Localism Bill

The Localism Bill devolves powers to councils and neighbourhoods and aims to give local communities more control over housing and planning decisions. It includes measures to reform the planning system, the provision of housing and a range of local authority governance issues. The Bill will abolish Regional Spatial Strategies (which set a regional-level planning framework for England) and will establish neighbourhood plans and neighbourhood development orders, by which it is intended that communities will be able to influence council policies and development in their neighbourhoods.

Announcements around the localism bill suggested that the Government intends to introduce a 'presumption in favour of sustainable development' as set out in the Conservative Party's 2010 Green Paper 'Open Source Planning' and then in the Coalition Agreement. The presumption is that:

> *individuals and businesses have the right to build homes and other local buildings provided that they conform to national environmental, architectural, economic and social standards, conform with the local plan, and pay a tariff that compensates the community for loss of amenity and costs of additional infrastructure.*

The presumption, however, does not feature in the Localism Bill. It has instead been included in a new overarching Government planning policy document, the National Planning Policy Framework (NPPF).

The Draft National Planning Policy Framework (July 2011)

The Government has recently published the draft National Planning Policy Framework ("the Draft NPPF") for consultation. The NPPF will replace the current suite of National Planning Policy Statements, Planning Policy Guidance notes and some Circulars with a single, streamlined document.

The NPPF will set out the Government's economic, environmental and social planning policies for England. Taken together, these policies articulate the Government's vision of sustainable development, which should be interpreted and applied locally to meet local aspirations. The Draft NPPF continues to recognise that planning system is plan-led and that therefore Local Plans, incorporating neighbourhood plans where relevant, are the starting point for the determination of any planning application. In assessing and determining development proposals, local planning authorities should apply the presumption in favour of sustainable development and seek to find solutions to overcome any substantial planning objections where practical and consistent with the NPPF.

On climate change the Draft NPPF states that the Government's objective is that planning should fully support the transition to a low carbon economy in a changing climate, taking full account of flood risk and coastal change. To achieve this objective, the planning system should aim to:

• secure, consistent with the Government's published objectives, radical reductions in greenhouse gas emissions, through the appropriate location and layout of new development, and active support for energy efficiency improvements to existing buildings and the delivery of renewable and low-carbon energy infrastructure ; and

.• when setting any local requirement for a building's sustainability, do so in a way consistent with the Government's zero carbon buildings policy and adopt nationally described standards. If local councils wish to set their own targets they can, and the policies in the Framework would not prevent such targets provided in their implementation they do not make development unviable.

The Draft NPPF also promotes a proactive approach to identifying opportunities for renewable and low carbon energy.

Regional Planning Policy

It should be noted that with the change of Government in May 2010, regional powers are in the process of being abolished which will probably result in the removal of regional level policy relating to planning and development. However planning policy under the previous Government informed the preparation of the AAP which is the principal planning guidance. Since the AAP still provides the overall planning context for the Application Site, the following discussion of policy is still relevant.

East of England Regional Assembly – The Regional Spatial Strategy

Regional Spatial Strategies are the top tier of the Statutory Development Plan in all regions of England and have the specific objective of contributing to sustainable development.

The East of England Regional Spatial Strategy provides the framework for local planning policy in response to the following identified sustainability drivers:

- Putting in place a framework that promotes sustainable development, especially to address housing shortages, support the continued growth of the economy and enable all areas to share in prosperity, whilst driving up energy efficiency and carbon performance, improving water efficiency and recycling an increasing percentage of waste;
- Reconciling growth with protection of the environment and avoiding adverse effect on sites of European or international importance for nature conservation;
- Concentrating growth at the key centres for development and change, which include all the region's main urban areas and have potential to accommodate substantial development in sustainable ways to 2021 and beyond, whilst maintaining the general extent of the green belt;

The Revision to the Regional Spatial Strategy for the East of England, the East of England Plan (May 2008)

Following proposed changes to the Draft Regional Spatial Strategy in December 2006, Policy ENV8 has been revised and strengthened by splitting it into policies ENG1 and ENG2:

Policy ENG1: *Carbon Dioxide Emissions and Energy Perform*ance states that local authorities should:

- Encourage the supply of energy from decentralised, renewable and low carbon energy sources and through Development Plan Documents set ambitious but viable proportions of the energy supply of new development to be secured from such sources and the development thresholds to which such targets would apply. In the interim, before targets are set in Development Plan Documents, new development of more than 10 dwellings or 1000m^2 of non-residential floor space should secure at least 10% of their energy from decentralised and renewable or low carbon sources, unless this is not feasible or viable;
- Promote innovation through incentivisation, master planning and development briefs which, particularly in key centres for development and change, seek to maximise opportunities for developments to achieve, and where possible exceed national targets for the consumption of energy. To help realise higher levels of ambition local authorities should encourage energy service companies (ESCOs) and similar energy saving initiatives.

Policy ENG2: *Renewable Energy Targets* states that:

- The development of new facilities for renewable power generation should be supported, with the aim that by 2010 10% of the region's energy and by 2020 17% of the region's energy should come from renewable sources. These targets exclude energy from offshore wind, and are subject to meeting European and international obligations to protect wildlife, including migratory birds, and to revision and development through the review of this RSS

Local Planning Policy

North West Cambridge Area Action Plan

The main local policy for the Application Site is the Area Action Plan adopted in October 2009. This sets out a number of standards which the development must achieve. The main clauses in this policy relating to energy are the following:

- Code for Sustainable Homes. All dwellings after 2013, and over 50 dwellings before 2013 will be required to meet Code level 5. This requires a reduction in regulated emissions of 100% from 2006 Building Regulations. Currently the requirement is for this to be achieved on site, although it is anticipated that the requirements will fall into line with national building regulations, and a carbon compliance limit and an Allowable Solutions mechanism will be introduced. Additional non-mandatory credits are available in the Code for providing up to 15% CO_2 reduction through low and zero carbon LZC technologies.

- BREEAM. BREEAM Excellent is required for all non-domestic buildings. This means that a B-rated (or better) EPC is mandatory, requiring significant reduction in CO_2 emissions from national regulations for air-conditioned buildings, but smaller reductions in CO_2 for naturally ventilated. Additional credits are available in BREEAM for the inclusion of LZC technologies and community heating and / or CHP. It should be noted that the current 2008 BREEAM schemes are likely to be updated before the Proposed Development requires assessments, and may in future use an alternative energy credit calculation procedure.
- All non-residential development should achieve a 20% reduction in CO_2 emissions using renewable energy technologies where a renewably fuelled decentralised system is not viable.

Other local policy

Other local policies relating to energy include:

- Cambridge City Council Supplementary Planning Document on Sustainability. This requires a 10% reduction in CO_2 emissions from renewable energy technologies. Gas fired CHP is not classed as renewable but may be considered as a contribution. Passive solar design is considered a renewable technology in this guidance and CO_2 savings resulting from passive solar design can contribute to the 10% CO_2 reduction target.
- South Cambridgeshire District Council Development Plan Document. The South Cambridgeshire DC has a number of policies relating to energy. Policy NE/1 requires a 10% reduction in CO_2 emission from regulated levels through energy efficiency improvements, and NE/3 requires 10% of the remaining energy demands to be met by renewable technologies.

Local Policy Discussion

Cambridge City Council's SPD on Sustainability and South Cambridgeshire District Council's Development Plan Document are included above for completeness, however the Local Authority informs us that, since the Proposed Development is subject to an Area Action Plan, they are not applicable.

Nonetheless, Cambridge City Council's Supplementary Planning Document on Sustainability contains detailed information on the form and content required of an Energy Statement and it is our intention to follow the broad principles outlined in this document.

A number of different task groups have been used throughout the evolution of the Propsed Development. These comprise a number of Cambridge City Council, South Cambridgeshire DC, and Cambridgeshire CC representatives. The Energy and Waste Task group, led by Cambridgeshire Horizons, has been used to discuss the energy and waste proposals, but also the wider sustainability framework. The following summarises our interpretations of these discussions:

- Energy and carbon reductions will be reported in line with PPS1 and the Inspector's report. Namely that any target percentage reductions in CO_2 emissions through renewables will be met through decentralised energy on site. This is defined in the inspector's report thus:

  The term 'decentralised' refers to site-wide systems and smaller scale systems for groups or individual dwellings. There are a number of different types of decentralised energy systems, either fuelled by renewable energy or fossil fuels, which might be appropriate for use at North West Cambridge. The carbon emission savings will vary depending on the technology and fuel used. For example a renewably fuelled CHP system will have lower carbon emissions than a fossil fuelled system. This site, with its proposed mix of uses, is likely to be very suitable for CHP. The Policy requires that any proposals include the system that can viably deliver the greatest carbon savings for the site as a whole, bearing in mind factors such as technical and financial viability and phasing of the development. "

Gas-fired CHP with district heating may be a viable technology, at least in the short and medium term, for meeting carbon reduction targets and this is considered, for the purposes of this report as a decentralised form of energy.

Similarly, the economics of building integrated technologies, such as photovoltaic panels, have been transformed recently through Government incentives (FITs, and in the future the RHI) and, for the purposes of this report, these technologies are considered as decentralised.

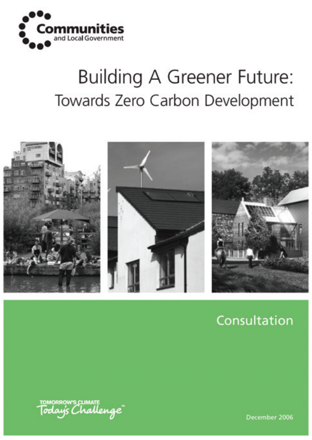
- As required in Cambridge City Council's SPD on sustainable construction and is in line with the reporting guidelines in BREEAM, energy consumption, where reported in detailed Energy Statements, will be modelled according to the latest National Calculation Methodology in force, i.e. Building Regulations 2010 and not on actual simulations of energy use based on expected occupancy patterns etc.
- Energy consumption will be modelled at detailed design stage assuming a changing climate according to the UKCIP climate change scenarios with the objective that the buildings are designed to be adaptable to climate change.

1.3 Defining minimum targets and standards

Introduction

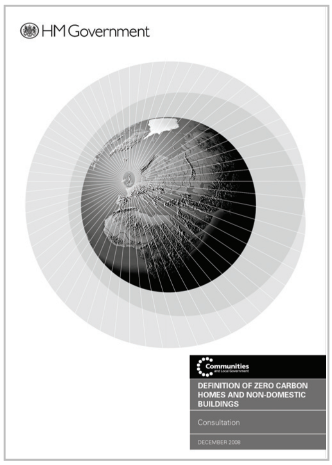
As can be seen from the previous section, there is a raft of policy relating to energy and CO_2 emissions in the built environment. One challenge is to develop a set of common targets which meet the requirements of all of these. Another challenge is to develop proposals which meet both the current and potential future revisions of this policy. In this section we examine in more detail main drivers for energy and CO_2 emissions on the Application Site, Part L of the Building Regulations, and the Code for Sustainable Homes.

The Building Regulations – Part L Conservation of Fuel and Power The Part L Building Regulations cover the conservation of fuel and power. The Building Regulations first started to turn its focus on reducing CO_2 emission in the 2002 revisions of Part L. Revisions to Part L 2006 brought the UK Building Regulations in line with the EU's Energy Performance of Buildings Directive (EPBD). The 2006 revisions to Part L (non domestic) required a 23.5% saving over the 2002 standards for fully naturally ventilated spaces and 28% savings for mechanically ventilated and cooled spaces. For domestic buildings, a 20% improvement was required over 2002 standards. Part L 2010 was introduced in October 2010, and requires a further 25% reduction in regulated CO_2 emissions over the 2006 standard.



Following consultation, the Government's Building a Greener Future: Policy Statement announced in July 2007 that all new homes will be zero carbon from 2016. In Budget 2008, the Government also announced its ambition that all new non-domestic buildings should be zero carbon from 2019 (with earlier targets for schools and other public buildings).

With the government setting out a clear goal of all new homes and schools being net zero carbon by 2016 and all other new buildings by 2019, focus has turned to the final definition of zero carbon and the suitable intermediary step changes in requirements in 2013.



The initial intention of these 'zero carbon' targets was for all the CO_2 emissions reduction to be made on the development site or through systems directly connected to the site, for example private wire systems or heat networks. However a number of assessments of the policy led to the finding that, on a large number of sites, meeting the higher targets may not be possible due to the inability to incorporate appropriate technologies.

In December 2008 the Government published Definition of Zero Carbon Homes and Non-Domestic Buildings: Consultation followed on the definition of zero carbon homes and in particular an approach based on:

- high levels of energy efficiency in the fabric of the home
- a minimum level of carbon reduction to be achieved onsite or through directly connected heat; and
- a list of (mainly offsite) Allowable Solutions for dealing with the remaining emissions (including from appliances)

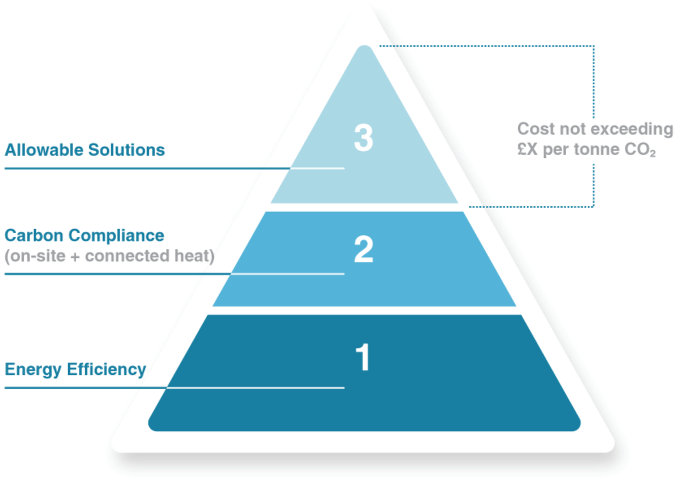


Figure 1. The proposed energy hierarchy set out in the Government's consultation on the Definition of Zero Carbon Homes.

The government then announced in July 2009 that the Zero Carbon Definition will follow the methodology outlined in the 2008 consultation with the Carbon Compliance element set at 70% of regulated emissions (the DER). The Carbon Compliance (expressed as a % of the regulated load emissions) sets a minimum fraction of emissions which must be reduced by on-site measures, such as energy efficient building design and low and zero carbon technologies. Policy development in the non-domestic sector is some time behind the domestic sector, but a similar system is proposed, with a carbon compliance level set at 54% in the aggregate[2], as outlined in the Consultation "Zero Carbon for new Non-Domestic Buildings" (November 2009)

Finally, the Government announced in its March 2011 budget that it would be adopting the recommendations of the Zero Carbon Hub in its report Carbon Compliance: Setting an appropriate limit for zero carbon new homes - Findings and Recommendations (published February 2011). This document makes recommendations to change the metric for carbon compliance from a relative percentage (i.e. 70% reduction) to an absolute emission of carbon dioxide (kg/m2) that is differentiated between dwelling types (flat, terraced house, detached house). In effect this reduces the target from 70% to:

- 60% for detached houses
- 56% for attached houses
- 44% for low rise apartment blocks

Above the Carbon Compliance level, the remaining emissions can either be offset using more on-site technologies and efficiency measures, or through investment in an "Allowable Solution". An Allowable Solution is a method by which additional CO_2 reductions can be made either on the site or offsite using other means. Government is yet to make a definitive announcement on Allowable Solutions and there is therefore considerable uncertainly surrounding how they might be structured. The Zero Carbon Hub has published some recommendations for Allowable Solutions[3] which outline the following possibilities:

[2] The technical and economic viability of CO_2 reducing measures is very dependent on the use of non-domestic buildings, with large CO_2 reductions easier in some use-types than others. Therefore the Government is proposing an aggregate method, where different use-types will have different carbon compliance levels, such that with a typical build mix, the overall average will be around 54%.

[3] Allowable Solutions for Tomorrow's New Homes - Towards a workable Framework, Zero Carbon Hub, July 2011

'On-site' options

- Installation of smart appliances
- Application of 'flexible demand' systems (supporting demand side management)
- Use of grid-injected biomethane linked to the site by Green Gas Certificates
- Installation of communal heat accumulator (site based heat storage)
- Home electric vehicle charging
- Electricity storage for the home (to store electricity generated from PV panels)
- On-site waste management (Vacuum waste collection systems)
- LED street lights for the site

'Near-site' options

- Export of low carbon heat from site based district heating scheme (i.e. support for cost of pipe-work)
- Retro-fitting of low/zero carbon technologies to local communal buildings
- Investment in creation or expansion of locally planned sustainable energy infrastructure (e.g. district heating or on-site wind turbines)
- Investment in local electric vehicle charging infrastructure
- Investment in low carbon street lighting for local area Local micro-hydro schemes
- Communal waste management solutions
- Local energy storage solutions

'Off-site' options

- Investment in Energy-from-Waste plants (e.g. Anaerobic Digestion and Pyrolysis/Gasification plants)
- Investment in low carbon electricity generation assets up to a maximum determined scale eg excluding large scale off shore generation
- Investment in district heating pipe-work to connect new loads to existing schemes or support new schemes
- Investment in retro-fitting of low carbon technologies to communal buildings
- Investment in embodied carbon reduction initiative
- Investment in low carbon cooling
- Investments in energy storage and demand-side management/flexible demand projects to counter intermittent renewables

Allowable Solutions must provide genuine additional CO_2 reductions, and so simple offsetting measures such as the purchase of green electricity are not compliant as this would in turn effectively increase the CO_2 content of the remaining grid electricity. Methods to directly offset the emissions from the development could take a variety of forms, one example being a developer investing in wind farms, and then providing shares of the wind farm company to the house owner (these would be attached to the house and so passed on to subsequent occupiers).

The cost of meeting the Allowable Solutions is proposed to be capped, such that in difficult areas, developers are not penalised. The Allowable Solutions proposal can thus effectively be seen as a potential income stream from new development. The consultation on zero carbon homes suggests a lower value similar to the shadow price of carbon (about £40 per tonne CO_2) to an upper limit circa £200 per tonne CO_2. These values would be based on a lifetime (expected at 30 years) so if a building is one tonne of CO_2 reduction short of the target, the maximum expenditure for Allowable Solutions would be £200 X 1 tonne CO_2 X 30 years = £6000. The Government impact assessment has assumed this central cost of £75 over 30 years and so it is likely that this is their preferred option.

It is currently unknown how an Allowable Solutions scheme would work and who would be in charge of implementing it. However one mechanism which may be used is the use of a fund which developers would pay into, and which is then used for low carbon projects. Indeed Cambridgeshire County Council is in the process of setting up such a carbon offset fund which is likely to be a precursor of the allowable solutions mechanism. The fund is being linked to investment in low carbon district heating schemes in the County.

When discussing future CO_2 emissions limits, the Code for Sustainable Homes is often referred to due to the use of mandatory CO_2 reduction levels at each level of the Code. These are 25%, 44%, and 100% reduction in regulated emissions at Code levels 3, 4, and 5, and 100% reduction in regulated and un-regulated emissions at Code level 6. (Note that these reductions are in relation to Part L 2006). The 2010 version of the Code does not include the Carbon Compliance / Allowable Solutions mechanism due to an absence of a recognised Allowable Solutions scheme, but it is expected this will be included in the Code once defined (Allowable Solutions was included in the initial consultation on the 2010 version of the Code in the expectation that a scheme would be in place).

Figure 2 below illustrates the latest Government published advice on CO_2 reduction targets, with reductions in regulated and un-regulated loads, and the fractions which are required from Carbon Compliance, and possibly Allowable Solutions. It should be noted that in the March 2011 Budget the government announced that the definition of zero carbon no longer includes unregulated emissions (appliances). This means that zero carbon homes in 2016 will need to meet the energy requirements of Code 5 (rather than Code 6) and therefore homes on North West Cambridge will not have to meet the energy requirements of Code 6 post 2016.

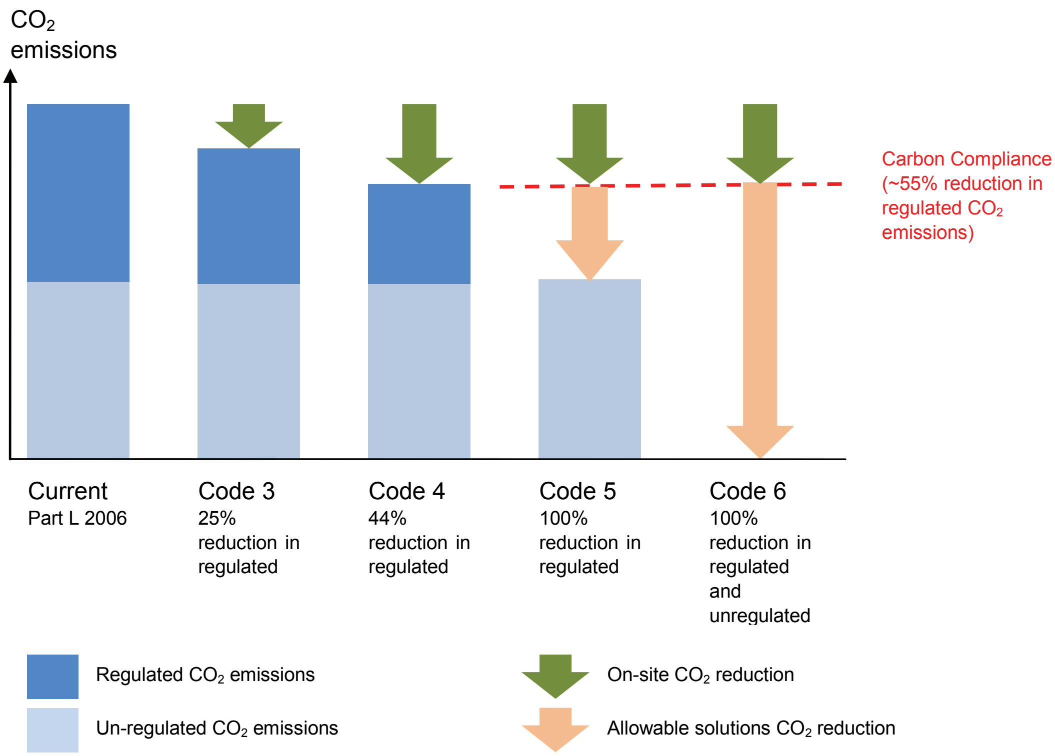


Figure 2. CO_2 emission targets under proposed revisions for Part L of the building regulations (2006), and their relation to the Code for Sustainable Homes.

Code for Sustainable Homes

The Code for Sustainable Homes is an environmental assessment system for new housing in England which was introduced in April 2007 based on BRE's EcoHomes scheme. The Code assesses a development against a set of criteria under nine main categories. The latest version dates from 2010. The Code awards a rating to each dwelling type within the development based on a scale of Level one to six (denoted by stars) as shown in Table 1. The rating depends on whether the dwellings meet a set of mandatory standards for each level, as well as an overall score.

Mandatory requirements exist under the following credits:

- Energy
- Water
- Embodied Impacts of Construction Materials;
- Surface Water Runoff;

- Construction Site Waste Management;
- Household Waste Storage Space and Facilities.

The credits achieved for each dwelling type are then multiplied by the environmental weighting factor for each category to calculate the number of points achieved.

The biggest influence on the cost of Code compliance is the mandatory CO_2 reduction target. The Code for Sustainable Homes CO_2 reduction targets are aligned with the building regulations and future revisions as described in the previous section. The code was originally related to Part L 2006, and the targets in the current version of the Code remain the same, but with adjustments to use Part L 2010 as the baseline. The Code sets additional mandatory requirements for energy efficiency at levels 5 and above as discussed later in this report.

Another important mandatory credit is for water consumption. At levels 3 and 4, the Code requires a maximum potable water demand per person of 105 litres per day. This can generally be achieved using highly efficient water fittings. At levels 5 and 6, the demand it limited to 80 litres per person per day which required efficient fittings and some form of recycling (rain water or grey water).

The following table summarises the overall credit requirements alongside those for CO_2 reduction and water consumption.

Table 1. Minimum requirements for the six levels under the Code

Code Levels	**CO_2** Improvement over TER (Part L 2010)	**Water** litres/person/day	**Total Points** Score out of 100
Level 1 (★)	0% (compliance with Part L 2010 only is required)	120	36
Level 2 (★★)	0% (compliance with Part L 2010 only is required)	120	48
Level 3 (★★★)	0% (compliance with Part L 2010 only is required)	105	57
Level 4 (★★★★)	25%	105	68
Level 5 (★★★★★)	100%	80	84
Level 6 (★★★★★★)	Zero Carbon	80	90

Combined policy and regulation requirements

The above overview provides a very high level summary of energy policies which will affect the development. The majority of this discusses the building regulations and proposed changes – these will be the overlying driver for Proposed Development and will influence standards required by councils and rating schemes.

It is important to recognise that over the phasing of the development, council policy (in particular simple percentage-type policies) is likely to change as building regulations "catch-up". Rating schemes may also alter their standards / assessment procedures to fit in line with the national methodologies.

The review provides a number of parameters which must be considered the site energy strategy for the Application Site. In summary:

A. Buildings should be built to a high level of energy efficiency, potentially to higher standards than required under national regulation. This includes the consideration of passive solar design.

B. Most phases will be required to meet significant CO_2 reductions overall, leading to net zero carbon from 2016 for domestic and 2019 for non-domestic.

C. All dwellings approved on or after 1 April 2013 (and before 2013 if over 50 dwellings) will probably be required to provide at least a 70% CO_2 reduction in regulated loads using on-site technologies (assuming the Code definition aligns with predicted national building regulations and that 70% is selected as the carbon compliance level).

D. Additional CO_2 savings will be required (up to net zero carbon which includes non-regulated loads) either on-site or offsite through Allowable Solutions.

E. A certain element of renewable energy will be required to meet the percentage targets.

Due to the high overall CO_2 reduction targets, it is likely that any strategy will need to include a large element of renewable energy technologies. In addition, reducing energy demand with energy efficiency improvements is usually the most economic route up to a certain limit and forms the first part of any energy / CO_2 reduction hierarchy.

Section 2: Technical assessment and feasibility analysis

The previous section provides a description of the development and discusses the drivers for reducing CO_2 emissions. This section of the report summarises the technical analysis conducted, from assessing the baseline conditions through to a feasibility assessment of a range of measures and technologies aiming to reduce CO_2 emissions. The section is split into the following chapters:

- 2.1 Initial opportunities and constraints scoping
- 2.2 Baseline consumption and emissions
- 2.3 Building design and energy efficiency
- 2.4 Daylighting
- 2.5 Low and zero carbon technology options

2.1 Initial opportunities and constraints scoping

Introduction

Before conducting any detailed analysis, an initial exercise of examining the opportunities and constraints posed by the Application Site was completed. A summary of this is as follows.

Opportunities offered by the Application Site

The Proposed Development offers a number of opportunities for implementing low and zero carbon energy strategies:

- Large development. The size and scale of development means that larger systems may potentially be considered which are either not suitable for smaller scale sites, and / or offer greater economies of scale. An example is biomass CHP which has very few commercial offerings at the small scale, but an increased number of examples at the larger scales. However, in the context of biomass CHP, even the Proposed Development as a stand-alone site is still relatively small.
- Mixed development. The mixed nature of the Proposed Development combining domestic and non-domestic uses may mean that the overall energy load is more constant, presenting a more suitable baseload to district heating based technologies.
- Absence of existing infrastructure. The lack of existing infrastructure may enable site-wide energy schemes such as district heating to be installed at lower cost.
- Adjacency to other areas. Links to other sites such as West Cambridge to the south of Madingley Road may provide further opportunities for a larger scale district energy system, improving both the performance and economics for the Proposed Development in addition to providing CO_2 and energy benefits to the neighbouring sites. The Applicant's ownership of both sites considerably improves the potential of a joint scheme. However this does not form part of this planning application which is concerned only with the Application Site.
- Relatively good transport links. The Application Site is accessed by a two strategic links into Cambridge. This may assist with incoming fuel, for example the delivery of biomass.
- Mid-density housing. The Proposed Development has a mix of housing densities and commercial buildings combined with large areas of open space. The flexibility offered in the application proposals could allow the inclusion of technologies which may not be feasible on a more compact high density urban site.

Limitations posed by the Application Site

The Application Site also poses a number of limitations or issues which need to be considered in the development of an energy strategy. Examples include:

- Long term phasing. The phasing of the Proposed Development over 13 years or more means that a strategy should meet the needs of each phase whilst taking advantage of the opportunities of the overall scale of the site. This may require a phased strategy which includes some redundancy or over-provision in the earlier years.
- Uncertain future build-out. Alongside the long term phasing are unknowns around future building types, especially in the non-domestic sector. The strategy needs to be flexible to allow a range of building types and scales to be connected without requiring subsequent infrastructure modification.
- Visual impact. The Proposed Development is seen as a gateway to Cambridge and should take account of design aesthetics whilst recognising that the inclusion of LZCs can provide a showcase of sustainability.

- Viability. The Proposed Development is to deliver 1,500 key worker housing units for University and College staff. This places a strong emphasis on economic viability of the private house sales to fund the key worker housing. This requirement may limit the extent to which low and zero carbon solutions can be incorporated onto the Application Site.

These opportunities and constraints are all explored in further detail in the following sections, with full analysis of technology and strategy options.

2.2 Baseline consumption and emissions

Energy demands from the baseline site

The North West Cambridge Area Action Plan contains a requirement for the 2006 Building Regulations to be used as a baseline for the calculation of the percentage savings to be realised from on-site renewable energy.

Following meetings with the Energy and Waste Task group, it has been agreed to use metered data from real buildings as a benchmark for non-domestic buildings rather than the purely theoretical energy modelling provided in Part L which does not often accurately reflect in-use energy consumption. This will enable an understanding of what the actual loads may be taking into account user behaviour and process loads. For domestic buildings, there is a greater correlation between modelled data and consumption and modelled data is assumed.

This presents something of a dilemma however in that there is a paucity of metered data for many building types and no guarantee that the metered data that is available is representative of a building just compliant with 2006 Building Regulations.

Where possible, therefore, building data has been obtained from well designed buildings from the last decade thought to be representative of the current state of the art. Where possible data has been obtained from the Applicant's buildings as these are likely to best represent the way in which the Applicant occupies and uses its buildings assuming similar usage patterns into the future. The next chapter then describes how energy efficiency is being further improved through the application of advanced passive design principles across the Proposed Development and the effect that this is likely to have on site energy demand. Benchmarks from known and iconic low energy buildings will be used here to reflect the ambitions being shown by the Applicant.

The energy use of the Proposed Development is dominated by 4 types of building:

- Residential – housing
- Residential – student halls of residence / senior care
- Commercial and Academic research – desk-based
- Commercial and Academic research – laboratory-based

This section on benchmarking will therefore concentrate most closely on appropriate benchmarks for these types of building. The remaining buildings make up a relatively small percentage of the overall build mix and hence their influence on overall site carbon emissions is comparatively low. We have, however, included them in the energy and carbon analysis.

Note: The introduction of Part L 2010 in October 2010 requires a reduction in CO_2 of 25% from Part L 2006 levels. All future revisions of Part L will similarly be referenced to Part L 2006, and therefore our report uses Part L 2006 as a baseline for future levels. Given the timescales of the Proposed Development, all buildings will therefore as a minimum comply with the Part L 2010 levels, and therefore exceed the 2006 requirements.

Dwellings

In contrast to non-domestic buildings there is some evidence that, when taken across a large range of building stock, the Government's Standard Assessment Procedure (SAP) is capable of accurately predicting the actual energy consumption of dwellings, albeit with the caveat that many new dwellings are underperforming due to discrepancies between the assumptions used in modelling and standards achieved during construction. A trial of 700 homes at Stamford Brook found that:

> *By taking into account factors that reflect the way occupants use the dwellings, such as temperature and ventilation, and also factors that allow for the difference between designed performance and actual construction, such as the party wall effect and true boiler efficiency, we have shown that the SAP/BREDEM model gives a reasonable estimate of annual energy use that is typically within 500 or 600 kWh of measured use.*

A number of recommendations from this trial have been built into the new version of SAP 2010 (such as party wall heat loss and true boiler efficiencies) but much of the discrepancy is due to detailing and quality of construction. For this reason tendering designers and contractors will be required to demonstrate that they are capable of coordinating a joined up approach from design to handover that results in standards assumed in SAP both through precedent (what they have built before) and monitoring on site using:

- thermographic imaging
- pressure testing
- detailing and monitoring of thermal bridging
- commissioning of building services

By following this process we have confidence that the dwelling benchmarks can be taken from SAP modelling. For the purposes of the planning application we have modelled 3 broad dwelling types which would have the following energy consumption if built to the baseline 2006 standard:

Table 2. Baseline domestic energy benchmarks based on SAP modelling. (Electricity demand includes regulated loads from SAP, and unregulated loads using the Code for Sustainable Homes calculation methodology)

Dwelling Type	**TOTAL** Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Flats	58 (29)	47
Terraced and semi-detached houses	58 (24)	41
Detached houses	74 (24)	39

Non-domestic Buildings

Offices and Laboratories

The total area of academic and commercial research applied for is 100,000m^2 with at least 60,000m^2 academic employment floor space including faculty development and up to 40,000m^2 of commercial employment floor space. For the purposes of energy modelling we have assumed that commercial and academic research buildings have the same energy demands.

By contrast it is important to distinguish between two *types* of research building; desk-based research (i.e. conventional office space), and high intensity laboratory research. We have assumed for the purposes of modelling that there is an equal 50:50 split between these types of building. It is thought that 50% errs on the side of caution in energy terms since there is likely to be less laboratory use.

Desk-based research

It is assumed that all private and academic desk-based research is carried out in conventional office space and that this will either be naturally ventilated or mixed mode.

Two fairly recently-built University academic departments are shown below. Although built before the update of building regulations in 2006 they are naturally ventilated well-daylit buildings broadly representative of university academic research buildings built to 2006 standards:

Table 3. Energy consumption benchmarks from two recently completed University desk-based research use.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Faculty of Education (completed in 2005)	66	88
Faculty of English (completed in 2004)	64	111
Average	**65**	**100**

Laboratories

Energy use in laboratories tends to be heavily dominated by process loads from laboratory equipment which is often left running 24 hours per day and is very difficult to regulate (indeed is not regulated by Building Regulations). There may also be extensive use of fume cupboards leading to high air-change rates. The following table provides a range of energy consumption benchmarks from different sources for laboratory buildings including some from West Cambridge:

Table 4. Energy benchmarks from literature and recently completed University buildings for laboratory use.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Benchmarks from literature		
CIBSE Guide F	94	155
CIBSE TM 46 (energy benchmarks for DECs)	136	160
ECON 54: Energy Efficiency in Further and Higher Education	128	105
Some selected West Cambridge Buildings:		
William Gates	36 (10)	187
Physics of Medicine	195 (56)	249
Institute of Manufacturing	46 (24)	138
Average (literature benchmarks and Cambridge University buildings)	**106 (44)**	**166**

The data indicates that energy consumption can vary widely depending on the exact use of the building. In particular large pieces of specialist equipment can have a big impact on overall energy demand and at the moment it is not possible to predict the types of equipment required.

Halls of residence / Senior Care

Energy use in University Halls of residence and senior care homes is dominated by domestic hot water, particularly where space heating has been reduced through efficient envelope design. The following benchmarks are taken from best practice literature and 3 University halls of residence built at the University of Nottingham.

Table 5. Energy benchmarks from literature and recently completed University buildings for residential use.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Benchmarks from literature		
CIBSE Guide F	160	50
CIBSE TM 46 (energy benchmarks for DECs)	255	60
ECON 54: Energy Efficiency in Further and Higher Education	204	85
Average	**206**	**65**
Some selected new University Halls of Residence		
Nottingham Jubilee Campus – purpose built low energy campus		
Melton Hall (3,510m^2)	212	72
Southwell Hall (4,035m^2)	166	59
Newark Hall (8,082m^2)	153	61
Average	**193**	**64**

Hotels

Energy use in hotels is characterised by very high domestic hot water use in a similar manner to halls of residence. Electricity usage is predominantly for lighting and services, with very low levels of appliances.

Table 6. Benchmark energy consumption for hotels.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Benchmarks from literature		
CIBSE Guide F – best practice	255 (100)	90
EU:thermie – Rational Use of Energy in the hotel sector – Good Energy use	300 (136)	70
Average	**278 (118)**	**80**

Primary School / Nursery

Energy use in primary schools has historically been dominated by space heating but recent increases in IT use have meant that electricity use is increasing with a concomitant decrease in gas consumption. Domestic hot water use is characteristically very low. The last published DCSF benchmarks in 2002-2003 are now thought to be out of date as they do not account for the increase in IT-related energy consumption and are hence excluded from the final average:

Table 7. Benchmark energy consumption for schools

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Benchmarks from literature		
DCSF, Energy and water benchmarks for maintained Schools 10th percentile, i.e. best practice, 2002 - 2003	61	18
CIBSE TM46 Energy Benchmarks (note: includes secondary schools)	150	40
Orchard Park Primary School (Cambridge completed in 2006)	95 (2)	50
Average (excluding 2002 DCSF benchmark)	**123 (2)**	**45**

Supermarket

Energy use in supermarkets is dominated by electricity used for food refrigeration which can account for over 40% of overall energy use. Several eco or zero carbon stores have been built in recent years by the major supermarket operators and these will be used as a benchmark for the proposed building's energy consumption.

Table 8. Benchmark energy consumption for supermarkets.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Benchmarks from literature (based on gross internal area)		
CIBSE Guide F (good practice)	100	450
CIBSE TM46 Energy Benchmarks	105	400
Average	**103**	**425**

Remaining Local Centre Buildings - Small shop (general retail) / GP Surgery / Community Centre

The following benchmarks will be used as the baseline for the remaining building types to be found in the local centre:

Table 9. Benchmark energy consumption for retail, GP surgery, and community facilities.

Small Shop	**TOTAL** Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
CIBSE TM46 Energy Benchmarks (all electric general retail)	0	165
CIBSE Guide F		
Banks and Building Societies	63 (2)	71
Electrical goods retail	0	172
Clothes Shop	65	234
Book Store (all electric)		210
Average of Guide F benchmarks (best practice)	**32**	**172**
GP Surgery	**TOTAL** Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
CIBSE TM46 Energy Benchmarks (clinic –	**170**	**70**

best practice)		
Community Centre	**TOTAL** Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
CIBSE TM46 Energy Benchmarks (community centre)	**200**	**70**

CO_2 emission factors

Carbon emissions associated with the use of fossil fuels and their displacement through the use of renewable energy technologies are very sensitive to the carbon emission factors assumed in any modelling. Carbon emission factors are a measure of the amount of carbon released by an activity (commonly in units of kg.CO_2/kWh).

In particular emissions associated with the use of grid electricity change as the mix of technologies (coal, gas, wind, nuclear) used to generate electricity changes and this has an important bearing on the savings realisable through the adoption of technologies such as heat pumps or combined heat and power.

As an example, the 2006 edition of building regulations assumed a figure of 0.422 kg.CO_2/kWh for grid electricity whereas the edition proposed in 2010 adopts a figure of 0.517 kg.CO_2/kWh; an increase in emissions of 25% primarily caused by changes in the methodology used to estimate the emission factor.

The Zero Carbon Hub has recently published guidance on how CO_2 emission factors should be calculated in future editions of building regulations[4]. It is proposed that the factor be based on a proportion of new-build (currently gas CCGT) and operational marginal (currently coal) plant on the grid. This methodology gives a high grid factor in the early phases of the Proposed Development due to the presence of coal generation on the grid with a rapidly declining grid factor in the early 2020s due to the projected increasing use of renewables and nuclear.

This suggests that in the early phases of the Proposed Development, technologies that *displace* grid electricity such as gas-fired CHP will be favourable (since they are partly replacing high CO_2 coal) but, in the long-term (2025 and beyond), technologies that *use* low carbon grid-electricity such as heat pumps or extraction of heat from steam turbine based power stations will gradually become more favourable.

This varying CO_2 emission factor creates a dilemma in how to present CO_2 savings. The phasing of the Proposed Development over 13 years (or more) means that the calculated saving from one technology in a given year will be different when calculated for another building in later years.

The approach adopted therefore to solve this dilemma is to present overall CO_2 emissions and therefore CO_2 savings over the 13 year build-out of the site. As an example, we will demonstrate that the implementation of the renewable energy technologies put forward results in total CO_2 savings of 20% over a 13 year life period (i.e. the build-out of the site). Table 10 shows the CO_2 emission factors (kg.CO_2/kWh) which are used in each year of the lifecycle analysis.

Table 10. CO_2 emission factors used in calculating lifecycle CO_2 emissions. Kg.CO_2/kWh

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Gas	0.198	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227
Electricity	0.517	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.501	0.501	0.501
Grid Displaced Electricity	0.529	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.501	0.501	0.501

[4] Carbon Compliance for Tomorrow's New Homes: Topic 2 – Carbon Intensity of Fuels. Zero Carbon Hub. October 2010.

Predicted Baseline Energy Consumption

Predicted baseline energy consumption for the Proposed Development has been calculated based upon the description of development [and illustrative masterplan]. The phasing assumed in the model is indicative based on a build out and occupations from 2014. The development is assumed to be completed in 2025-2026 with the majority of the local centre completed early in the phasing followed by dwellings and then the commercial and academic buildings and collegiate accommodation.

If these buildings were to be built to Part L 2006 building standards gas and electricity consumption across the site would increase year on year as shown in Figure 3. It should be noted that the Area Action Plan requires 2006 Building Regulations to be used as the baseline despite the recent introduction of an update to Building Regulations in 2010.

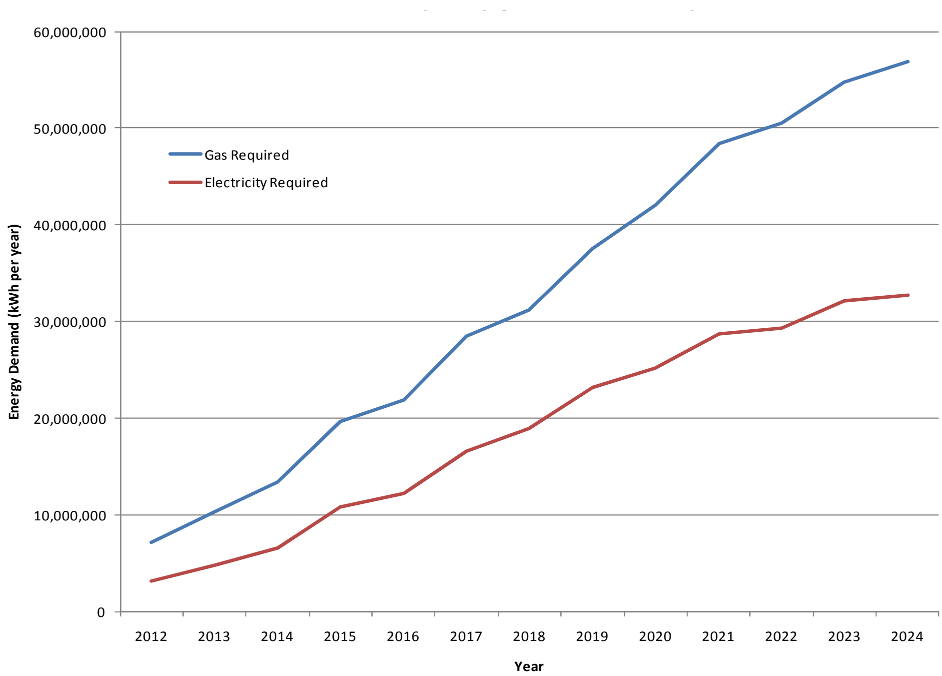


Figure 3. Baseline energy and gas demand over the phased build during the period 2014 – 2026.

At completion the annual gas and electricity consumption and CO_2 emissions would be as given in Table 11 assuming that the buildings are conventionally heated with gas boilers and provided with electricity from the national grid. CO_2 emissions are provided as a cumulative amount over the 13 year development period. This is to allow comparison with the energy strategies later in this report, with the cumulative figure removing the impact of annual electricity grid CO_2 intensity changes over the period.

Table 11. Summary of baseline energy consumption and CO_2 emissions (13 year cumulative) from the completed development at completion rounded to 2 significant figures.

	Annual Energy Use, MWh p.a.	Associated CO_2 emissions, tonnes over 13 years
Gas consumption	57,000	110,000
Electricity consumption	33,000	200,000
TOTAL		**310,000**

2.3 Building design and energy efficiency

Dwelling energy efficiency

High efficiency homes are often termed "passive houses" meaning that they operate passively both in terms of energy and other services. They are to some extent the ultimate extension of energy efficiency standards. This section discusses the potential for these standards on the Application Site.

Passive design of dwellings

A "Passive House" is designed to operate with minimal additional external energy resources. High levels of fabric efficiency including good insulation and airtight construction are used to minimise space heating demands. Any space heating required after using internal gains is derived from solar energy with passive houses typically making use of large south facing conservatories to capture solar energy. By controlling window openings in the conservatory, and between the conservatory and main dwelling, temperature and ventilation can be controlled. No additional heating system is required. This is the purist form of "Passive House" and additional measures will be used to mitigate water heating and electricity consumption; typically the generation of renewable heat and electricity from solar energy and wind turbines. To its full extent, a Passive House may be "autonomous" and have no connections to external infrastructure, capturing all water on site, and disposing of all waste water on site.

"Passivhaus" is a German standard for the construction of highly efficient dwellings. The central requirement is to reduce space heating standards to 15 kWh/m^2 per year or less compared with more than 150 kWh/m^2 for a typical older home in the UK. The Passivhaus approach has a number of strict requirements governing performance including the need for a mechanical ventilation and heat recovery unit (MVHR), but does rely on additional energy consumption for heating unlike a truly passive house. Relaxations under the German standard include less stringent requirements for orientation and solar gains, and the use of top up heating from electric elements in the heat recovery unit.

Changes in national UK regulation

The Zero Carbon Hub has proposed a back-stop energy efficiency standard (Fabric Energy Efficiency Standard or FEES) which all post 2016 homes will be required to meet. An assessment of the costs and benefits of energy efficiency measures has led to targets for space heating of 39 kWh / m^2.yr for terraced homes and flats, and 45 kWh / m^2.yr for semi and detached homes. This level is deemed as representing a high standard of energy efficiency without posing an undue cost burden. The targets have essentially been set at a point where further increases in energy efficiency become significantly expensive when compared to the cost of low and zero carbon sources of energy (for example, photovoltaics)

Achieving these targets will require a step change in energy efficiency standards from current building practices with wall U-values, infiltration rates, and thermal bridging at around half or less current typical levels. In some areas the standards are very similar to the Passivhaus standards with the following exceptions:

- Infiltration levels should be 3 m^3/m^2.hr @ 50 Pa or better.cf Passivhaus of typically less than 1 m^3/m^2.hr @ 50 Pa.
- There is no requirement for mechanical ventilation or heat recovery. (MVHR is not necessary with the proposed infiltration limits whereas it is a requirement for Passivhaus).
- Window U-values should be 1.2 W/m^2.K or less (costs start rising significantly below around 1 W/m^2.K) cf Passivhaus of 0.8 W/m^2.K.
- There is no requirement for correct orientation.

Therefore these standards represent very high levels of efficiency, but without the requirement of some of the most expensive components of Passivhaus detailed above.

The FEES standards have been used in the latest version of the Code for Sustainable Homes (November 2010) to define energy efficiency, and the backstops levels detailed above are mandatory for achieving Code levels 5 or 6.

Analysis for the Government [5] suggest that the costs of meeting the proposed standard are between £2,500 for flats and £10,000 for detached houses. The same analysis shows that the costs of Passivhaus levels are roughly £6,200 for flats and £19,500 for detached houses. This analysis includes an allowance for omitting the heating systems with the assumption that sufficient heating is provided by electric resistance heating in the MVHR with additional solar gains though orientation.

The above costs are only for the energy efficiency standards (essentially reducing space heating) and do not include additional costs for other renewable or low carbon technologies.

Application of energy efficiency levels for the Application Site

Energy efficiency options for the Application Site

The current proposals are for all housing on the Application Site to meet the proposed 2016 back-stop energy efficiency standards, FEES, as a minimum to achieve Code level 5. In comparison with current efficiency levels, this represents a step change in building practice and will result in all dwellings having very low space heating demands. If the FEES standards are modified in future, then the current proposals will change to be in line with the revisions and meet the mandatory requirements for Code 5.

The main decision for the Proposed Development is whether to take efficiency levels further than the back stops required under national legislation from 2016. The following analysis (and recent Government analysis) demonstrates that this taking efficiency levels further is not currently cost effective.

Without making a step to Passivhaus, elemental values, in particular infiltration and window U-values could be improved further to reduce space heating demand. On the positive side, this reduces the space heating load, and thus the energy required for space heating. On the negative side, the costs for this will start to increase disproportionally, and the further energy and CO_2 savings may be very small. Space heating is already a small fraction of energy and CO_2 as Table 12 demonstrates:

Table 12. Projected CO_2 emissions for homes built to the Zero Carbon Hub back-stops position, and Passivhaus standards. (All figures are based on SAP modelling. It is likely that this under-predicts the CO_2 emissions associated with the Passivhaus standard for space heating).

Efficiency Level	Space Heating kg.CO_2/m^2	DHW kg.CO_2/m^2	Total Electricity kg.CO_2/m^2	TOTAL CO_2 kg.CO_2/m^2
Zero Carbon Hub back-stop (FEES)	4.4	4.6	19	28
Passivhaus	0.6	4.6	21	26

Although Passivhaus reduces space heating-related CO_2 emissions from 4.4 kg/m^2 to 0.6 kg/m^2, domestic hot water (4.6 kg/m^2) and electricity (21 kg/m^2) still dominate and overall emissions are not radically reduced. Indeed electricity has gone up slightly due to the need for mechanical ventilation with heat recovery.

To gain maximum benefits from increasing efficiency levels above the backstop level, some of the costs need to be offset, for example through removing the need for a main heating system. In a Passive House, this is often achieved though maximising solar gains with orientation. With the German Passivhaus standard, there is less reliance on orientation, and small amounts of electric space heating are used.

Due to the densities and built forms of dwellings in the Proposed Development, it is not expected that the full Passive House approach is possible – there is simply not enough room to include large solar collection areas, and orientate all dwellings in the correct manner. Installation of solar renewable technologies will also be limited,

[5] Defining a Fabric Energy Efficiency Standard for Zero Carbon Homes – Appendix D. Zero Carbon Hub. 2009.

particularly in the high density flats. There are also concerns about the marketability of Passive Houses on a large scale.

The costs of going to the German Passivhaus standard are significant (over twice the back stop energy efficiency level) and this large additional cost will only reduce space heating and no other loads. Using an alternative form of heating such as electric immersion or resistance will be required, and it may be the case that this offers no CO_2 reduction from the backstops position combined with CHP, due to the high CO_2 content of grid electricity, and loss of CHP electricity generation. Large amounts of renewable electricity would also be required to offset the electricity consumption (due to appliances and cooking) and any additional electricity consumption from heating.

Proposals for the Application Site

Meeting the nationally proposed levels of energy efficiency for 2016 across all dwellings will ensure that high levels of energy efficiency are incorporated in to the designs. Whilst this is expected to be a national regulation from 2016, the standards can still be considered as highly sustainable and ambitious.

In the higher density parts of the Proposed Development, which are predominantly flats, large savings through energy efficiency will not be achievable due to the already low levels of space heating. Therefore whilst higher levels of efficiency could be included, the benefits would be limited and costs very high. There are also potential downsides to very high levels of insulation and air tightness such as overheating and internal air quality. In these areas, it is therefore likely that the backstops energy efficiency position is most suitable.

In the lower density parts of the Proposed Development, such as the detached houses, there is more potential for energy efficiency improvements. The space heating loads in these homes are proportionally larger giving scope for greater reduction. There is also more potential in these areas to use orientation measures to make best use of solar gains for heating.

There could be opportunities for some of the low density houses to be constructed to Passivhaus standards where technically and economically viable. The size and density of these houses could mean that suitable orientation (particularly along Huntingdon Road) is possible with adequate space for solar technologies. By developing a proportion of these homes to Passivhaus or equivalent standards, there are opportunities for investigating the commercial viability of building to these standards, ongoing monitoring and research by the Applicant, and having a “green” option for “green consumers” who may be willing to pay a premium. If these homes were developed alongside less-efficient homes, then it would be possible to distinguish the designs and performance in marketing to justify a cost uplift. This option will be further explored at detailed design.

For the purposes of this outline application the minimum back-stop energy efficiency level as defined by the Zero Carbon Hub is assumed and results in the following energy consumption figures:

Table 13. Proposed energy and CO_2 benchmarks for dwellings based on meeting the energy efficiency back-stops position.

Carried over from Baseline	**Heat Demand, kWh/m^2, (of which domestic hot water)**	**Electricity Demand (including demand for cooling), kWh/m^2**	**CO_2 emissions, kg.CO_2/m^2**	**CO_2 emission reduction from baseline**
Part L 2006 – Flats	58 (29)	47	**35**	
Part L 2006 - Terraced and semi-detached houses	58 (24)	41	**32**	
Part L 2006 - Detached houses	74 (24)	39	**34**	
Proposed Energy Efficiency Standard	**Heat Demand, kWh/m^2, (of which domestic hot water)**	**Electricity Demand (including demand for cooling), kWh/m^2**	**CO_2 emissions, kg.CO_2/m^2**	
FEES 2016 – Flats	47 (29)	45	32	9%
FEES 2016 - Terraced and semi-detached houses	47 (24)	38	28	13%
FEES 2016 - Detached houses	59 (24)	37	30	12%

Non-domestic building energy efficiency

Passive means of ventilating and cooling non-domestic buildings will be prioritised throughout the Proposed Development. In particular, conventional office and academic accommodation will be naturally ventilated, making use of thermal mass and appropriate orientation and shading to minimise overheating where possible. Plan depths will be designed to enable occupants to be generally close enough to a window to receive natural light and air. Deep plan buildings will generally be restricted to single storey where roof lights can provide natural light and ventilation or require the inclusion of design features such as atria where similar benefits of daylight and natural ventilation can be achieved.

Other non-university commercial and public sector buildings such as the supermarket, hotel and primary school will also generally be required to adopt low energy, passive design approaches through the use of design guidelines and possibly green leases.

Some research buildings will need to be mechanically cooled due to heat gain from large internal equipment loads such as from laboratory equipment and IT. In these buildings low energy cooling methods such as mixed mode ventilation, free cooling and ground cooling will be considered in addition to passive measures such as thermal mass, orientation and shading. The same approach will be considered for buildings along the western edge where noise effects from the M11 are most pronounced.

Further detailed energy efficiency measures that might be employed in non-domestic buildings are described in the following section on CO_2 reductions.

Assessment of energy and CO_2 reductions with energy efficiency

The following benchmarks represent predicted energy demands from non-domestic buildings at the Proposed Development following implementation of energy efficiency measures described above and in more detail in each section below.

Desk-based research

Benchmark data from a number of recently built low-energy offices is shown in the table below. The data represents a mix of low-energy design approaches including natural ventilation and mixed mode as would be expected at the Proposed Development. Broadly, buildings that are naturally ventilated (Heelis for example) show higher gas consumption and lower electricity consumption. Buildings that are mixed mode (Zebra for example) show the opposite trend with lower gas consumption associated with heat recovery ventilation and higher electricity use associated with more intensive building services (chillers, fans and pumps).

Table 14. Energy benchmarks for high efficiency desk based research buildings.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Recent University of Cambridge desk-based research	**65**	**100**
Example iconic low-energy offices:		
BRE Environmental Building (at the BRE campus, Garston)	65 (5.5)	48
Elisabeth Fry Building at University of East Anglia	32 (4.8)	61
Zebra (Defra offices at Alnwick)	12 (5 estimated)	60
Heelis (National Trust Headquarters)	76 (5 estimated)	31
Nottingham Jubilee Campus – non-residential buildings – purpose built low energy campus	49	103
Average	**47**	**61**

As can be seen from the above data the thermal performance of recent University of Cambridge buildings approaches that of some of the best low-energy offices. Electricity use, by contrast, is nearly double the average and over 3 times the best performer. This is likely to be primarily as a result of:

- Longer operating hours
- Increased IT usage as a consequence of the building function (desk based research)
- Poorer lighting performance
- Greater occupant density

Of the above, only lighting performance can be stipulated within the building design. Operating-hours and IT density are a function of the use to which the University puts its buildings. It is interesting to note that the low energy Nottingham University Jubilee campus has comparable electrical use: reasons for this may include IT equipment or occupant's behaviour. Lighting energy will therefore be targeted in the new development through a combination of lamp efficiency, lighting controls and daylight design (see chapter 2.4 on daylighting).

The following passive design measures will be considered in desk-based research buildings:

- Narrow floor plans (generally less than 16m to allow cross ventilation and good daylighting)

- Appropriate window design to allow high levels of daylight and good ventilation
- Appropriate shading to allow wintertime heat gain but cut-out summertime heat gain whilst maintaining adequate daylight levels
- Natural or mixed mode ventilation with high efficiency plant
- High thermal performance (U-values and air-tightness)
- Exposed thermal mass

The benchmark performance therefore sought for desk based research at the Proposed Development is best practice for heat and a more Cambridge University specific benchmark for electricity:

Table 15. Proposed target energy benchmarks for desk based research buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**65**	**100**	**63**
Desk-based research	**46 (5)**	**75**	**47**
Carbon reduction from 2006 baseline, %			**25%**

Laboratories

Since Laboratory energy use is dominated by process loads, it is not thought that the fabric design of individual laboratory buildings is likely to have a profound effect on overall energy consumption. However all of the passive design measures committed to for desk-based research will be applied to the laboratory buildings.

Table 16. Proposed target energy benchmarks for laboratory–based buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**106 (44)**	**166**	**105**
Laboratories (HEEPI best practice)	**79**	**143**	**88**
Carbon reduction from 2006 baseline, %			**16%**

It is clear from evidence at West Cambridge that the deepest carbon savings in laboratory buildings will have to be sought through management of the processes that go on within them. Data from Heepi (Higher Education Environmental Performance Improvement) suggests that the very best laboratories can achieve large energy savings over the average. Heepi best practice will therefore be aimed for at the Proposed Development employing a variety of measures to reduce process loads:

- Pre-design workshops with users to assess loads and build-in energy efficiency
- Fume cupboards – assessment of need and review of technologies for least energy use following risk assessment. Heat recovery with plastic heat exchangers and automatically descending sashes are now available and will be reviewed on all lab projects
- Air-change rates – very high air-change rates are often unnecessarily specified for labs. Review of appropriate rates will be made at design in all projects.
- Variable speed pumps and fans.
- Zoning of building to allow parts to be shut down when not in use
- "Kill" switches to shut off non-essential services in parts of the building
- Specifying equipment with the highest energy rating (A rated fridges etc).

See: www.**heepi**.org.uk/.../**Lab**%20benchmarking%20paper%20v4%2027.7.07.doc

It should also be noted that there is a wide degree of variation in the energy use of different types of laboratory buildings with, for example, physics and electronics labs showing very high electricity consumption. The benchmark used above can therefore be seen as an average across the Proposed Development using West Cambridge as precedent.

Halls of residence / Senior Care

As far as we are aware there have been no high profile low energy Halls of Residence built to advanced practice energy efficiency standards in recent years that can be used as a benchmark for the Proposed Development. In the absence of this information we have pro-rated the 2006 benchmark data against the Prison model that was completed for the Zero Carbon consultation:

Table 17. Proposed target energy benchmarks for residential buildings at the Proposed Development

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**193**	**64**	**70**
Halls of residence	**144 (100)**	**56**	**56**
Carbon reduction from 2006 baseline, %			**20%**

In order to achieve these energy figures the halls of residence will be built to similar standards as the domestic energy efficiency back stop:

- Infiltration: < 3m^3/m^2/hour
- U-values: <1.4 W/m^2/K windows, < 0.2 W/m^2/K walls and floor, < 0.15 W/m^2/K roofs
- Window areas: At least 20% of floor area

It will be noted that with high levels of insulation heating loads are, like hotels, dominated by domestic hot water for showering. Therefore measures such as low flow showers and percussion taps will be considered.

Hotel

There is not much evidence of the volume hotel business investing in ultra-low efficiency buildings and therefore energy demand data is scarce. Whitbread opened their first low-energy hotel last year in Tamworth (Premier Inn) and heating demand has been calculated from Corporate Social Responsibility data. Whitbread are due to open another low energy hotel in Burgess Hill so this may be a sign of a gradual change in the industry. The Tamworth hotel features the following energy efficiency measures:

- Ultra high thermal performance and air tightness
- Heat recovery ventilation
- Hot water heat recovery (from greywater system and catering)
- Low flow (aerated) taps and showers
- LED lighting

A hotel operator has yet to be procured. A green lease will be considered with tendering operators so that at least the same levels of energy efficiency implemented at Tamworth are applied to the hotel at the Proposed Development (taking into consideration that the proposed hotel is 3* and may therefore have slightly higher inherent demands) and hence the following benchmarks will be used:

Table 18. Proposed target energy benchmarks for hotel buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**278 (118)**	**80**	**94**
Whitbread Low Energy Hotel, Tamworth, estimated from CSR data (super-insulated, air-tight, heat-recovery ventilation, low-flow shower heads, LED lights, solar thermal etc)	**100 (70)**	**Not provided (assumed to be 80)**	**60**
Carbon reduction from 2006 baseline, %	**-**	**-**	**36%**

School

There has been a wealth of information on low energy primary schools ever since the Building Schools for the Future programme was initiated. As discussed in the baseline section primary schools have made marked improvements in gas use through efficient envelope design. Much of the carbon saving as a result has unfortunately been eroded through increasing IT use and extended out of hours usage by the community as the benchmarks show from 3 recently completed primary schools taken from the DSCF Publication “Schools for the Future” which identifies schools that have implemented sustainable energy conscious design.

Table 19. Energy benchmarks for high efficiency school buildings.

	TOTAL Heat Demand, kWh/m^2 **Of which** domestic hot water (or baseload) demand, kWh/m^2 shown in brackets where known	Electricity Demand (including demand for cooling), kWh/m^2
Recently completed low carbon primary schools – DCSF Schools for the future		
Birchensale Middle School	38	59
Notley Green Primary School	69	67
Kingsmead Primary School	88	72
Average (recently completed)	**65**	**66**

Energy saving measures that will be considered in the primary school include:

- Natural ventilation or mixed mode ventilation with heat recovery in the winter. Adequate ventilation in classroom can improve educational conditions. CO_2 sensors could be used to help monitor the indoor air quality.
- Appropriate shading and thermal mass and natural ventilation design to obviate the need for air-conditioning or comfort cooling (at least under current climate)
- Energy efficient lighting design and controls
- Optimised window area and shading to make best use of winter heat gain whilst minimising summer heat gain

- Air tight and thermally efficient fabric

Of the above schools Birchensale clearly gives an aspirational target for the new primary school and will be used as the benchmark for the Proposed Development:

Table 20. Proposed target energy benchmarks for school buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**123**	**45**	**47**
Primary School	**38**	**59**	**37**
Carbon reduction from 2006 baseline, %	**-**	**-**	**20%**

Supermarket

Several eco or zero carbon stores have been built in recent years by the major supermarket operators and these will be used as a benchmark for the proposed building's energy consumption. A green lease will be considered with the supermarket operator to explore which of the following features typical of an eco-store are incorporated:

- Fully daylit store using north lights
- Motion sensing and daylight dimming lighting
- LED lighting used in refrigeration cabinets
- Doors on fridges and freezers (note – this is being trialled in some supermarkets but some operators may be reluctant to implement)
- Lobby doors (2 sets of doors) on walk-in cold stores
- Mixed mode ventilation with openable rooflights and windcatchers
- CO_2 (or other low global warming potential) refrigerants
- Variable speed fans and pumps

The following will therefore be used as the benchmark for the supermarket on the Proposed Development:

Table 21. Proposed target energy benchmarks for supermarket buildings on the Proposed Development.

NOTE: Data based on Gross Internal Area	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**103**	**425**	**236**
Supermarket – benchmark data from recently built zero carbon store	**0**	**370**	**189**
Carbon reduction from 2006 baseline, %	**-**	**-**	**20%**

Small shop (general retail)

A number of high street store operators are introducing energy saving measures and these may be encouraged in green leases. The Applicant will be constructing the shell and core of these shops and will therefore incorporate high levels of fabric energy efficiency.

Table 22. Proposed target energy benchmarks for small retail buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**32**	**172**	**92**
Retail – pro-rated from Part L data	**23**	**172**	**91**
Carbon reduction from 2006 baseline, %	**-**	**-**	**1%**

GP Surgery

GP surgeries are commonly very similar to cellular office buildings albeit with a higher gas load due to domestic hot water use. For this reason similar environmental strategies will be considered such as:

- Narrow floor plans (less than 16m to allow cross ventilation and good daylighting)
- Appropriate window design to allow high levels of daylight and good ventilation
- Appropriate shading to allow wintertime heat gain but cut-out summertime heat gain whilst maintaining adequate daylight levels
- Natural or mixed mode ventilation with high efficiency plant
- High thermal performance (U-values and air-tightness)
- Exposed thermal mass

The recently completed Plowright surgery in Swaffham employs the techniques outlined above and will therefore be used as the benchmark for energy performance.

Table 23. Proposed target energy benchmarks for GP surgery buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**170**	**70**	**68**
Plowright Surgery, Swaffham – low-energy GP surgery completed in 2006	**77**	**54**	**42**
Carbon reduction from 2006 baseline, %	**-**	**-**	**38%**

Community Centre

No data is available on low energy community centres and hence the CIBSE TM 47 data is being assumed for the purposes of this analysis. However low energy techniques will be employed in the design of the proposed centre.

Table 24. Proposed minimum standard energy benchmarks for community centre buildings at the Proposed Development.

	Heat Demand, kWh/m^2, (of which domestic hot water)	Electricity Demand (including demand for cooling), kWh/m^2	CO_2 emissions, kg.CO_2/m^2
Part L 2006 Benchmark carried over from previous chapter	**200**	**70**	**75**
No data	**200**	**70**	**75**
Carbon reduction from 2006 baseline, %	**-**	**-**	**0%**

Summary Table

The following table summarises the energy demand and CO_2 benchmarks for each of the building types proposed for the Application Site before the application of renewable energy technologies. These benchmarks will be incorporated into environmental performance specifications as targets which building designs should aim to achieve where possible.

Table 25. Summary of target performance standards proposed for the Application Site.

Building Type	**Heat Demand, kWh/m^2, (of which domestic hot water)**	**Electricity Demand (including demand for cooling), kWh/m^2**	**CO_2 emissions, kg.CO_2/m^2**
Research – office based	46 (5)	75	47
Research – laboratory	79	66 (not including process loads which vary according to research)	49
Student Residences / Senior care	144 (100)	56	56
Hotel	100 (70)	80	60
Primary School	38	59	37
Supermarket	0	370	189
Small shop	23	172	91
GP Surgery	77	54	42
Community Centre	200	70	75

External Lighting and internal car-park lighting

One of the principal uses of energy not connected with buildings is for street lighting; both for roads and footpaths / cycle paths. The benchmarks for buildings above include on-plot external lighting, and in this section we discuss public space external lighting.

A typical benchmark for street lighting is 0.25 W / m^2 illuminated area. Based on an illuminated area of 337,000 m^2, and 12 hours day average operation, the annual energy demands for the Proposed Development are predicted to be circa 369 MWh electricity per year. This compares with the overall predicted baseline electricity consumption for the site of 32,775 MWh per year, and is therefore considered negligible for further calculations. This does not mean however that energy efficiency will be ignored in the design of street lighting.

It is likely that the ownership of the lighting will be split across the Proposed Development into adopted lighting on adopted roads, and Applicant-owned lighting on land remaining in the ownership of the Applicant. Therefore the design standards of external lighting across the Proposed Development may vary. Where viable, the following measures will be used for reducing energy demand further:

- All lighting to have a luminous efficacy of at least 50 lamp lumens per circuit watt.
- Daylight sensors to prevent operation during daylight hours
- Time control to turn off selected lighting for certain periods (for example between midnight and 6 am)

In addition the lighting will be designed where feasible in accordance with best practice to reduce light pollution by using efficient luminaries. Design guides such as "Lighting Guide 6 – The Outdoor Environment" (Society of Light and Lighting) will be used to inform the design. Where required, lighting levels may need to be modified to allow for the inclusion of security services such as CCTV.

Climate Change Adaptation – Assessment of changes in heating and cooling demand in 2050

The North West Cambridge Area Action Plan shows a clear requirement for buildings on the Application Site to be adaptable to higher summertime temperatures as a result of climate change:

> *New development will need to be adaptable for unavoidable changes in climate without further increasing emissions with active heating and cooling systems. There is much that can be achieved through 'passive measures' such as the location, layout, orientation, aspect and external design of buildings and landscaping around buildings that can help occupants to cope more easily with the effects of climate change.*

Designing buildings which can adapt to climate change should result in buildings which are comfortable for residents in future years, and have minimal running costs. Both of these factors are important to the Applicant and provide a strong driver for considering climate change adaptation.

The UK Climate Impacts Programme (UKCIP) at the University of East Anglia has provided weather files for the years 2050 and 2080 that can be used to simulate how buildings respond to higher summertime temperatures. The Chartered Institution of Building Services Engineers (CIBSE) carried out analysis on 3 building types (Dwellings, Offices, and Schools) in 2005 using data from UKCIP[6]. The results showed that dwellings can be adequately adapted to increasing summer temperatures up to 2050 but that offices and schools will, despite adaptation measures, need to include some form of active cooling by 2050. CIBSE therefore recommended that these buildings be at least mixed mode to enable cooling to be retrofitted at a later date.

Subsequently the Zero Carbon Hub has carried out comparisons of different thermal modelling software to determine whether the overheating algorithm in SAP needs to change. This work highlights the inadequacy of SAP and makes recommendations about future climate change adaption policy. The work is ongoing and will be kept under review as the detailed design work on the Proposed Development progresses. Modelling of individual buildings will be carried out at detailed design stage to quantify the impact of future higher summertime temperatures so that the proposed environmental strategy for each building is able to cope with current and future temperatures.

Table 26 outlines the climate change adaptation principles which are proposed for the development.

Table 26. Proposed climate change adaptation measures to increase the likelihood that dwellings can cope with future increased summer temperatures.

Building Type	Climate Change Adaptation under UK-CIP Medium emissions scenario
Dwellings including student accommodation	Some or all of the following passive design measures will be implemented such that temperatures do not exceed 28 °C in living spaces and 25 °C in bedrooms for more than 1% of occupied hours. • Cross ventilation • External shading

[6] CIBSE TM 46: Climate Change and the Indoor Environment, 2005

	• Secure day-time ventilation (such as shutters) • High thermal mass • Higher ceilings to allow stratification and punkah fans Active cooling will not be permitted as a method to reduce summer temperatures to acceptable levels.
Naturally ventilated non-domestic buildings	It is acknowledged that naturally ventilated non-domestic buildings may need to be retrofitted with cooling by 2050. Therefore these buildings will be designed with appropriate space (plant and duct space) for the retrofit of mixed-mode ventilation and active cooling should this be required. This will increase the likelihood that these buildings do not become redundant as a result of higher summertime temperatures. These buildings will inherently need to feature measures to reduce internal temperatures from the outset in order to avoid the need for air-conditioning. • Appropriate orientation • Cross ventilation • External shading • Thermal mass • Window design to ensure appropriate ventilation rates
Mixed mode non-domestic buildings	Some buildings will, due to high internal gains (such as labs), need to be actively cooled from the outset. These buildings will be designed such that plant is either sized for future climate change or modularised to enable plant to be scaled up. These buildings will also benefit from passive measures in order to minimise the use of active cooling: • Appropriate orientation • Cross ventilation • External shading • Thermal mass • Window design to ensure appropriate ventilation rates

Estimated changes in energy use as a result of higher summertime temperatures

The following table summarises the changes in energy use predicted by the work of CIBSE in 2005 where buildings are designed for adaption to climate change as described above

Table 27. Predicted changes in energy demand with climate change for different building types.

Building Type	Change in energy use with climate change (CIBSE 2005)
Dwellings including student accommodation	Since it is proposed that domestic buildings can be designed to cope with higher summertime temperatures without the use of air-conditioning, it is predicted that overall carbon emissions will fall as a result of reduced boiler use in the winter: • Change in gas use: -17% • Change in electricity use: nil
Naturally ventilated non-domestic buildings	It is predicted that some form of mechanical cooling will have to be retrofitted in naturally ventilated non-domestic buildings by the 2050s however gas use for heating is predicted to fall: • Change in gas use: -32% • Change in electricity use: +7%
Mixed mode non-domestic buildings	It is predicted that additional cooling will be used by the 2050s however gas use for heating is predicted to fall: • Change in gas use: -21% • Change in electricity use: +15%

In almost all of the buildings examined in CIBSE TM36 overall CO_2 emissions fall over time as a result of a disproportionate reduction in gas used for heating. The net reduction is also caused by the expected drop in electricity grid emissions that will be used to power the increase in air-conditioning use. For this reason the carbon emissions modelling used for this Carbon Reduction Strategy will be based on the worst case (i.e. the present-day climate scenario). As stated above however, buildings will be designed to reduce or completely mitigate the need for air-conditioning as a result of increasingly hot summers.

Behaviour change

Low carbon lifestyles will be promoted through the management of the estate. Educational initiatives to teach residents and visitors about the sustainable technologies employed are being considered. Part of the service charge might be used to fund carbon advice via an energy portal on the site intranet.

An energy portal would enable residents to compare the energy performance of their home against the average across the estate. Residents that wish to do so will be able to share their energy use data with others and share tips about reducing consumption.

Subject to further discussions with industry, smart metering and appliances will be trialled in homes – a country wide roll-out is proposed by Government from 2013. Residents could have variable electricity tariffs depending on the time of day and the amount of electricity being produced on-site. This could mean, for example, that washing machines “know” when to turn on depending on the output of photovoltaic panels on the roof of the home helping to increase the amount of renewable electricity used on-site rather than exported. Fridges and freezers could turn off intermittently for short periods of time to help reduce peak demands on the grid.

There is a growing amount of literature on the energy savings possible through behaviour change, particularly where stimulated through awareness (smart metering etc). The latest report on the subject from the Department for

Business, Enterprise and Regulatory Reform[7] (now BIS) pools data from various sources and estimates savings of 2.8% for electricity and 2% for gas.

Predicted Energy Demand Following Application of Energy Efficiency Measures

The following graph shows predicted gas and electricity consumption across the Proposed Development assuming that buildings are constructed to advanced practice levels of energy efficiency as described in the preceding text.

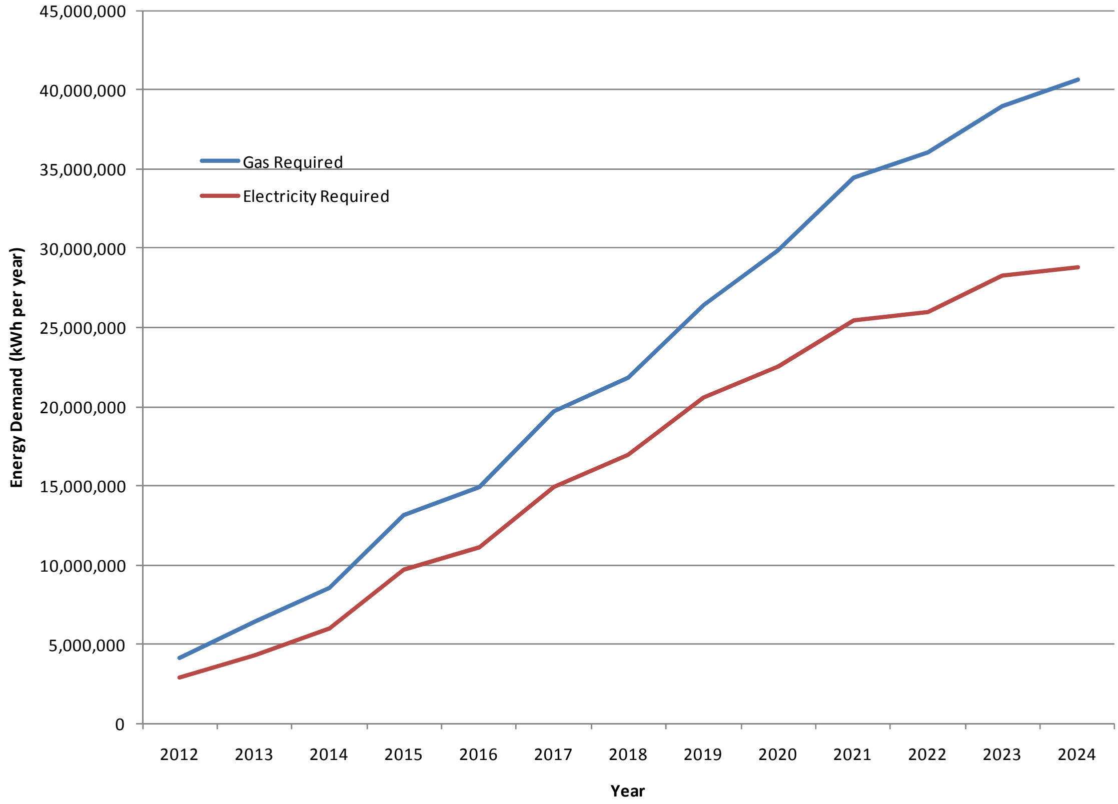


Figure 4. Approximate energy and gas demand over the phased build during the period 2012 – 2024 following the application of energy efficiency measures.

At completion in 2025 annual gas and electricity consumption and CO_2 emissions would be as follows assuming that the buildings are built to advanced practice levels of energy efficiency and conventionally heated with gas boilers and provided with electricity from the grid:

[7] Appraisal of Costs & Benefits of Smart Meter Roll Out Options, BERR, 2007

Table 28. Summary comparing baseline and proposed electricity and gas demands, and resulting savings in CO_2 emissions.

	Baseline Energy Use (from previous chapter), MWh	Energy Use assuming advanced practice energy efficiency, MWh	% Change in Energy and CO_2 emissions
Annual gas consumption	57,000	41,000	28%
Annual electricity consumption	33,000	29,000	12%
Associated CO_2 emissions over 13 year lifecycle, tonnes	310,000	250,000	19%

Further energy and CO_2 savings will realised through the use of low and zero carbon technologies. These are described and quantified in a following chapter.

2.4 Daylighting

Area Action Plan and other Policy Drivers

There are a number of policy and regulatory drivers favouring the adoption of good passive solar design at the Application Site.

Firstly, the Area Action Plan says that development will be required to demonstrate that it has been designed to adapt to the predicted effects of climate change.

Secondly, the Area Action Plan requires most of the dwellings on the Application Site to be designed to Code for Sustainable Homes level 5. Credits will be needed under every section in order to gain enough points to achieve Code Levels 5 and above.

Daylighting – Code for Sustainable Homes requirements

Both the Code for Sustainable Homes and BREEAM give credit for providing good levels of daylight. Up to 3 credits are available under the Code for Sustainable Homes for good daylighting. This has the stated aim of improving quality of life and reducing the need for energy within the dwellings. Table 29 shows the credit structure for the daylighting credits.

Table 29. Code for Sustainable Homes daylighting credits.

Criteria	Credits
Kitchens must achieve a minimum average daylight factor of at least 2%	1
All living rooms, dining rooms and studies (including any room designated as a home office under Ene 9 – Home Office) must achieve a minimum average daylight factor of at least 1.5%	1
80% of the working plane in kitchens, living rooms, dining rooms and studies (including any room designated as a home office under Ene 9 – Home Office) must have a view of the sky.	1

The daylight factors in the code for sustainable homes are taken directly out of the British Standard for daylighting and are considered to be the absolute minimum for adequate daylight. A daylight factor greater than 5% means that electric lighting will almost never be required during the day and less than 2% means that electric lighting will always be required.

As mentioned in the introduction, dwellings aiming to achieve code levels 5 and 6 are likely to need to score at least one if not all three credits under daylighting.

Daylighting Analysis

A daylighting analysis has been undertaken in order to gain an understanding of whether in principle adequate daylighting can be achieved consistently with the density of development proposed after allowing for any overshadowing. Figure 5 shows an extract of the analysis undertaken which focuses on a selection of elements of development layout which are representative of one (but not the only) way in which parameter compliant development might be brought forward. The analysis measures the vertical sky component (VSC) which is a measure of overshadowing. It is generally accepted that a VSC of in excess of 27° is required for adequate daylight (i.e. > 2%) to be easily achievable.

The analysis indicates that for the majority of the Proposed Development there is the potential for good daylight. The following images from the model show that the majority of facades are red indicating that the VSC is in excess of 27°. Blue areas show where the VSC is below 27° indicating that careful design of windows and room layouts will be required to avoid poor daylight.

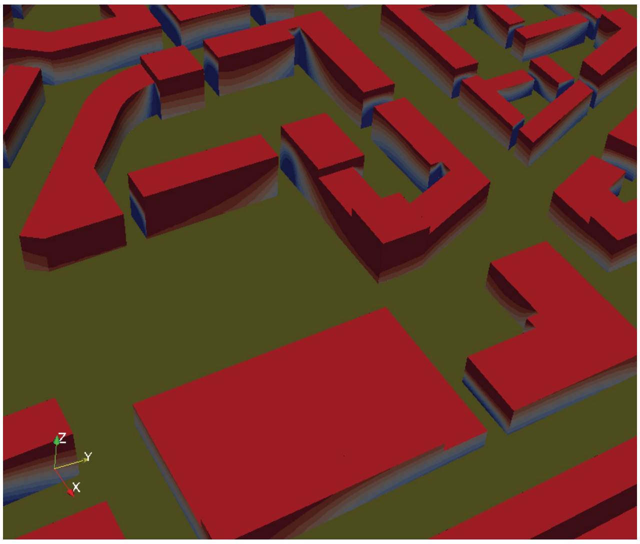


Figure 5. Extract showing analysis of a possible local centre layout, showing a majority of facades with a vertical sky component in excess of the 27° required

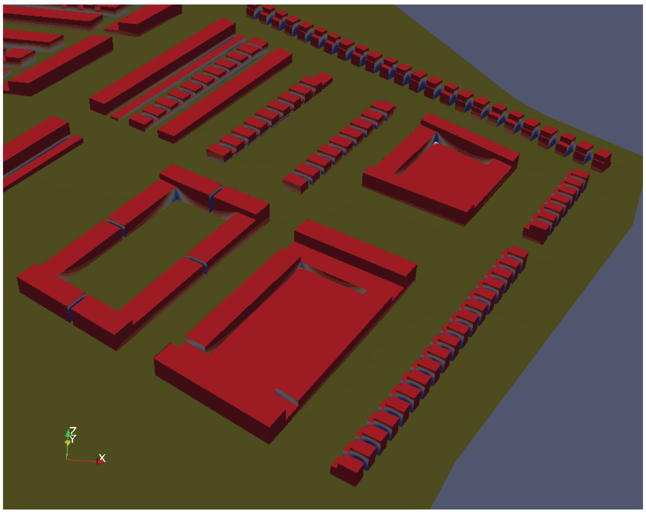


Figure 6. Extract showing analysis of a possible Storey's Field layout, showing a majority of facades with a vertical sky component in excess of the 27° required

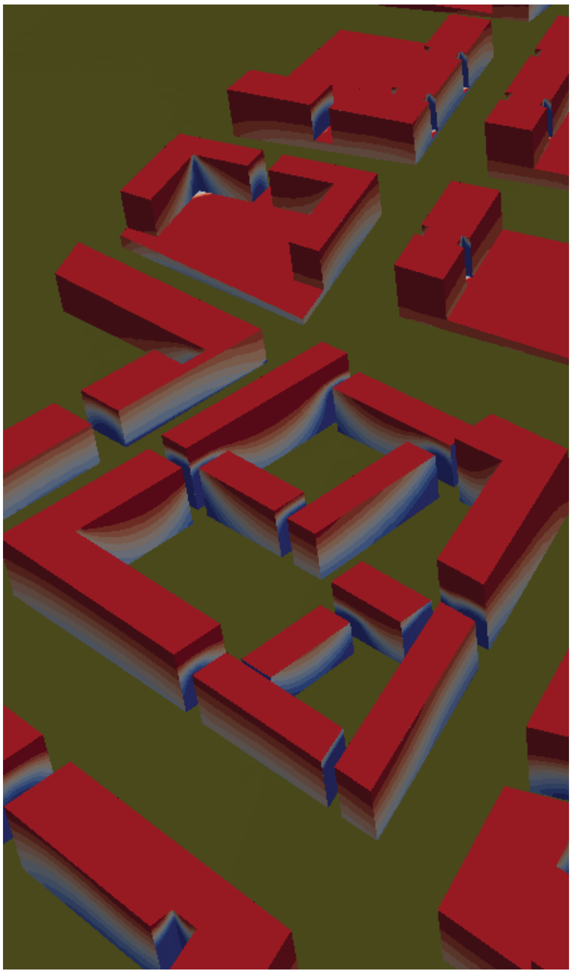


Figure 7. Extract showing analysis of a possible Ridgeway Village layout, showing a majority of facades with a vertical sky component in excess of the 27° required

Figure 7 shows that a small number of denser areas, for example the student residential blocks and some of the tighter clusters of commercial buildings in the neighbourhood centre show higher levels of overshadowing. Any areas such as these would be addressed at detailed design.

Design solutions are available that can overcome the slightly higher levels of overshadowing found in these areas. The following will therefore be reviewed at detailed design:

- Increased ceiling heights at ground floor
- Narrower plan depths and potentially decreasing plan depths at higher storeys to reduce overshadowing
- Alternative uses at the internal corners of buildings – cycle storage, lift and stair cores
- Corner flats with dual aspect on adjacent walls
- Internal design of single aspect flats – these may have to be fairly shallow plan to facilitate good daylight.

2.5 Low and zero carbon technology options

Chapter Summary

It is acknowledged that reliance on fossil fuels at the Application Site must be minimised through the use of lower carbon sources of energy. This chapter examines the appropriateness of a large number of low and zero carbon sources of energy for the Proposed Development. These are summarised in the following table:

Table 30. Summary of potential energy technologies

Technology	Suitability for the Proposed Development	Comments
Community gas CHP	Suitable for all areas connected to a district heating network.	Gas CHP combines a mature technology with large CO_2 reductions and is capable of meeting the regulated CO_2 limits with small amounts of additional PV where required.
Community biomass boilers	Technically suitable for connection to a DH network	Whilst technically suitable, there are high risks surrounding future availability and cost of fuel. This could be offset by the Renewable Heat Incentive. Greater CO_2 reductions could also be made from biomass using a CHP based technology.
Biomass CHP	Technically suitable for complete development but with phasing difficulties.	Biomass CHP can deliver large CO_2 reductions, but delivering the technology to meet the relatively small heat demand during the early phases will incur higher costs and efficiency penalties. The technology at the scale for the Proposed Development is currently considered to be immature / pre commercial, and there are significant concerns over the availability and future cost of fuel.
Anaerobic digestion	Large scale - not suitable due to waste requirements. Small scale – potentially suitable as part of water treatment.	Large scale AD is not considered suitable for the Proposed Development based on the large feedstock requirements (up to 50,000 tonnes per year) and the nature of the technology for a residential development. Discussions with suppliers have suggested an AD scheme has marginal viability in this area. A small scale scheme based around water treatment could be viable if on-site water treatment is proposed. At present, the intention is for all water-treatment to take place off-site at the local treatment works.
Large scale wind	Not suitable	Large scale wind is not considered suitable for the Proposed Development due to the requirements for buffer zones and potential visual impact.
Small scale wind	Technically suitable	There could be opportunities for incorporating small scale wind turbines on some parts of the Application Site. However the performance is likely to be poor due to the urban nature of the Application Site, and the contribution to CO_2 savings negligible, even with a large number of turbines.
Photovoltaics	Suitable for all buildings	PV has very few limitations and could be installed on the roofs of all buildings. The maturity of the technology means this is a relatively low risk solution. Maximum

		contribution is obtained if roof slopes can be designed to be predominantly south facing. Financial support available through the Feed-in-Tariff at least until 2012.
Solar thermal	Suitable for buildings not connected to a heat network.	Solar thermal conflicts with CHP technologies, but could be provided in those buildings with a sufficient hot water demand which are not connected to a heat network. The maturity of the technology means this is a relatively low risk solution.
Heat pumps	Suitable for later-phase commercial buildings.	Heat pumps are not predicted to save much (if any) CO_2 under the current grid mix. However with decarbonisation of the grid, they may be more suitable for later phases of the development. Balancing cooling and heating loads in the non-domestic buildings may help improve the overall efficiency of a ground connected heat pump system. A cooling network could enable centralised chillers to be used to provide additional waste heat.
Micro CHP	Not suitable at this stage	Micro CHP is not currently considered suitable due to the maturity of the technology. However this technology may become suitable (in particular fuel cell) as the technology matures, particularly in areas not connected to a heat network.
Biomass heating	Not suitable	Biomass boilers are not considered suitable for individual buildings due to air quality concerns, lack of heat load diversification, and plant space requirements (including fuel storage) for each building. In general, a large centralised biomass scheme is preferred over small individual installations. Concerns around the future availability and cost of biomass fuel also remain.

Introduction

This chapter provides an overview of the low and zero carbon energy resources available to the Application Site, and the technologies that may be used to provide energy.

The chapter is split into the following sections:

- Renewable and low carbon energy resource availability
- Assessment of low and zero carbon energy supply and distribution technologies
- Summary of technology viability in relation to the Application Site.

For each low and zero carbon technology option, basic information is provided on the system, followed by a discussion on how the technology could be applied to the Proposed Development, and what the opportunities and constraints may be.

Resource opportunities for the Application Site

Solar

The UK Solar resource is relatively uniform across the country with only slightly higher levels in the south. The resource map (Figure 8) shows that the Cambridge solar irradiation is around 1150 kWh/m^2 per year. The actual ability to harness this resource is heavily dependent on the technology selected and the orientation.

Figure 8. Solar Resource Cambridge (Source: Photovoltaic Geographical Information System (PVGIS)

Wind

The average annual local wind speed is estimated at around 6m/s based on data from the Department of Energy and Climate Change NOABL wind speed database, at a height of 45m [8]. This is at the lower limit for typical commercial scale wind farm development. This estimate is based on a 1km squares and the windspeed at the Application Site will depend on the local topology and surrounding trees and buildings which provide a surface "roughness" with the effect of slowing down the wind and introducing turbulence. At lower levels, the windspeed will be reduced due to wind shear – this is the effect of friction with the ground slowing the wind.

Alongside wind speed, the orientation is important. Winds in the UK are predominantly South Westerly followed by North Easterly. The wind rose in Figure 9 illustrates the speeds and directions from Coltishall in East Anglia based on Met office data for the East of England. As with wind speeds, the orientation will also partially be site dependent and require monitoring to be set up as part of a detailed feasibility study into wind technologies.

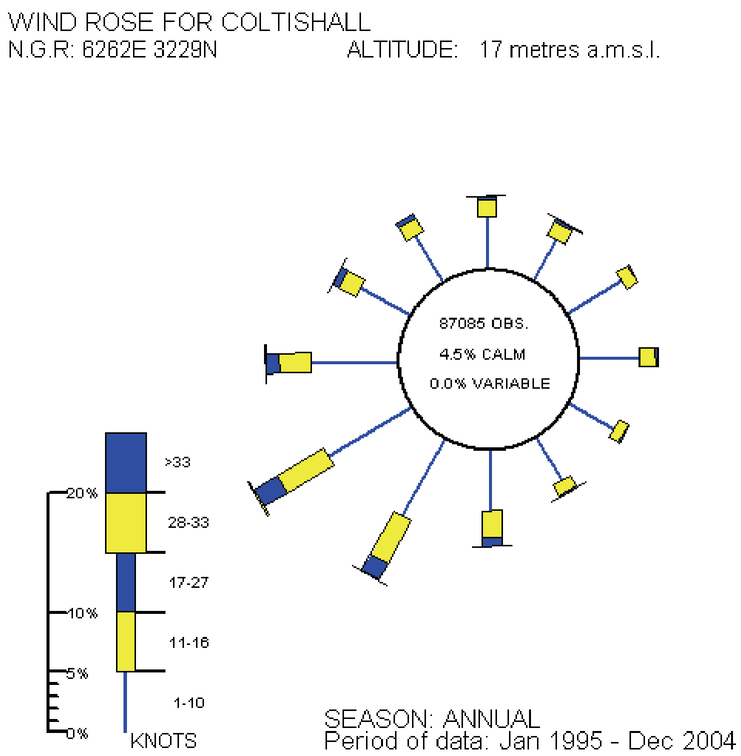


Figure 9. Wind rose from Coltishall in East Anglia (source – Met Office)

The Application Site is potentially well suited to a South Westerly predominant wind with this aspect being relatively open over the M11 and rural landscape beyond.

A recent report for Cambridge City Council examines options for decarbonising the city[9]. Its conclusions on wind are that the resource in Cambridge is "highly constrained due to the relatively modest raw resource and urban characteristics". It suggests that the best opportunities for wind lie in the rural areas outside of the city, potentially offering opportunities for carbon offsetting. In general, the urban areas are identified as unsuitable for large scale wind due to a number of constraints including buffer zones to residential areas (see section on wind turbine potential below).

[8] http://www.decc.gov.uk/en/windspeed/default.aspx

[9] Decarbonising Cambridge: A Renewable and Low Carbon Energy Study. Element Energy for Cambridge City Council. 2010.

Biomass

Virgin wood and Waste Wood

The evidence base report produced for Cambridgeshire City Council and South Cambridgeshire District Council rightly states that securing biomass supply is of prime importance for renewably fuelled biomass schemes[10] . It is vital that a scheme which relies on biomass has a long term secure supply of fuel which can be relied on into the future. This security should also include security of cost to ensure that a system can be developed which is economically viable. At present, biomass supply chains are in their infancy in the UK.

Recent increases in the price of virgin wood have led developers of biomass projects to look for alternative sources of fuels as evidenced by DEFRA in their 2008 report on Waste Wood as a Biomass Fuel [11]:

> *"Currently there is high demand for (virgin wood) material (e.g. from the furniture and panel board industry) which has recently led to increased wood prices. Whilst demand for low grade waste wood remains low and landfill tax increases, there is likely to be relatively high availability for low grades of waste wood."*

Since the DEFRA report was published waste wood has increasingly been used in energy schemes. As an example a 4MW waste wood plant has recently opened in Huntingdon (owned by a waste wood handler). But a recent report from the Forestry Commission indicates that even this resource is becoming exhausted [12]:

> *"The demand for recovered wood has been increasing sharply. This trend will continue if all the new wood energy plants being planned become operational, and by 2013 potential annual demand will exceed potential availability, even assuming that none is used for co-firing. By 2017 potential demand for recovered (waste) wood at 7 million tonnes per annum is forecast to be almost 36% above potential (UK) availability of 4.5 million tonnes per annum."*

The report goes on to say that the UK will be a net importer of all biomass fuel after around 2012. It could be expected therefore that if no long-term UK-based wood supplier is secured for the Proposed Development a large proportion of any biomass burnt would be imported. Indeed, the Department for Energy and Climate Change (DECC) assumes a large percentage of imported biomass in its 2050 scenarios to achieve an 80% cut in the UK's carbon emissions.

Imported biomass may have a low embodied carbon content due to the relative efficiency of transportation by ship however once the biomass begins to be transported inland the embodied carbon can increase due to transportation miles. In addition there are long term questions about the overall sustainability of imported biomass whether as a result of deforestation or losses in habitat over which the buyer has little control.

Doubts about this long term viability of virgin wood have led the developers of Northstowe to look to waste wood as the fuel for their proposed combined heat and power plant. Renewables East commissioned a study in 2009 into the availability of waste wood for Northstowe. This report concluded that up to 500,000 tonnes per year were available in the study area (broadly East Anglia) of which 50,000 to 84,000 tonnes per year would be available to Northstowe in the catchment area around the Application Site based on waste flows through aggregating facilities. This figure is based on Northstowe obtaining a 30% share of the 170,000 tonnes estimated to be available within a 60-minute drive time zone considered sustainable in the report.

For comparison, the Cambridgeshire County Council waste contractor, Donarbon, currently handles 10,000 tonnes of waste wood per year and the expected fuel consumption of the 10MW plant proposed for Northstowe would be in the order of 70,000 tonnes per year.

This suggests that a waste wood fuel supply (estimated demand of 10 – 15 thousand tonnes per year) could be found for the Proposed Development at least in the short term. What is not clear, however, is the price that would

[10] Planning Policy Sustainability Standards Technical Viability Study. .K.J. Tait and Bidwells. 2008.
[11] Waste Wood as a Biomass Fuel. DEFRA. 2008.
[12] Wood Fibre Availability and Demand in Britain 2007 to 2025. John Clegg Consulting Ltd. 2010.

have to be paid for it. Anecdotal evidence suggest that as biomass fuel chains have developed over the last few years and the number of installations has increased, this has not led to economies, but rather increased competition for fuel accompanied by a rise in prices.

As the DEFRA report points out the principal attraction of waste wood is that it currently commands a gate fee (i.e. you will be paid to take it away) as a result of landfill tax, which for 2010 is £24 per tonne. It is thought that as the waste wood market matures and more biomass plants are built "agglomerators" will appear to handle waste wood and pass it on to energy schemes. The price that energy schemes will pay for this wood will then be dependent on demand which is difficult to predict. Ever more stringent building regulations and other carbon legislation (e.g. RHI) are likely to see an increase in demand for waste wood however and the price is likely to increase as a result.

Refuse Derived Fuel

Another potential source of fuel for a biomass plant at the Application Site could be refuse derived fuel (RDF), sometimes referred to as solid recovered fuel (SRF) when processed. Cambridgeshire is served by a Mechanical and Biological Treatment (MBT) unit at Donarbon which handles the county's black bin waste. After abstraction of recyclables the plant produces large amounts of a compost-like fraction that has a calorific value of around 8 MJ/kg according to Donarbon. Cambridge City Council's Decarbonising Cambridge study estimates that the plant could produce fuel with a yearly heating value of up to 500 GWh although this is based on a calorific value of 18.5 MJ/kg. Simple arithmetic suggests therefore that a more appropriate value would be 220 GWh or 220,000 MWh. This compares with the estimated heating demand for the Proposed Development of approximately 40,000 MWh. To further put things in context the RDF produced at Donarbon is derived from the whole of the county's black-bin waste. This should dispel any notion therefore that the waste produced by the Proposed Development itself could supply a large part of its energy needs.

Dialogue has commenced with the operators of Donarbon, the Dickerson Group, for the supply of RDF to the Proposed Development for use in a RDF fuelled CHP application. A definitive conclusion to these discussions will not be made prior to the submission of this planning application and hence the scheme cannot be predicated on an RDF-fuelled CHP energy supply. This does not preclude an application for such a scheme in the future should a fuel supply be negotiated with Donarbon.

Straw

Another potential source of fuel for a biomass based system is straw from farms. The world's largest straw power station is based near Ely around 15 miles north of the Application Site, and is rated at 38 MW, consuming around 200,000 tonnes of straw per year. The power station is owned by Energy Power Resources Limited (EPRL) who has also created a dedicated company for the provision of straw, Anglian Straw Limited.

The task of collecting the straw requires a significant amount of coordination with Anglian Straw collecting bales from over 500 sites across East Anglia. A discussion with Anglian Straw brought out the following points:

- Anglian Straw is not interested in supplying straw to third parties – all their stock is currently used at the EPRL facility.
- Obtaining straw is a difficult process due to competing uses (and higher prices) for animal feed and bedding. Farmers are in general very reluctant to sell their straw for energy generation.
- Anglian Straw currently collect most of the locally available straw resource leaving very little available resource for other schemes.

These points, combined with the fact that the Ely power station is being modified to operate on other fuels, and that another power station being developed locally by EPRL will not be straw based, suggest that straw is a difficult resource to reliably obtain.

Discussions with the Cambridge University farmer reinforce the view that selling straw for energy generation is the last resort for many farmers. The Cambridge University farm currently has a surplus of around 1000 tonnes per year, although this is likely to fall with changes to farming practices and the development of the Application Site displacing farming activities. Straw is currently often re-ploughed into the land, and collection of this resource poses additional cost and time-burden to the farmer. There are also nutrient benefits to ploughing the straw into the land and in the Cambridge area: phosphates are expensive, and straw is high in nutrient content.

For these reasons, straw is not considered a viable resource for the Proposed Development for the purposes of the current energy strategy.

Biomass Summary

Conclusions from the Cambridge City Council “Decarbonising Cambridge” report on biomass are that:

> *“there is significant uncertainty surrounding the resources currently available”*

and that:

> *“Many barriers exist to using biomass, particularly in urban environments. These include fuel sourcing, security of fuel supply, transportation costs, impacts on traffic congestion, fuel storage issues and air quality concerns…”.*

In the long term, biomass resources are extremely limited and many estimates put the total amount of biomass resource at around 1% (order of magnitude) of our current energy use. This means that as a finite resource, biomass should be used in the most suitable and efficient applications. One could argue that supplying heat in stationary applications is not an efficient application when alternative forms of energy are available, and heat loads can be reduced. Generating electricity only is also inefficient and the most efficient process would be CHP.

We are currently at a transition in biomass availability. In the past, there has been enough biomass resource for the limited number of applications, although supply chains were not well developed. Now we are in a position where with the development of supply chains and an increase in applications, the resource is becoming limited, leaving future uncertainties over cost and availability.

Whilst biomass resources are limited, where they are available, they should be used in the most efficient manner possible. The most suitable local biomass resource appears to be RDF from Donarbon, but significant further work is required by a number of parties to investigate the feasibility of accessing and using this fuel, and this fuel cannot be relied on for this planning application.

These risks and future uncertainties around fuel supply need to be considered alongside the technical viability of biomass based systems. We are not therefore recommending any biomass technologies at this stage from a fuel supply perspective.

Existing heat from other sources

The Application Site is located close to the city centre surrounded by existing residential and academic / research facilities. There are no neighbouring sources of waste heat or district heating schemes which could be linked to.

On-site CHP and District Heating

District Heating (DH) is a means of distributing heat from a centralised heat generator to a number of individual heat loads. This enables technologies such as combined heat and power (CHP) to be used which provide a higher overall efficiency than separate centralised electricity generation, and individual building heating systems. The type of CHP can vary from smaller scale gas engines to large scale use of waste heat from centralised power stations.

It is important to distinguish district heating from CHP. Whilst the two approaches are often used together to maximise the efficiency benefits of large scale CHP systems, district heating networks can be used to distribute heat from a range of heat sources (not necessarily CHP), and CHP systems can be used on single building applications without DH.

The drivers for CHP and district heating have typically been based around economics and fuel supply. Due to the overall high efficiencies of schemes, the schemes can operate economically when compared with incumbent heating systems and grid electricity. However as climate change concerns have led to the requirement for reducing CO_2 emissions, district heating has the advantage of being able to lower emissions through the higher efficiencies, and use of lower carbon fuels (such as biomass) which may not be practical at an individual building scale.

The benefits of CHP arise from the overall high efficiencies which may be obtained. The traditional method of generating electricity at power stations is inefficient, with around 50% of the energy inputs being wasted even for high efficiency Combined Cycle Gas Turbine stations. A CHP plant is essentially a local, smaller version of a power station. CHP provides a much more efficient method as the system generates electricity but also makes use of the heat that is usually emitted to atmosphere. Since the electricity is generated closer to where it is needed, losses in transmission and distribution are also reduced. Gas fired CHP is the most mature technology with systems typically providing an overall reduction in energy usage of approximately 30% compared with conventional power stations and gas boilers, and therefore significant CO_2 reductions. CHP can also be run using biomass or biogas to provide further reductions in CO_2 emissions and these fuel supplies mean the heat and electricity can be counted as renewable energy.

CHP systems are usually sized to provide the baseload heat in a heat led system. This means that the system can operate throughout the year improving the economics. Boilers are usually also installed to provide peak heating and act as a back-up during the CHP maintenance. By smoothing the heat demand using thermal storage, the fraction of heating provided by a CHP system can be increased resulting in greater CO_2 reduction and less use of the boilers.

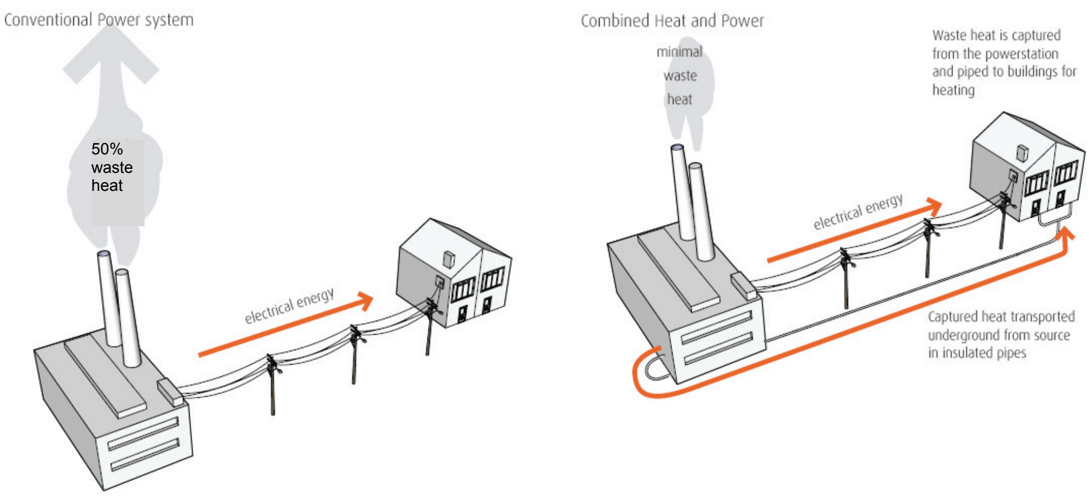


Figure 10. The benefits of Combined Heat and Power (CHP).

District heating schemes comprise a network of flow and return insulated pipes, usually buried beneath roads, which are connected to an energy centre containing the heat supply plant. The heat is usually transported using hot water (typically 90 – 120°C flow temperature, 40°C to 60°C return temperature). A series of smaller pipes branching off from the network distribute the heat to individual buildings, where the building heating system either uses the hot water directly, or via a user-controlled heat exchanger (known as a hydraulic interface unit).

The use of district heating is widespread in other countries, particularly Scandinavia, Germany, Austria and Eastern Europe. The schemes were typically installed as part of a municipal service and many remain in public ownership. The type of housing on the continent, typically comprising relatively high housing density and flats, is ideally suited to DH. This high housing density results in a high heat density, meaning that a relatively large amount of heat can be distributed and sold over a relatively small network, maximising the cost effectiveness of the DH scheme. The long history of DH schemes in these countries means that the technology is accepted and understood by consumers, there is a strong regulatory framework in which schemes can operate, and there are a number of commercial suppliers and operators of equipment and schemes.

The UK has a very different history of DH. At present there is very little installed capacity, with schemes typically limited to social housing (often publicly funded in the past) and large sites such as Universities and Hospitals.

Examples of more recent individual schemes are Southampton (operated by Utilicom), Sheffield (Veolia), Nottingham energy from waste (Nottingham City Council), and Aberdeen (Aberdeen Heat and Power supported by the City Council).

Housing in the UK is typically of lower density and fewer flats which firstly means that DH will have a higher network cost and be less economic in a large number of areas due to the lower heat density. Secondly, the UK, initially through coalfields, and then through the North Sea gas and oil fields, had until recently a plentiful supply of fossil fuels meaning that energy security was not an issue. This led to the rapid expansion of central heating from oil and gas boilers in the 1970s and 80s.

Gas CHP

Spark ignition gas-engines are the most common technology for small and medium scale CHP schemes. The engines are often based on vehicle or marine engines modified to run on natural gas, with heat extraction taken from the oil cooler, water jacket, and exhaust gases.

The electrical efficiency of gas-engine CHP varies with capacity. At the smaller scale in the low 100s of kW, the electrical efficiency may be circa 30%, but for large scale engines of 5 MW, then electrical efficiencies can approach 40%. Higher electrical efficiencies mean that for a given gas input, more high carbon grid electricity is displaced resulting in higher overall CO_2 savings. The overall efficiency of gas-engine CHP systems is greater than 80% if all the extracted heat is used.

Due to the wide range of gas-engine CHP systems available, the engines are often installed in a modular configuration allowing the overall system to have a degree of load following. For example in a two engine system, both engines may operate throughout winter, with only one engine in summer. If a single large engine was installed instead, it may provide the same amount of heat in winter, but either not operate during summer, or dump excess heat, both of which reduce the CO_2 benefits.

Gas CHP – Application to the Proposed Development
Gas CHP could be installed in one or more energy centres around the Proposed Development connected to a district heating system. The long development time of the Proposed Development requires a phasing of the energy infrastructure and modular gas CHP engines installed progressively as the site is built out can provide this phasing.
Potential energy and CO_2 savings
It is estimated that gas-CHP could supply around 70% of the Proposed Development's annual heat demand. If district heating supplied all buildings on site then the built-out installed capacity would be in the region of 3 to 4 MW(e). Total CO_2 savings over the 13 year (2012 to 2025) lifecycle would be 72,000 tonnes at an average of 5,500 tonnes per year. This equates to a 29% CO_2 saving when compared to the baseline with energy efficiency model.
Potential advantages
Gas-fired CHP is a mature technology with reliable, working applications throughout the world including the UK. The scale of the technology allows a phased modular build out to allow the installation to be optimised to meet the Proposed Development's energy demands during the construction phases.
Potential risks and disadvantages
Gas-fired CHP relies on a finite fossil fuel resource (gas) and therefore cannot be the long term energy solution for the Proposed Development. However the UK Zero Carbon Hub report on carbon compliance demonstrates that fossil fuels (particularly coal) are predicted to continue to be the marginal plant on the UK grid until at least

the mid 2020s[13]. This means that gas CHP would continue to save carbon for at least the life of the first installed engines.

Conclusions

The combination of gas CHP and district heating provides long term flexibility, with an energy generation technology which is ideally suited to the short term build out of the Application Site, providing large CO_2 reductions during its lifetime, and a distribution network which provides long term flexibility for future fuels and technologies.

Biomass Technologies

The resource assessment that begins this chapter concludes that risks around biomass availability preclude the use of biomass technologies at North West Cambridge, at least until a firm conclusion is reached over the potential to source Refuse Derived Fuel from Donarbon. For the sake of completeness however we include a review of biomass technologies below:

Biomass heating

Biomass can provide large CO_2 reductions through the provision of low carbon heat for space heating and hot water. The systems typically consist of a single (or multiple boilers) located in an energy centre with an automatic feed mechanism transferring the feedstock to the burner. Additional backup gas boilers are normally installed to provide peak heating loads and back-up capacity. Biomass boilers are similar to CHP systems in that they are best suited to meeting a steady baseload, and thermal storage can be used to increase the fraction of heat met.

The economics and performance of biomass boilers improve with size and so systems are more suited to large buildings, or groups of buildings, up to a district heating scale. Biomass boiler energy centres need a sufficient amount of space to store feedstock with adequate access for large delivery vehicles. All biomass systems will require flues to exhaust the combustion gases and particulates at a height which reduces the potential for pollution within and around buildings. These flues are typically at least 3 metres higher than all the surrounding buildings or more, and detailed dispersion analysis will be necessary to confirm that they are adequate.

Feedstock for biomass boilers can vary, but in larger scale schemes for district heating, lower cost feedstocks such as waste wood and wood chip are the preferred options. Wood pellets are generally used for small systems at a building scale.

Biomass Boilers – Application to the Proposed Development

Biomass boilers could be installed in one or more energy centres around the Proposed Development. Each energy centre would need to contain additional space for fuel storage, and access by delivery vehicles. The most effective use of biomass boilers would be connection to a district heating network providing an aggregated heat demand with a suitable base load for boiler operation. However biomass boilers could also be installed on an individual building basis for larger commercial and academic facilities (see later).

Potential energy and CO_2 savings

A district heating system with biomass boilers providing 80% of the heat (and hence requiring biomass boiler capacity of about 50% of the peak heat demand) would save around 56,000 tonnes of CO_2 over the 13 year lifecycle at an average of 4,400 tonnes per year. This equates to a 22% saving when compared to the baseline with energy efficiency model.

Potential advantages

Biomass boilers are an established and mature technology, with widespread use both in the UK and Europe. By using low carbon fuels, they can provide low carbon heating saving 4,400 tonnes per year of CO_2. Larger-scale

[13] See footnote 4

centralised biomass boilers can be fitted with flue cleaning equipment to minimise air pollution.

Potential risks and disadvantages

Biomass heating provides smaller CO_2 reductions than using the fuel in an alternative technology such as biomass CHP. Therefore this is not an efficient use of a finite biomass resource. It is however a better use than biomass for electricity only production where there are a number of such projects.

The supply of fuel is also a considerable risk with uncertainties as to the future availability and cost. Smaller scale boilers (perhaps in separate energy centres or for individual buildings) will potentially produce higher levels of air pollution with an absence of flue cleaning equipment.

Biomass boilers are suited to meeting baseload heating demands, and therefore are incompatible with other low and zero carbon heat producing technologies such as gas fired CHP.

Conclusions

Biomass boilers are technically suitable for the Proposed Development, but there are large concerns around the future availability and cost of biomass fuel, and potential air quality issues.

Biomass CHP

The term “biomass CHP” covers an array of technologies and processes which may be used to convert a form of biomass or biofuel to renewable heat and power. Technologies have been demonstrated over a wide range of capacities from 10s of kW to 10s of MW (or larger if electricity generation from co-firing is included). In general, biomass CHP technologies, particularly at the smaller size range, are very immature although there has been considerable recent interest following the drive to reduce CO_2 emissions, improved building regulations, and various incentive schemes across Europe.

Biomass CHP technologies primarily fall into two types: gasification systems, where the biomass fuel is gasified and then burnt in a gas CHP system; and steam turbine systems, where the fuel is combusted to raise steam and drive a turbine.

Biomass gasification CHP systems consist of a gasifier and modified gas CHP engine connected to a generator. The gasifier partially oxidises the biomass (or other carbon rich fuel) at between 700°C and 1000°C to produce a hydrogen rich syngas and CO_2 and CO by-products. The efficiency of the gasification process (kWh energy in syngas divided by kWh of energy in wood) is typically around 80% or less due to heat used in the process. The syngas is scrubbed using a number of procedures before being combusted in the modified gas engine – this scrubbing process is one area where development is still required to ensure that the engine is fed with a suitably high quality of gas to prevent tars and other residues being fed into the engine.

Gas engines designed to operate on syngas (or biogas) have a slightly lower electrical efficiency than natural gas engines, typically around 30%. Combined with the gasification losses, the overall efficiency of gasification systems can be much lower than for a natural gas equivalent engine. However the gasification process (and engine availability) means that biomass gasification systems can be built at a relatively small scale, down to 100s of kW, making them suitable for small developments or single applications.

In general, larger biomass CHP schemes are based on steam turbine electricity generation. Biomass fuel is combusted to generate steam in a high pressure boiler, which is then used to drive the steam turbine which in turn operates a generator. In a system designed for CHP operation, heat can be extracted with a small loss in electrical efficiency and used in the DH network. Biomass steam turbine CHP systems generally have a relatively low electrical efficiency of between 15% and 28%. However the steam turbine technology and biomass combustion processes are well understood and commercially mature, and this is generally the favoured option for larger scale biomass projects. Smaller turbine systems are also currently being developed in the sub MWe range. However these are based on a hot air process, where biomass combustion is used to drive high pressure air through a turbine or an alternative two-phase fluid for use in the Organic Rankine cycle.

Biomass CHP systems, at the smaller scales suitable for large buildings or site-wide schemes, are a relatively immature technology with very few installations. Whilst there are a number of installations around the UK and Europe, there is still a lot of development required to make these systems truly commercial and reliable.

A range of input fuels could be considered for biomass CHP ranging from virgin wood-chip to refuse derived fuel (RDF). The potential of each of these fuel resources is considered earlier in this chapter.

Biomass CHP – Application to the Proposed Development

The justification for providing a biomass CHP or energy from waste plant on or near the Application Site is predicated on the ability to make use of the waste heat generated to heat buildings on the Proposed Development. It is therefore appropriate that an installation should be sized to meet the heat load in order to generate the highest CO_2 savings for the precious biomass resource used.

As described in the preceding chapter the heat load increases slowly over the build-out of the Proposed Development as more and more buildings are added. This means that unless the installation of biomass CHP is delayed until completion of the development, a great deal of heat dumping will take place in the intervening years. A larger unit to serve the nearby West Cambridge may improve economics though the quantity of heat dumping will still be the same if sized to meet the final Proposed Development heat load. Low carbon electricity produced whilst “heat dumping” or serving West Cambridge may be useable as an Allowable Solution.

Further work is required to establish the most appropriate scale, location and type of technology though a potential location has been identified in the parameter plan in the extreme North West plot on the Application Site. Indicatively a 1.5MW(e) biomass CHP would meet the baseload heat requirements of the Proposed Development.

Potential energy and CO_2 savings

A biomass CHP plant providing 70% of the entire Proposed Development’s heat demand would save around 120,000 tonnes of CO_2 over the 13 year lifecycle at an average of 9,000 tonnes per year. This equates to a 48% saving when compared to the baseline with energy efficiency model.

Potential advantages

Biomass CHP is currently a relatively efficient means of using biomass fuel to save CO_2, with greater savings being achieved than in a heat only application. If all heat is used, biomass CHP provides the greatest CO_2 saving of all site-wide options thus reducing the need for additional renewable and low carbon technologies to meet future Building Regulations and the Code for Sustainable Homes requirements.

Potential risks and disadvantages

The long term phasing of the Proposed Development means that a large proportion of the heat generated would be dumped whilst the site is constructed. By the time the Proposed Development is complete, the initial installation may be approaching the end of life, and thus has effectively been ‘wasted’.

Biomass CHP technologies at the small scale required for the Proposed Development (and indeed at larger scales if the Proposed Development was to link to other sites) are immature and highly risky at present. There are few commercial installations operating at this scale and many are experiencing operational difficulties. For this reason, many systems are still considered prototype and in development.

Biomass fuel availability is seen as a considerable risk to biomass CHP as discussed earlier in this section.

Conclusions

Biomass CHP or energy from waste is theoretically technically suitable for the Proposed Development albeit with difficulties concerning the phased construction of the development. The technology would be compliant with the Area Action Plan and meet CO_2 savings required in BREEAM and Code Assessments. However the barriers of technology maturity and availability with lack of proven performance, and the issue of fuel availability and security are significant.

Energy from waste – Anaerobic Digestion

The anaerobic digestion process takes organic waste and breaks it down in an oxygen depleted atmosphere to produce bio-methane which can then be used to generate heat and/or electricity. The systems typically consist of large digester tanks which are used to digest macerated organic waste. The tanks can operate in a continuous or batch process with the latter typically taking around 15 – 20 days. Most systems in the UK are based on this "wet process" and derive from sewage treatment systems. Common feedstocks are food waste, abattoir waste, and slurry from farms. The waste preparation in the form of maceration can be relatively energy intensive with around 25% of the total electricity output being used for this stage.

Alternative "dry" systems are being developed in Germany which take dry organic waste streams such as green waste, and digest in sealed bunkers to generate methane. These systems require a greater degree of manual waste handling, but are more adaptable to drier feedstock (which allows inclusion of arboricultural arisings).

In both cases an output waste stream is produced which can be split into a wet liquor and a drier compost type product, both of which will need disposing.

AD schemes are typically only commercially viable at around 1 MW electric upwards when assessed as an energy generation scheme, and this would require circa 30 – 50 ktonnes of suitable organic waste per annum. A system of 1 MWe would probably produce less than 1 MW heat (a large fraction of heat generated is used in the process).

Anaerobic Digestion – Application to the Proposed Development
An anaerobic digestion system would require a large footprint, but could potentially be accommodated on the Application Site. The scheme would rely on waste from a range of sources, both within the University as a whole (estimated resource at [less than 5,000 tonnes per year)] and from external sources. Typical systems use 40,000 tonnes of waste p.a. An AD scheme could also be installed as part of an on-site waste water treatment facility.
Potential energy and CO_2 savings
Due to the significant feedstock demands, it is likely that a system would be selected which is as small as commercially available and viable, typically around 1 MWe (producing less than 1 MW of heat). This would therefore only be part of an energy strategy and would be supplemented by additional heat generation technology. The CO_2 reduction from an AD scheme would be similar to a biomass CHP system of similar capacity, but the overall savings would depend on which technology the AD is partnered with. A system connected to an on-site water treatment facility is likely to be significantly smaller and would not be a major component of the overall energy strategy.
Potential advantages
Anaerobic digestion is a relatively clean technology with little impact on air pollution. Whilst there are only a few AD installations in the UK, the technology is relatively mature and simple, and has a high uptake in other European countries. The Applicant can contribute a small fraction of waste for a scheme, estimated at around 5,000 tonnes including farm slurry. (However a large fraction of this is slurry, which has a low calorific value).
Potential risks and disadvantages
AD schemes require a significant volume of waste as feedstock. It is estimated that the Proposed Development will generate around 5,000 tonnes of waste per year (3,245 of which is residential and therefore collected and taken to the council waste facility owned by Donarbon). Therefore around 20 times the Proposed Development's waste is required to operate a modest scheme. If the residential waste could not be used, then this increases to around 100 times.

Discussions previously held with some major UK suppliers and operators of AD systems in connection with the Applicant have highlighted the competition for feedstock, and the risks associated with obtaining sufficient feedstock. For this reason, potential operators required abattoir waste to be included, which is likely to generate significant opposition locally. The demand for feedstock and unknown sources also poses significant risks in terms of future costs.

An AD scheme will generate significant volumes of digestate (both solids and liquids). It is important that a disposal route can be found for this, potentially as a fertiliser. This would ideally be local to reduce transportation requirements.

Transportation of feedstock to the Proposed Development will be significant, estimated at around eight 20 tonne lorry loads per day.

AD technologies are relatively industrial by their nature, with large site requirements, potential for odours from waste handling, and noise associated with deliveries and operation.

A system connected with a water treatment facility is obviously dependent on on-site water treatment being proposed. Due to the phasing of the development, and spare capacity in the existing local water treatment works, an on-site water treatment facility is not proposed.

Conclusions

Large scale AD is not currently considered as a viable solution for the Application Site due to the large waste demand, and the relatively low site waste output. This is confirmed by discussions with suppliers and operators of AD schemes.

However a smaller AD scheme as part of an on-site sewage treatment plant could be more viable and potentially installed if on-site water treatment is proposed at a later stage. This will however likely be only a minor component of the overall energy strategy.

Connection to other areas

West Cambridge

West Cambridge is located to the south of Madingley Road opposite the Application Site. West Cambridge is predominantly made up of academic and research buildings with some additional residential capacity. The West Cambridge Site is currently around half built out and is the main area of expansion for the Applicant at present.

The potential for CHP and district heating on West Cambridge has been considered has the potential for linking West Cambridge and Application Site together. The conclusion is that the main benefit of linking the sites is to export heat from the Proposed Development to existing buildings on West Cambridge as part of the Allowable Solutions for the Application Site, if the additional cost of the linking heat main pays back. This strategy depends on the final definition of what form Allowable Solutions may take which is still to be announced by the Government.

Many of the other apparent advantages are not so strong. The scale of each site is large enough to justify separate energy centres with little benefit to be gained from combining energy centres for a gas CHP based system. Exporting heat to new / future buildings on West Cambridge from the Proposed Development will provide no CO_2 benefit to the Proposed Development because these CO_2 reductions will be allocated to the new West Cambridge buildings for future Part L compliance. It is also possible that a more effective use of exporting heat to the existing buildings on West Cambridge is to act as Allowable Solutions for West Cambridge, rather than for the Proposed Development.

One potential area where connecting to West Cambridge could be advantageous is if a single large scale technology such as biomass CHP or energy from waste is selected for the Application Site. As discussed in this report, the commercial applications of these technologies are generally much larger than the heat load of the Proposed Development. Adding the heat load of West Cambridge (which is similar to the Proposed Development in scale) may make these technologies more viable. However for many technologies, the joint heat load is still likely to be lower than the requirements of the technology scale.

The recommendations are that, given the current uncertainties around Allowable Solutions and the lack of definition, the energy strategy for the Application Site should be designed not to include a connection to West Cambridge in the short term, but be flexible for modification as and when further information is known.

Connection to other areas

West Cambridge is the main area of interest being a large site also in the Applicant's ownership. However there could be opportunities for connection to other neighbouring sites including Girton College, Fitzwilliam College, and existing housing areas.

Connection to individual buildings or colleges will represent a very small fraction of the overall Proposed Development heat demand and therefore is unlikely to impact the overall energy strategy. Due to the timescales of the project, it would be difficult to gain buy-in with these buildings at the current time, and it is likely that detailed proposals would be required or even an operational scheme before such customers would take the decision to commit to connecting to the network.

Connection to existing housing in the area could potentially provide large CO_2 benefits by providing low carbon heat to 'hard-to-treat' homes. Cambridge is characterised by Victorian terraced housing which will be difficult to make more thermally efficiency, but which could benefit from low carbon heat from a heat network. However there are significant barriers to the uptake of district heating in these areas:

- The cost of installing heat networks into low rise housing areas can be very high. Recent estimates suggest a cost of between £7,900 and £10,900 per dwelling (assuming terraced or semi-detached) for the installation of pipework and interface units[14]. These costs would either need to be covered by home-owners, or through the effective heat tariff.
- Developing a viable district heating scheme requires a high uptake of customers in the first few years. Without regulation, it is difficult to encourage domestic customers to connect to a scheme.
- The majority of the homes in Cambridge neighbouring the Application Site are in private ownership and therefore any district heating scheme would need to deal with many different potential customers to encourage connection. This task may be simpler if there were large areas of social housing owned by a small number of organisations.

These barriers represent a very large risk to district heating scheme development, and there are virtually no examples of successful schemes in the UK except for where there has been significant public sector involvement in supporting the development of schemes. This support may be financial, contractual (providing guaranteed heat take-off from public sector buildings and housing) or even developing and owning the scheme with a joint venture.

Given the above barriers, and the potential minimal impact of connecting to other loads on the basic energy strategy, connection to areas outside the Application Site is not considered for the site wide energy strategy. However there may be opportunities into the future for the scheme to expand to other buildings and neighbourhoods if the regulatory and economic environments enable this to be viable.

Site scale renewable energy technologies

Large scale wind

At the national level, wind power is seen as one of the most economically attractive and mature renewable technologies, reflected in the fact that wind turbines only receive one ROC whereas other less mature technologies in need of research investment such as biomass CHP receive 2 ROCs. Recent advances are seeing ever larger

[14] The Potential and Costs of District Heating Networks. DECC 2009. (Authors – AECOM and Pöyry).

(5MW plus) machines and these are expected to form a high percentage of the national target for the generation of renewable energy by 2020.

A typical modern 2 MW turbine will have a blade diameter of around 80m and hub height of around 60 – 80m. Minimum average annual wind speeds of around 6 m/s) are required for economic operation. Siting of the turbines is critical to optimise performance and most windfarms are located in high wind areas with no nearby obstructions which may impede the wind flow and cause turbulence. Typical locations including open rural areas or high areas on hills and mountains.

There are a number of design rules (which are open to interpretation on a case by case basis) which determine the density and location of wind turbines. Typically turbines are located 5 or more blade diameters apart to reduce interference between turbines, and this limits the density to around 3 – 4 large turbines per km^2. Other large considerations are around noise and flicker, and a general guideline is that a minimum distance of 500m from residential properties should be maintained. Visual impact is also clearly an important deciding factor although this is highly subjective and assessed on a case-by-case basis. A number of other factors also apply including maintaining buffer zones around roads and railways to prevent toppling risk.

Product/Rotor diameter (m)	V15	V17	V19	V20	V25	V27	V39	V44	V47	V52	V66	V80	V90
Year of installation	1981	1984	1986	1987	1988	1989	1991	1995	1997	2000	1999	2000	2002
Capacity (kW)	55	75	90	100	200	225	500	600	660	850	1750	2000	3000
MWh/year	217	265	301	346	481	647	1304	1581	1947	2530	4705	6768	9152

Figure 11. Comparison of wind turbine size (Vestas).

Large scale wind – Application to the Proposed Development

If large scale turbines were to be used to provide on-site CO_2 reduction, then around 6 MW installed capacity would be required to meet the 70% carbon compliance level for all the dwellings. This could be met by three 2MW turbines with 80m blade diameter and 60 – 80m hub height.

Large scale wind may potentially be used as an Allowable Solution depending on the outcome of the Government decisions on how this offset may work. If so, a number of turbines could be developed remotely from the Application Site to provide additional CO_2 reductions above the carbon compliance level. The issue of additionality in CO_2 savings would need to be considered and will probably be covered by the final regulations on

Allowable Solutions.

Potential energy and CO_2 savings

Assuming a 20% load factor (which is relatively low for commercial scale turbines to account for the poor location) then a 2 MW turbine would save around 1750 tonnes CO_2 per year, or 7% of the baseline Proposed Development emissions.

Potential advantages

Commercial scale wind is the most established and proven renewable technology globally with a number of technology suppliers and specialist developers.

There could be potential for large scale wind through Allowable Solutions at another location, if this is an option adopted by Government.

Potential risks and disadvantages

Commercial scale wind is inappropriate to the development due to the size and impact of the turbines on the Application Site and surrounding areas. Incorporating large scale turbines on the Proposed Development would require large buffer zones to the dwellings which may impact on the number of dwellings which can be accommodated on the Application Site.

Whilst a subjective matter, large scale turbines would have very large visual impact both of views of Cambridge from the Motorway, and also within Cambridge. Some might see this as being an adverse impact.

There are currently no commercial turbines in South Cambridgeshire or Cambridge City and all proposals have developed strong local opposition. It is highly likely that proposals for large scale turbines on the Application Site would also be strongly opposed.

Conclusions

Large scale wind is inappropriate for the Application Site due to the scale of the technology. It is therefore not considered as an on-site technology.

Large scale wind is considered as suitable for additional CO_2 reductions above carbon compliance if allowed under the Government Allowable Solutions regulations.

Small scale wind

There are a number of smaller scale wind turbines available which are designed for operating in more restricted areas where large commercial scale devices are unfeasible. These turbines typically have power outputs measured in the low 10s of kW and are usually tower mounted. Blade diameters are typically up to around 10m and tower heights of up to 25m although higher mountings will allow the turbine to perform better.

Many of the constraints which exist for commercial scale turbines also exist for small scale devices, albeit with much smaller buffer zones of around 20m for roads and railways, and 50 – 100 m for dwellings. This means that whilst small scale turbines can be integrated into urban and semi-urban environments, there are still many limitations, especially with residential developments.

Small scale turbines are also highly susceptible to local wind conditions due to their low height, especially in built up areas, where neighbouring buildings cause turbulence and slow down the wind, resulting in a poor resource. Results from trials of roof mounted turbines at the Elephant and Castle show load factors of around 7% (compared with between 25% and 30% for most large scale commercial turbines) [15]. Another monitored installation at the Hockerton Housing project has a similar load factor of 8.3% for a 6kW Proven. This turbine is mounted on a 24m mast in a

[15] Ashenden Wind Turbine Trial: Phase 2 Update. http://www.elephantandcastle.org.uk/windturbinetrial

rural location [16].Therefore despite the ability to locate these small turbines in urban locations, the output is likely to be fairly low, and only locations which are open with a strong wind resource should be considered.

Figure 12. Small wind turbines located at Hockerton Housing (a Proven 6kW and Gazelle). Both are mounted on 24 metre masts.

Small scale wind – Application to the Proposed Development

The Proposed Development could provide locations for the installation of small scale wind turbines. The area with the best potential and with access to the prevailing SW wind direction is along the western edge of the Application Site adjacent to the M11 motorway. The turbine mounting would need to be designed to provide a good hub height above the level of the motorway and overcome the dip adjacent to the motorway around the Washpit Brook. It is estimated that around 27 15 kW devices could be installed in this area.

Another area which may offer some potential in terms of space is Storeys Field although the wind resource is likely to be poor due to surrounding buildings and trees. Wind Turbines at the Application Site are therefore not considered viable.

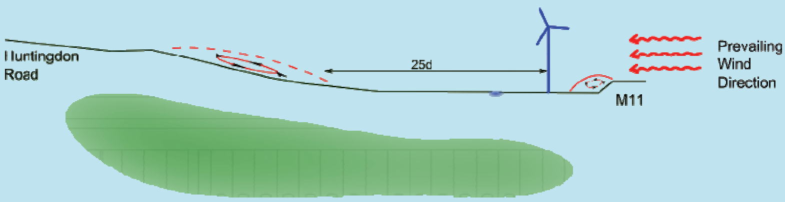


Figure 13. Schematic cross section of the Application Site showing location of potential turbines along the western edge. Both the M11 embankment and the rise to the north will impede wind flow.

16 http://www.hockertonhousingproject.org.uk/SEFS/ID.1369/SEFE/ViewItem.asp. Figures based on the output from a Proven 6 kW machine.

Potential energy and CO_2 savings
Assuming an optimistic 10% load factor, a single 15kW turbine would produce 13 MWh per a year providing a saving of 6.5 tonnes CO_2 per year. 27 turbines with this performance (considered the number achievable along the Western Edge) would reduce the overall Proposed Development CO_2 emissions by about 0.7%.
Potential advantages
The electricity produced by small scale wind is not dependent on building loads (unlike heat producing renewables) and the potential is therefore a resource limitation. Feed in tariffs may mean that small scale can operate economically depending on the performance. Small scale wind is also a visible demonstration of renewable energy which can aim to educate people and encourage other installations in the areas.
Potential risks and disadvantages
The performance of turbines in an urban environment such as on the Application Site is likely to be very poor with the figures presented here being optimistic. A large number of turbines (27) are required to make a very small CO_2 reduction (less than 1%), and there is a risk that the turbines are a "token effort". If the turbines do perform poorly, and for large periods of time they do not rotate, there could be negative press for the Applicant and small wind industry. This happened to the micro wind industry following a push into building mounted devices.
Conclusions
There is technical potential for incorporating small scale wind turbines, but the benefits in terms of energy generation and CO_2 reduction are very small. In addition, the wind resource on the Application Site is likely to be poor due to neighbouring trees and buildings and there is a risk that turbines will have very low performance. Small-scale wind is not proposed for the Proposed Development.

Micro scale Low and Zero Carbon technologies

Photovoltaics

Solar photovoltaic (PV) arrays generate electricity from the incoming sunlight. In general, PV is a flexible technology which is compatible with most building types and other technologies, as the output is not dependent on the building energy demands. The PV arrays are typically located on roofs and consist of a number of separate panels linked together. Around 10 m^2 of roof space is required per kW of power, and a typical domestic installation would be around 1 - 2 kW. The limiting factor is generally the amount of suitable roof space available, and this needs to account for surrounding space for maintenance of the PV array, and competing roof space uses such as mechanical plant. As a rule of thumb, active PV area can be around 50% of total roof area for a typical building, although for optimised buildings, this could be much higher. In the residential sector PV panels are now produced for use as roofing materials e.g. in place of roof slates.

PV systems operate best when located on a roof within 30 degrees of due south at around 30 – 40 degrees inclination. However the systems will work with a small drop in output for other orientations within circa 30 – 40 degrees of south, and other inclination angles. Therefore whilst orientation is important it does not need to be optimised in all cases.

PV technology is generally expensive requiring high upfront capital investment. However the ongoing costs are low with no fuel requirements and minimal maintenance. The technology is eligible for Feed-in-Tariffs (FiTs) which will improve lifecycle costs to the extent that payback should be within the lifetime of the system. Alternatively, ROCs could be collected for systems if they provide a greater incentive.

As a method of achieving CO_2 reductions, PV is very flexible. Unlike heat producing renewable technologies, the output is not limited by the building loads, and so with electricity export, the size of the array can be maximised. This used to cause an economic loss (through a low price being paid for the exported electricity) but the advent of FITs now means there is minimal economic disadvantage of exporting.

Figure 14. Roof mounted PV panels.

Photovoltaics – Application to the Proposed Development

The ongoing ownership of the Proposed Development by the Applicant opens opportunities for the lifecycle benefits from the FITs to be returned to the Applicant. The extent to which the Applicant can offset the high capital costs against attractive tariffs will depend on the procurement strategy taken forward.

At present, PV is being considered as part of the energy strategy. This could fulfil a number of roles:

- Acting as a major CO_2 reduction measure on buildings which make use of building scale strategies.
- Providing additional CO_2 reductions on buildings connected to site wide systems
- Providing a revenue stream for the Applicant if the tariffs provide economic operation.

Buildings and roofs will be orientated and/or designed in order to facilitate the incorporation of PV within buildings. This provides the flexibility to install solar systems without impacting the development proposals, if they are deemed suitable. Rooftops facing Huntingdon road would not be of suitable orientation and will therefore not feature PV technologies.

There is also the potential for use of PV in standalone applications. Examples include remote power applications such as electronic road signs, bus stops and parking meters where there is a significant saving in cabling costs for a conventional supply. There are a number of commercially available products for each of these. The CO_2 savings from these applications would not contribute to meeting carbon compliance for building regulations but would contribute to overall levels of renewable energy provision on the Proposed Development.

Figure 15. A solar powered "tree" street lamp and a parking meter.

Larger scale PV installations in the form of mini 'PV-farms' could be installed to provide additional CO_2 reductions. Developing larger scale PV schemes may provide more economic systems but until the Government announces its proposals for Allowable Solutions, the extent to which these can or cannot contribute to CO_2 reduction for carbon compliance is unknown.

Potential energy and CO_2 savings

Roof / building mounted

The Proposed Development, when fully complete will have a roof area of approximately 170,000m^2 which, if fully covered in PV, would provide a peak electrical output of around 12 MW. This assumes that roofs are either flat or designed with pitches facing between south-east and south-west and unshaded.

A 12MW PV installation would produce around 10,200 MWh p.a. (around 35% of the Proposed Development's electricity demand) and save 62,000 tonnes of CO_2 over the 13 year lifecycle at an average of 4,800 tonnes per year. This equates to a 25% CO_2 saving when compared to the baseline with energy efficiency model.

Standalone applications

The main driver for solar PV standalone applications such as bus shelters and parking meters is not one of energy or CO_2, but of connection cost. These applications generally have very low levels of energy consumption, but the cost of connecting each installation to the electricity grid, especially in existing areas where there may not be a connection point easily available, can be extremely high. In these cases, the cost of a PV solution can be lower. For the Proposed Development, the site infrastructure will be designed to allow connection for all applications and therefore there is probably no economic benefit from using solar PV standalone systems. The CO_2 reductions which would be gained from this are also minimal, and larger reductions can be made elsewhere with the same investment.

Potential advantages

Photovoltaic technology is very mature and reliable. In 2009, a total of 7.5 GW of PV was installed worldwide, and in the UK, there is currently estimated to be somewhere between 20 and 30 MW installed. It is estimated that between 10 and 20 MW will be installed in the UK in 2010 – 2011 alone. This compares with an additional 3.8 GW in Germany for 2009.

By generating electricity, the solar resource is not limited by energy loads (unlike heat-producing technologies) and the limiting factor becomes the capacity which can be physically contained on the Proposed Development and afforded economically.

The introduction of the Feed in Tariffs (FITs) in the UK will improve the likelihood that PV installations are economic by providing a revenue for each kWh of electricity generated. However the Applicant will need to set up a suitable contract mechanism if these revenues are to be recouped to offset the significant capital expenditure rather than claimed by the householders.

Roof / building mounted

PV systems generally require very little maintenance and pitched roof-top systems generally self-clean.

PV could provide large levels of CO_2 reduction for the Proposed Development if large areas of roof are covered. There is no conflict between PV and other LZC technologies allowing these CO_2 reductions to be additive to other options.

By integrating PV with roofs, the installation of PV on the site can be phased allowing a spread of expenditure.

PV arrays can have minimal visual impact when installed on buildings. It can be possible to integrate panels with the building fabric (for example, solar “slates”) or hide the arrays on flat roofs.

Standalone applications

Stand-alone PV systems for low power demands (for example, bus shelters and parking meters) can be cost effective by removing the need for an expensive electricity connection. However due to the density of the Proposed Development, it is likely that most areas will have easy access to an electricity connection.

Potential risks and disadvantages

PV is a high capital cost technology, even with recent and predicted reductions in cost. Therefore it is important that the FITs can be claimed where possible to help with the lifecycle costs.

The future of FITs post 2012 is uncertain following the Governments Comprehensive Spending Review. There is therefore a risk of reduced cost effectiveness if the FITs are reduced or withdrawn (it is currently expected that the scheme will remain, but with lower tariffs).

PV ideally requires optimum orientation (although there is some degree of freedom). Therefore the development layout enables buildings to be orientated correctly, and the buildings need to be designed with suitably designed roofs (to be addressed in design guidelines). One option is to build flat roofs which allows greater degrees of freedom for installation with banked arrays of PV panels.

Conclusions

Roof / building mounted

PV is one of the technologies with relatively few limitations, and which can provide large CO_2 reductions for the Proposed Development. The technology is mature and reliable, and currently supported by financial incentives. The use of building-mounted PV is therefore considered suitable for the development.

Standalone applications

Standalone PV applications for infrastructure such as bus shelters and parking meters is not proposed unless desirable from a technical and economic perspective for certain applications in certain areas.

Solar thermal

Solar domestic hot water systems can provide around 50% of the annual domestic hot water demand, with most of the demand being provided in the summer months. The systems consist of collectors, usually located on the roof, and a storage tank which can store the thermal energy from the time of generation (typically during the day) to the demand (typically the evening and early morning).

Solar thermal collectors operate best when located on a roof facing within 30 degrees of due south at around 30 – 40 degrees inclination. However the systems will work with a small drop in output for other orientations up to east – west facing (these systems often have a collector on each east and west facing section of the roof).

Solar thermal systems may be eligible for future renewable heat incentive (RHI) although it is not known how this will be administered until the Government announces the outcome of the RHI consultation. It is expected that a flat rate incentive will be offered per system to remove the requirement for heat metering.

Solar thermal systems are generally not used with CHP and district heating technologies as they reduce the summer thermal demand, which is when low carbon surplus heat is normally available from CHP. The additional CO_2 benefit from solar thermal is therefore relatively small and the cost of the solar thermal system cannot be justified.

In some countries large solar thermal systems are connected to community heating schemes making use of large thermal stores to generate and store heat in the summer and use the heat during the winter. These thermal stores can be large well insulated water tanks or ground water. The benefits of these schemes are debateable and overall, they only provide a relatively small proportion of the overall annual heating load due to hot water demand as a fraction of total heating, and large thermal losses from the stores, up to 50%[17]. The size of the solar arrays is also extremely large, and to maximise the benefits of this expensive technology, climates with high levels of summer insulation are required (such as Continental Europe).

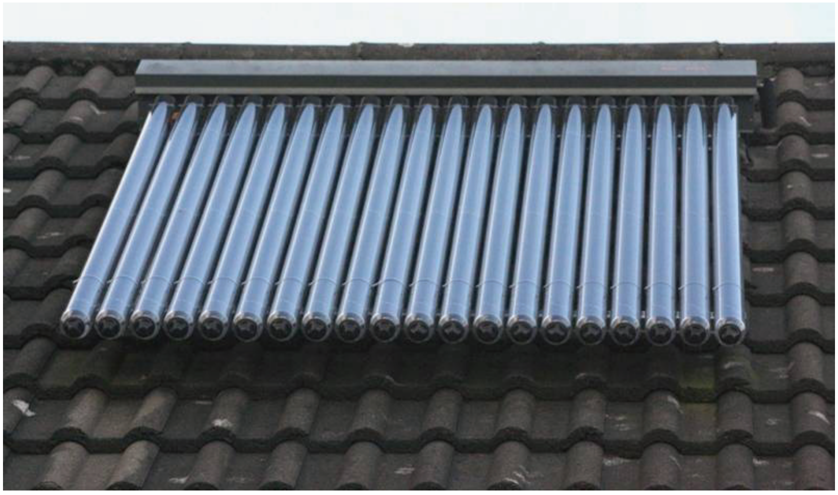


Figure 16: Evacuated tube solar thermal system mounted on a domestic roof. (Image courtesy of Andy McCrea)

Solar thermal – Application to the Proposed Development
Solar thermal systems could be used in the Proposed Development for both dwellings and non-domestic buildings. The orientation requirements and limitations are similar as for PV. The potential for solar thermal is limited however, unlike PV, by the demand for hot water. In areas of high hot water demand, such as dwellings, the fraction of CO_2 reduction available from solar thermal will be much higher than that obtained in low hot water demand buildings such as the commercial research buildings. Solar thermal systems would not be advantageous for areas of the Proposed Development connected to a district heating system, due to competition for the heat load reducing the economics and CO_2 reduction available from a CHP scheme.
Potential energy and CO_2 savings

[17] Roth, K., Brodrick, J. 2009. *Seasonal Energy Storage*. ASHRAE Journal.

Solar Thermal systems providing hot water to all buildings on the Proposed Development would save around 17,000 tonnes of CO_2 over the 13 year lifecycle at an average of 1,300 tonnes per year. This equates to a 7% saving when compared to the baseline with energy efficiency model.

Potential advantages

Solar thermal systems could be suitable for all buildings with a hot water demand.

The technology is mature with a proven track record and low maintenance requirement. Whilst relatively expensive in terms of delivered energy and CO_2 reduction, the proposed renewable heat incentive will improve the economics.

Potential risks and disadvantages

The potential for CO_2 reduction is limited by the available hot water demand which is likely to be low in many of the highly energy intensive commercial buildings. It is therefore unlikely to make a significant reduction in CO_2 emissions for these buildings.

Solar thermal is incompatible with a district heating scheme. Therefore the presence of a DH scheme (and the desire to maximise the size of the scheme) means that the overall potential across the Proposed Development for solar thermal is reduced.

Solar thermal only provides heat during the summer and so plant is still required to provide hot water in the winter. This may mean top-up from a gas boiler, or for a passive house with little space heating demand, top up from electric resistance heating.

Conclusions

The heat network proposed for the Proposed Development will be connected to a large number of homes and non-domestic buildings, but probably not all. Therefore solar thermal systems will have potential on some parts of the Proposed Development to complement other building scale low and zero carbon technologies.

Heat pumps

Heat pumps use electrical energy to drive a compression cycle and transfer thermal energy from a low temperature heat source to a building's heating systems operating at higher temperature. The electricity required to drive the compressor is less than the energy value of the heat which it produces. The ratio of heat produced to electricity required is known as the Coefficient of Performance (CoP), rather than efficiency, as it exceeds 100%. For example if one unit of electricity is required to create 3 units of heat energy, then the CoP of the system is 3. Although the heat from a heat pump is often described as renewable there are still CO_2 emissions associated with this heat as most of our electricity is from non-renewable sources.

The relatively high CO_2 intensity of grid electricity in comparison to other heating fuels and the costs of electricity mean that the CoPs of heat pump systems need to be sufficiently high to allow the system to compare favourably in terms of CO_2 and cost with other fuels such as gas and oil. At present, the average CO_2 intensity of grid electricity is about 2.5 times higher than that of boilers using natural gas (after accounting for boiler efficiency), then a CoP of at least 2.5 is required for the heat pump to give a positive CO_2 benefit. However, as the grid reduces in CO_2 intensity with increased renewable and low carbon generation, heat pumps will become more favourable on a CO_2 basis. The CoP of a heat pump is directly linked to the sink and source temperatures, i.e. the temperature gradient. For this reason it is important to optimise the building heating system temperatures using as low a temperature as possible which implies the use of underfloor heating.

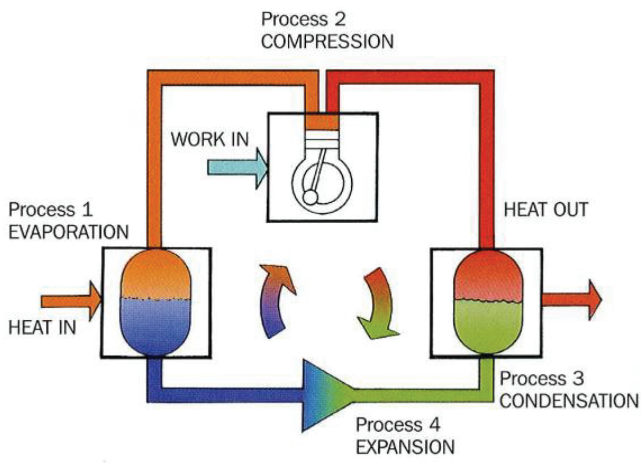


Figure 17. Heat pump vapour cycle. The overall efficiency or "coefficient of performance" is governed by the "Heat In" and "Heat Out" temperatures, with higher efficiencies being achieved for low output temperatures. (Image courtesy of Andy McCrea).

There are two main types of heat pump system of interest to this study; air source heat pumps and ground source heat pumps.

Ground source heat pumps (GSHPs) make use of the relatively constant ground temperature throughout the year. This is related to the annual average air temperature for the Application Site and for the UK is generally around 10°C. The thermal energy can be extracted from the ground using three basic methods:

- Using pipe loops laid under the surface with a heat exchange coolant circulated through them. These systems typically require around 250 m^2 of ground collector area per a 5 kW loop, and are most suited to smaller and domestic applications due to the lower cost.
- Using a closed loop vertical borehole. In this system, a closed pipe loop with coolant is orientated vertically in a borehole of 70 – 100m deep (which can sometimes be combined with foundation piles in new buildings) requiring significantly less horizontal ground area than surface systems, making them suitable for urban locations. The systems are more expensive than surface systems, and geotechnical studies and drilling costs mean that larger systems with multiple boreholes are generally more economic.
- Open loop vertical borehole. These systems extract groundwater and pump it to the surface to extract thermal energy before pumping it into a separate rejection well. Overall, no water is extracted from the ground, but some form of approval is usually required. The high costs of sinking two wells mean that the systems are only suited to large applications, typically 100s kW, and sufficient space is required to space the two wells, typically 100s m.

Figure 18: Image showing installation of surface collector loops for a ground source heat pump system prior to being covered and landscaped. The various collectors are placed in trenches (T) and join to form a single flow and return pipes connected to the heap pump (A and B). (Image courtesy of Andy McCrea)

Due to the relatively constant temperature of the ground, the CoPs of GSHP systems are around 3 depending on the system type and output temperature. Where the ground loading is balanced by summer cooling (effectively dumping heat into the ground during summer) then the CoPs can be improved further. However it is important to minimise output temperatures and low temperature heating systems such as underfloor heating are required to maximise the CoPs.

For borehole based systems, detailed geological and geotechnical assessment is required on a site by site basis to assess the geological structure and thermal conductivity of the ground.

Air source heat pumps (ASHPs) operate in a similar manner to GSHPs, but use an external air exchanger instead of ground loops or wells. The advantages of ASHPs are significantly lower costs due to the absence of ground works, and their ability to be installed on most buildings with minimal space requirements (although the size of the external exchangers and the noise emissions need careful consideration in the domestic sector).

However the external air temperature is extremely variable, and when the air temperature is low, the heating demand will be high, resulting in a large temperature gradient and reduced CoP. Therefore the average seasonal CoPs of ASHPs are typically lower than for GSHPs. In addition, there can be issues with icing up of the external heat exchangers in humid conditions, and the systems are run on a defrost cycle periodically to prevent this, reducing CoPs further.

Recent advances in ASHP design have led to a number of systems being marketed with much improved CoPs,

The Energy Saving Trust have recently Issued the results of a major heat pump monitoring trial[18]. The performance of over 80 domestic heat pumps was assessed and ASHPs had an average CoP of around 2.2.This is too low a performance to produce CO_2 savings for current levels of electricity grid emissions.

[18] Getting Warmer: A field trial of heat pumps. Energy Saving Trust. 2010.

Under current calculation methodologies (such as the UK SAP procedure and default CoP values), ASHPs will emit more CO_2 than natural gas–fired boilers with current grid CO_2 intensities, and so their use for the generation of low carbon heat may be limited to off gas grid areas in the short-term.

A further heat pump type which has not been explicitly modelled in this report is the water source heat pump. These operate in an identical manner to the ground source heat pump, but with the heat exchanger in a body of water such as a lake or river. The advantages of this are that COPs can be increased due to the good heat transfer coefficients of the water. This technology is not considered suitable for the Application Site due to the absence of a large body of water.

Cooling using heat pumps. Vertical loop ground source heat pumps can provide both heating and cooling by pumping heat in either direction. This can help increase the overall efficiency by ensuring that the ground is not depleted of heat or coolth.

Heat pumps can also be used to provide heating as a by-product of cooling. Where cooling is required, for example in a supermarket or data-centre, the extracted thermal energy can be used for heating in another area. This heat is effectively waste heat and so extremely low carbon. In a situation where the loads are balanced, for example in a building which has simultaneous heating and cooling demands, the system can operate at a building scale. Where the loads can be balanced over more than one building, a district heating network, and/or district cooling network could be used. District cooling networks distribute coolth from a central chiller to individual buildings using a cold water pipe network. These are much simpler than DH networks, because the ground is at a similar temperature to the circulating water, and therefore simple plastic pipe systems can be used with minimal or no insulation.

Heat pumps – Application to the Proposed Development

Heating

Heat pumps could technically be installed in all buildings on the Proposed Development. For single domestic units, air source systems will probably be the most suitable, whilst in the larger non domestic buildings (and possibly blocks of flats) ground based systems using boreholes are probably more suitable due to better efficiencies. Due to the density of the Proposed Development, there is probably limited scope for ground source surface-loop systems, apart from certain buildings such as the primary school (which could install ground collectors in the grounds).

Cooling

Some individual buildings may require cooling to maintain acceptable internal temperatures. The energy loads for this are included in the benchmarks. However where large cooling demands exist, such as the foodstore and a data-centre (if present), then the waste heat from this cooling could be collected and used for heating. One potential application is to provide heating for the hotel from the foodstore chillers.

If a cooling network was used on the site with large scale chillers located in the energy centre, then potential for waste heat capture is increased allowing a contribution to be made to the heating from a range of buildings.

Potential energy and CO_2 savings

Due to the relatively high CO_2 content of grid electricity predicted over the next 13 years and the low COPs measured in the Energy Saving Trust trials overall CO_2 savings from the application of ASHPs to all dwellings and GSHPs to all non-domestic buildings results in CO_2 savings of just 8000 tonnes over the 13 year lifecycle period. This equates to 600 tonnes per year or 3% of overall CO_2 emissions.

The potential energy and CO_2 savings from centralised cooling and waste heat capture have not been calculated due to considerable uncertainty around the potential cooling loads.

Potential advantages

Heat pump systems are relatively mature, with a large uptake in other parts of Europe (particularly Sweden where a long term financial incentives has supported uptake). Where the CO_2 intensity of the grid is sufficiently low, they can provide large CO_2 reductions compared with fossil based systems, and an efficient way of providing heat.

Heat pumps can be used for both heating and cooling for non-domestic buildings. By balancing these loads, overall CoPs can be made by ensuring that the ground is not cooled or heated excessively (the ground effectively acts as a thermal store).

Waste heat capture from centralised chillers will reduce the carbon intensity of the heat on the heat network, and provide lower fuel costs and CO_2 emissions. There may also be small local environmental benefits from reducing external environmental heating. Using centralised chillers and a cooling network will enable large, high efficiency chillers to be used, reducing the need for chillers in individual buildings freeing up plant space.

Potential risks and disadvantages

The results from recent field trials of domestic heat pumps by the EST have shown that CoPs are generally lower than planned or claimed by manufacturers [19]. This means that there may be no CO_2 reductions, or even increases in CO_2 (compared with gas boilers) and energy costs for residents may be high.

Heat pumps are most efficient when the difference in temperature between source and demand is minimal, therefore low temperature heating systems are preferred. This means that domestic hot water will either reduce the overall CoP, or require additional top-up heating.

Waste heat capture from chillers will require cooperation between different parties (for example the foodstore operator and the hotel operator). If connected to the central DH network, the network will also need to be designed to operate at lower temperatures to benefit from the waste heat. A centralised cooling network will require the installation of additional infrastructure although this will be simpler, less expensive, and a smaller scale than the DH network.

Conclusions

The short term carbon intensity of the grid rules out heat pumps providing a major contribution to heating needs across the Proposed Development for the first 15 years of development. This is due to the small CO_2 reductions achievable.

It is important to stress here, however, that the application of heat pumps beyond 2025 is likely to result in significantly greater CO_2 savings due to the expected decarbonisation of the grid. This may provide an incentive for their use later in the phasing of the Proposed Development.

CO_2 savings are greatest for non-domestic buildings that have room for a ground source array and have a balanced heating and cooling demand. For this reason, laboratory buildings and other cooled non-domestic buildings being built towards the end of the phased build-out may benefit from their use.

Additionally, in certain circumstances heat pumps will provide good CO_2 savings earlier in the phasing where a building (or adjacent buildings) has simultaneous heating and cooling demands. It is envisaged therefore that a centralised heat pump system in the local centre could take heat rejected from food store refrigeration and possibly data centre cooling and use it to provide pre-heat hot water in the hotel and student residences. Further discussion is required with the future food store operator to scope the potential for this arrangement. A centralised cooling network could be used to centralise the chiller capacity and increase the potential for capturing waste heat.

Assuming that biomass CHP is not viable on the Proposed Development then at some point, when fossil fuels (particularly gas) become prohibitively expensive either due to world-wide shortage or an inherent carbon price, heat pumps are likely to be the principal form of heating across the Proposed Development. It is impossible to predict when this will occur, however measures will need to be put in place (such as low-temperature heating systems) to ensure that heat pumps can be easily retrofitted in the future.

It is also possible to use large-scale heat pumps at the central Energy Centre and supply the district heating system. Again for this option to be available in the future it will be important to use low temperatures for the

[19] Getting Warmer: A Field Trial of Heat Pumps. The Energy Saving Trust. 2010.

district heating network design.

Micro CHP (including fuel cells)

Large scale CHP systems are generally used with significant single loads, or connected to a heat network. If a demand exists for the heat, then in general, the electrical efficiency improves with CHP capacity resulting in greater CO_2 reductions.

However where a heat network is not feasible or viable or there is not a single large heat load, then large scale CHP is not possible. Smaller scale CHP systems exist which are designed for single building and dwellings to meet this need.

For larger buildings, small spark ignition engines can be used operating off natural gas. These are similar to the large engines used in district heating schemes, but have lower electrical efficiencies resulting in a heat to power ratio of around 2:1, and correspondingly lower CO_2 reductions. It is important to ensure the CHP is sized to the load, and without diversity on a single building, the systems are generally small compared to the peak heating load. The costs for small engine based systems are higher per kW than for larger systems.

Micro CHP for the domestic sector is currently not commercially available although there are a number of products being developed. The closest to market is based around Stirling engines operating from natural gas, which have a large heat to power ratio. Field trials of Stirling based systems by the Carbon Trust have shown that unless a large baseload heat demand exists, the CO_2 savings from Stirling Micro CHP are small (typically 5% over a condensing boiler) or on some cases, even increase [20]. This is due to heat loads in smaller or more efficient dwellings being too low for effective CHP operation, and the resultant on-off cycling meaning that the Stirling engine does not achieve efficient operating temperatures. Fuel Cell CHP systems are also currently being developed for the domestic market and have a much higher electrical efficiency (typically around 35%) resulting in a much lower heat to power ratio and higher CO_2 savings. Fuel cell CHP technology is available at a large scale commercially (albeit at a much higher cost than gas engines) but at the domestic scale, is currently pre-commercial. Perhaps the closest to market in the UK is the Ceres Power solid oxide fuel cell (SOFC) domestic microchip unit which has been under development for the last few years, and which will be launched in combination with British Gas late in 2011 [21]. The lower heat to power ratio of fuel cells will mean they are better suited to new build and low thermal demand homes – it is expected that the units will have a low power to allow almost continuous operation in the winter with a buffer vessel. No commercial costs are currently available.

[20] Micro CHP Accelerator: Interim Report. 2007. Carbon Trust
[21] http://www.cerespower.com

Figure 19. DACHS 5.5 kWe CHP unit from BAXI–Senertec, based around a gas engine.

Micro CHP – Application to the Proposed Development
The dwellings at North West Cambridge will all have a relatively low heating demand, and therefore Stirling engine micro CHP is not considered a suitable technology. Whilst larger heat demands may be available for groups of dwellings or commercial buildings, the low electrical efficiency will mean that CO_2 reductions are limited and other larger scale options are likely to be more beneficial. Fuel Cell domestic scale micro CHP is currently pre-commercial, and despite industry plans, it is not possible to say with confidence when, and if, the technology will become commercial. There have been many years of development for small scale fuel cell CHP and many slipped milestones. Therefore fuel cell CHP is not considered viable at this stage as part of the energy strategy, but as future phases develop, the technology can be considered on a phase-by phase basis for the use in dwellings not connected to a district heating network. It is possible that by the later stages of development, fuel cell domestic scale micro CHP will be mass market and a replacement for condensing boilers.
Potential energy and CO_2 savings
Fuel cell micro CHP systems could deliver relatively large CO_2 reductions in the dwellings where they are installed. However this will depend on the availability of the technology and the performance characteristics. Micro CHP in non-domestic buildings could deliver small CO_2 savings, but will not perform as efficiently as larger scale CHP connected to the district heating network. Therefore connection to the DH network will be preferred for these buildings.
Potential advantages
Micro CHP enables the advantages of CHP to be obtained without the presence of a large scale DH network.
Potential risks and disadvantages

Domestic scale micro CHP is currently pre-commercial.

Larger scale CHP for non-domestic buildings is mature, but the limited heating loads presented by individual buildings will mean that the systems are relatively small and inefficient (compared to a community scale CHP system) and will provide lower CO_2 reductions.

Conclusions

Micro (and building scale) CHP is not considered viable for the Proposed Development at this stage. However the detailed design of future phases will continue to monitor the availability and performance of micro CHP as an option.

Biomass heat

Biomass can provide large CO_2 reductions through the provision of low carbon heat for space heating and hot water. The systems typically consist of a single (or multiple boilers) located in an energy centre with an automatic feed mechanism transferring the feedstock to the grate. Additional backup gas boilers are normally installed to provide peak heating loads and back-up capacity. Biomass boilers are similar to CHP systems in that they are best suited to meeting a steady baseload, and thermal storage can be used to increase the fraction of heat demand met.

Whilst the biomass boilers themselves are relatively low cost, the overall installation including fuel storage and feed can be relatively expensive, especially for smaller installations. For this reason, individual biomass boilers are less suited to single dwellings, where the significant space requirements and capital costs make the systems relatively expensive. In addition, the low thermal demands of a modern dwelling are not suited to the high outputs and slow response of biomass boilers (the smallest of which are around 10 kW compared to a 2 – 3 kW estimated demand for space heating in a modern dwelling).

The economics and performance of biomass boilers improve with size and so systems are more suited to large buildings, or groups of buildings, up to a district heating scale.

Biomass boiler energy centres need a sufficient amount of space to store feedstock with adequate access for large delivery vehicles. All biomass systems will require flues to exhaust the combustion gases and particulates at a height which reduces the concentration of pollutants within and around buildings to acceptable limits. These flues are typically at least 3 metres higher than all the surrounding buildings or more, and detailed dispersion analysis may be necessary to confirm that they are adequate.

Building scale biomass heating – Application to the Proposed Development

Building scale biomass heating is a potential option for the non-domestic buildings on the Proposed Development. This would require plant room in each single, or group of buildings which can accommodate the boiler, fuel storage, and provide adequate deliver access. Each plant room would require a flue to exhaust the gases above surrounding buildings.

The systems would be fed with either woodchip or wood pellets.

Potential energy and CO_2 savings

Biomass boilers can deliver low carbon heat and corresponding large CO_2 reductions depending on the heat load. The overall savings available from building scale boilers compared with a district system will be lower, due to the limitations of installing boilers in many of the buildings and the difficulties of installing a suitably sized thermal store to maximise the contribution to the total load. Individual dwellings are one important sector for which individual boilers are not technically viable, and therefore CO_2 reductions could not be made in this sector.

Potential advantages

Biomass boilers are an established and mature technology, with widespread use both in the UK and Europe. By using low carbon fuels, they can provide low carbon heating and therefore large CO_2 reductions for the buildings on which they are installed.

By installing biomass boilers at a building scale, a district heating network is not required. However this advantage is partially offset by the increased infrastructure requirements in each building including thermal storage, fuel storage (and delivery space) and flues.

Potential risks and disadvantages

Building scale biomass heating would be limited to using high cost feedstock such as wood pellets to reduce storage volumes. The market for pellets is becoming increasingly strong leading to increases in costs and future uncertainty of cost and availability.

Using biomass boilers at a building scale will generally provide smaller CO_2 reductions than at a community scale where the benefits of load diversity provide a more constant heat baseload and it is easier to incorporate thermal storage.

Providing delivery facilities, fuel storage, control systems and buffer tanks, combined with maintenance, for each building is very inefficient in terms of costs and space compared with a community system.

There could be a large impact on air quality with a number of distributed biomass energy centres, all of which are too small to be able to incorporate flue gas cleaning systems and tall flues which may be viable on a larger community scheme.

Conclusions

Biomass heating at a building scale is not considered a suitable technology for the Proposed Development and is not proposed.

Summary

This section provides a brief summary of which technologies may be suitable.

Technology	Suitability for the Application Site	Comments
Community gas CHP	Suitable for all areas connected to a district heating network.	Gas CHP combines a mature technology with large CO_2 reductions and is capable of meeting the regulated CO_2 limits with small amounts of additional PV where required.
Community biomass boilers	Technically suitable for connection to a DH network	Whilst technically suitable, there are high risks surrounding future availability and cost of fuel. This could be offset by the Renewable Heat Incentive. Greater CO_2 reductions could also be made from biomass using a CHP based technology.
Biomass CHP	Technically suitable for complete development but with phasing difficulties.	Biomass CHP can deliver large CO_2 reductions, but delivering the technology to meet the relatively small heat demand during the early phases will incur higher costs and efficiency penalties. The technology at the scale for the Proposed Development is currently considered to be immature / pre commercial, and there are significant concerns over the availability and future cost of fuel.
Anaerobic digestion	Large scale - not suitable due to waste requirements. Small scale – potentially suitable as part of water treatment.	Large scale AD is not considered suitable for the Proposed Development based on the large feedstock requirements (up to 50,000 tonnes per year) and the nature of the technology for a residential development. Discussions with suppliers have suggested an AD scheme has marginal viability in this area. A small scale scheme based around water treatment could be viable if on-site water treatment is proposed. At present, the intention is for all water-treatment to take place off-site at the local treatment works.
Large scale wind	Not suitable	Large scale wind is not considered suitable for the Application Site due to the requirements for buffer zones and potential visual impact.
Small scale wind	Technically suitable	There could be opportunities for incorporating small scale wind turbines on some parts of the Proposed Development. However the performance is likely to be poor due to the urban nature of the Application Site, and the contribution to CO_2 savings negligible, even with a large number of turbines.
Photovoltaics	Suitable for all buildings	PV has very few limitations and could be installed on the roofs of all buildings. The maturity of the technology means this is a relatively low risk solution. Maximum contribution is obtained if roof slopes can be designed to be predominantly south facing. Financial support available through the Feed-in-Tariff at least until 2012.
Solar thermal	Suitable for buildings not connected to a	Solar thermal conflicts with CHP technologies, but could be provided in those buildings with a sufficient hot water demand which are not connected to a heat network. The

	heat network.	maturity of the technology means this is a relatively low risk solution.
Heat pumps	Suitable for later-phase commercial buildings.	Heat pumps are not predicted to save much (if any) CO_2 under the current grid mix. However with decarbonisation of the grid, they may be more suitable for later phases of the development. Balancing cooling and heating loads in the non-domestic buildings may help improve the overall efficiency of a ground connected heat pump system. A cooling network could enable centralised chillers to be used to provide additional waste heat.
Micro CHP	Not suitable at this stage	Micro CHP is not currently considered suitable due to the maturity of the technology. However this technology may become suitable (in particular fuel cell) as the technology matures, particularly in areas not connected to a heat network.
Biomass heating	Not suitable	Biomass boilers are not considered suitable for individual buildings due to air quality concerns, lack of heat load diversification, and plant space requirements (including fuel storage) for each building. In general, a large centralised biomass scheme is preferred over small individual installations. Concerns around the future availability and cost of biomass fuel also remain.

Section 3: Strategy Discussion

The previous sections of this document describe the background and drivers for CO_2 reduction on the Application Site (Section 1), and assess potential measures and technologies which can be used to help reduce CO_2 emissions (Section 2).

This section discusses how these measures may be used to meet the specific requirements and form a strategy for the development. The strategy is split into the following chapters:

3.3 Allowable Solutions

3.4 20% renewables

3.5 Zero carbon building regulations compliance

3.1 Allowable Solutions

Introduction and benefits

It is almost certain that a cost effective solution to the Proposed Development's energy needs will require some element of Allowable Solutions to be met . It is difficult under the current policy unknowns to state exactly what the options are, but given the consultation on the Definition of Zero Carbon and the minister's response[22] and subsequent work by the Zero Carbon Hub, we believe the following options could be considered as acceptable Allowable Solutions.

'On-site' options

- Installation of smart appliances
- Application of 'flexible demand' systems (supporting demand side management)
- Home electric vehicle charging
- Electricity storage for the home (to store electricity generated from PV panels)
- On-site waste management (Vacuum waste collection systems)
- LED street lights for the site

'Near-site' options

- Export of low carbon heat from site based district heating scheme (i.e. support for cost of pipe-work)
- Retro-fitting of low/zero carbon technologies to local communal buildings
- Investment in creation or expansion of locally planned sustainable energy infrastructure (e.g. district heating or on-site wind turbines)
- Investment in local electric vehicle charging infrastructure
- Investment in low carbon street lighting for local area Local micro-hydro schemes
- Communal waste management solutions

'Off-site' options

- Investment in Energy-from-Waste plants (e.g. Anaerobic Digestion and Pyrolysis/Gasification plants)
- Investment in low carbon electricity generation assets up to a maximum determined scale eg excluding large scale off shore generation
- Investment in district heating pipe-work to connect new loads to existing schemes or support new schemes
- Investment in retro-fitting of low carbon technologies to communal buildings
- Investment in embodied carbon reduction initiative
- Investment in low carbon cooling
- Investments in energy storage and demand-side management/flexible demand projects to counter intermittent renewables

Cambridgeshire County Council is in the process of setting up a carbon offset fund that is likely to be a precursor of the allowable solutions mechanism. The fund is being linked to investment in low carbon district heating schemes in the County.

The work to date on Allowable Solutions by the Zero Carbon Hub and as assumed in Government economic analysis proposes a limit on the price of CO_2 such that it will never cost more than a certain amount per tonne (£75 per tonne is currently assumed by Government for a central case).

Options on the Application Site

One potential Allowable Solution is to produce greater CO_2 reduction on site. This is the most direct form of Allowable Solution. However the concept of carbon compliance and Allowable Solutions was developed due to the difficulties in producing on-site CO_2 savings, and that in some cases, there being no technically viable solutions. The proposed carbon compliance level (for dwellings) was developed as the maximum on-site saving that could be regulated without limiting development.

[22] Rt Hon John Healey MP. Ministerial Statement on Zero Carbon Homes. 16th July 2009.

For the Application Site, it may be possible to produce greater CO_2 reductions on site, for example by increasing the levels of PV. Another option is to develop a biomass CHP scheme (although there are many technical and financial risks involved with this as discussed elsewhere in the report). The decision to commit to greater savings will ultimately be based on viability, and the current proposed level set for Allowable Solutions (£75 per tonne) will likely be lower than any on-site solution.

Options available within Applicant's estate

If the Allowable Solutions component cannot be met on the Application Site, then the next preference will be to make reductions within the University estate. This not only benefits the Proposed Development, but also reduces energy demand (and energy costs) and CO_2 emissions (hence reduced CRC liability) for the University.

Potential options include:

- Export of heat from the Proposed Development to other sites owned by the Applicant such as West Cambridge. This solution is obviously applicable to energy strategies using district heating. CO_2 credits could be gained for providing heat to existing buildings on these sites, but potentially not for new buildings, as there is a risk of double counting the CO_2 reductions allocated to the new buildings for their Part L compliance.
- Investing in energy efficiency improvements to other buildings owned by the Applicant. If Applicant's buildings are improved, this could be a method of reducing the Proposed Development costs by using existing University budgets for renovation. It is unknown whether this option will be taken forward by government, and if accepted, it is likely that only more advanced methods of energy efficiency (i.e., those which are not being installed as a matter of course) would be accepted. The CO_2 offsets required for the Proposed Development are likely to be significant and it is possible that the potential for energy efficiency savings is not great enough for this approach to be the only Allowable Solution.
- Generation of low and zero carbon energy elsewhere on the University estate. Options include CHP, PV, or large scale wind (potentially on University farm land). With all these options, the issue of additionality needs to be considered, especially if incentives are to be claimed such as ROCs. At present, there is no guidance on how these issues may be resolved.

The Zero Carbon hub have proposed that Local Authorities will have first choice on the use of allowable solutions monies and therefore any options to invest in carbon management within the University Estate would have to be negotiated with the planning authority.

Options available outside university estate

Options outside of the University estate are similar to those within the estate. However implementing these measures will be considerably more difficult due to the need to engage a number of different partners. Additional Allowable Solutions measures which may be available include:

- Investment in large scale renewable energy. This mechanism may allow developers to invest in large scale renewable energy projects (such as wind farms or marine systems) constructed by renewable energy developers. If this is allowed, then accounting rules will need to be established to ensure that the CO_2 savings are allocated to the development.
- Investment in a carbon offset fund at the Allowable Solutions capped value. Cambridgeshire's local offset fund might be used prior to 2016 for developments to pay into where on-site CO_2 targets set by planning cannot be met. If these local funds could be used as an Allowable Solution, then the Proposed Development project could make a payment, and the fund would then invest in CO_2 reduction schemes.

Interaction of Allowable Solutions with the Code for Sustainable Homes

The code for sustainable homes energy credits are aligned with the Part L Building Regulations allowing the same assessment tools to be used and removing the potential for conflicting targets. Future proposed revisions to the Building Regulations are aligned with the current CO_2 reduction levels stated in the Code as outlined in Chapter 1.3 suggesting that this alignment will be continued in the future.

Prior to the introduction of the Carbon Compliance and Allowable Solutions concepts, the Code required all regulated CO_2 emissions to be reduced using on-site technology for Code 5, and all regulated and unregulated emissions to be reduced for Code 6 on-site. Following the announcement of the Carbon Compliance mechanism in 2009, the Code for Sustainable Homes consultation in 2010 included Carbon Compliance, allowing Code 5 to be achieved with a defined reduction in regulated emissions on-site with the remainder offset using Allowable Solutions. However no Allowable Solutions mechanism has been finalised by the UK Government, resulting in the 2010 Code (released in Autumn 2010) not referring to Carbon Compliance or Allowable Solutions and relying on 100% reduction on-site for Code 5.

It is expected that once an Allowable Solutions mechanism is in place the Code will include this within the CO_2 reduction credit. Therefore the analysis in this strategy is predicated on future versions of Code 5 including Carbon Compliance and Allowable Solutions.

Summary

This section outlines a number of potential options for the Applicant to achieve the Allowable Solutions component of the CO_2 reductions required, and assumes that this will feature in future revisions of the Code for Sustainable Homes. However until further guidance is given by Government, it is not possible to state which options, if any mentioned, will be taken forward.

3.2 20% Renewables

20% renewable requirement in the AAP: Interpretation and understanding

The North West Cambridge Area Action Plan contains a requirement for commercial development on the Application Site to achieve a 20% reduction in carbon emissions through the use of renewables should biomass CHP not be proposed:

> *Non residential development and student housing will be required to demonstrate that …e) it will reduce its predicted carbon emissions by at least 20% through the use of on-site renewable energy technologies only where a renewably fuelled decentralised system is shown not to be viable;*

Whilst the business case for biomass CHP remains uncertain it remains a possibility that the Proposed Development will source its renewable energy from microgeneration technologies such as PV, solar thermal and heat pumps. This chapter therefore reviews ways in which these technologies could provide 20% renewable energy in line with AAP policy.

Firstly, it is important to establish on what baseline the 20% reduction will be calculated. To maintain consistency with other parts of this report, reductions will be demonstrated against *actual* predicted emissions rather than compliance (i.e. Part L) emissions. Furthermore, in line with common practice (in particular GLA guidance) reductions are shown after the application of energy efficiency and low carbon sources of energy such as gas-fired CHP.

A literal interpretation of the 20% renewables policy may be that every individual non-domestic building needs to source 20% of its energy from renewable sources. This is unlikely to be possible in practice due to the wide range of building energy profiles and typologies even between buildings of the same type. For example, a highly energy-intensive physics laboratory over 4 floors will spatially be unable to achieve 20% whereas a naturally ventilated 3 storey office will be able to achieve significantly more than 20%.

For this reason we have proposed that the 20% renewables policy should be applied as an average across the Proposed Development and achieved by application of a set of design guidelines which set out how renewable energy is to be incorporated in each building.

Baseline emissions with energy efficiency and gas-fired CHP

Many of the non-domestic buildings at the Proposed Development will be suitable for connection to a district heating system. In particular, buildings with high hot water loads such as the student residences, the hotel and the GP surgery will achieve large carbon savings by connection to the system.

The following baseline energy consumption and carbon emissions are therefore expected in the non-domestic buildings on completion assuming that the student residences, the hotel, the GP surgery, the community centre, senior care and the primary school receive their heat from district heating:

Table 31. Non domestic energy and CO_2 reduction with application of gas fired CHP.

Non-domestic energy consumption and CO_2 emissions	Baseline energy use with energy efficiency MWh	Energy Use assuming energy efficiency and CHP in certain buildings, MWh	% Change in Energy and CO_2 emissions
Annual gas consumption	27,000	40,000	+ 48%
Annual electricity consumption	18,000	9,500	- 47%
Associated CO_2 emissions over 13 year lifecycle, tonnes	140,000	120,000	14%

As can be seen from the above table it is expected that the application of district heating and combined heat and power to the non-domestic buildings is expected to result in carbon savings of over 26,000 tonnes or an 18% improvement in these buildings. This compares with the 29% saving predicted for the whole estate including domestic buildings.

Discussion: Proposed Renewable Energy Technologies

As discussed in the previous section on appropriate renewable technologies there are 2 principle types of renewable:

1) Heating and cooling technologies – Biomass, heat pump, solar thermal
2) Electricity generating technologies – PV, wind

If a renewably fuelled DH system is proposed, then the AAP does not require that a specific 20% target is met. However this report discusses the risks around a renewably fuelled DH system, both in terms of technology, and fuel supply. Therefore this chapter is predicated on the non achievability of biomass CHP or biomass heating and demonstrates that without these, the 20% target can still be achieved. We have also ruled out large wind on the basis of visual impact and planning risk and small wind on the basis of low predicted output.

This leaves the following appropriate technologies for the Proposed Development:

- Heat pumps
- Solar Thermal
- PV

Those buildings that are connected to the district heating system will not benefit from solar thermal or heat pumps (as discussed in chapter 0). Fortuitously these are also buildings to be delivered early in the phasing when grid electricity has high CO_2 intensity and heat pumps are not favoured.

Later buildings, particularly those that have a high space heating demand such as naturally ventilated offices, would achieve large carbon savings through the use of ground source heat pumps once the grid decarbonises as predicted will occur in the mid-2020s.

It is therefore proposed that all non-domestic buildings will source their heating from a low carbon heating source whether ground source heat pump / solar thermal panels or district heating, whichever gives the highest carbon savings at the time of construction and is technically viable in the identified location.

Renewable electricity will be provided through extensive coverage of roof-mounted photovoltaic panels. The following specification is proposed in all non-domestic buildings.

Table 32. Proposed specification (non-domestic) for the incorporation of renewable energy technologies to meet a CO_2 reduction of circa 20%.

Heating technology (whichever of the following provides the highest carbon saving)	Electricity technology
Ground source heat pump providing at least 80% of space heating demand and solar thermal providing at least 50% of predicted hot water demand **OR**	PV panels with the equivalent output of monocrystalline PV having an area of at least 25% of the building's footprint and therefore anticipated to cover approximately 50% of the building's roof area[23]
100% of heating (space and DHW) to be delivered from low carbon district heating.	

[23] This assumes that around half of the roof area taken by the PV array will be lost to spacing between banks of panels, walkways, and other non-productive areas. With pitched roofs, the total PV area will be larger for a given roof area due to the reduced requirement for separate banks of panels.

Percentage renewables over 13 year lifecycle

The application of the renewables specification above results in the following 13 year lifecycle energy and CO_2 reductions:

Table 33. Lifecycle energy and CO_2 reductions with the application of renewable energy technologies.

Non-domestic energy consumption and CO_2 emissions	Baseline energy use with energy efficiency (MWh)	Energy Use assuming energy efficiency and CHP in certain buildings (MWh)	% Change in Energy and CO_2 emissions
Annual gas consumption	41,000	33,000	- 20%
Annual electricity consumption	8,500	7,000	- 18%
Associated CO_2 emissions over 13 year lifecycle, tonnes	120,000	93,000	- 23%

Table 33 shows that a combination of ground source heat pumps, solar thermal and PV covering 50% of the roof area of non-domestic buildings results in a carbon saving of more than 20% in line with AAP policy.

Percentage renewables in each year

As discussed above we are proposing to meet the 20% renewables requirement through application of design guidelines. This will result in some buildings achieving more than 20% renewables and some less. Equally the percentage is likely to be exceeded in some phases but not in others.

The variable percentages in different years are caused by the different mixes of buildings applying for detailed planning in any given year and changes to the carbon emission factor. If a larger percentage of high-rise buildings with little roof space for PV are applied for year in a given year the percentage will go down. Equally, if a large number of low rise buildings such as the school are submitted the percentage will go up.

3.3 Zero carbon building regulations compliance

Introduction

Although the majority of this report is based on actual predicted energy consumption and emissions across the Proposed Development each of the buildings will have to be submitted to building control and pass the energy section of Building Regulations. As discussed in the chapter "Defining Minimum Standards and Targets" Part L is being incrementally tightened up to a zero carbon standard in 2016 (for domestic buildings) and 2019 (for non-domestic buildings) and the Code for Sustainable Homes and BREEAM are both based on Part L assessments of energy consumption. This chapter reviews approaches to meeting energy legislation in different building types, particularly in the light of a decarbonising grid over the build-out period of the development.

More on Carbon Emission Factors

As discussed elsewhere in this report it is envisaged that each successive edition of Building Regulations will feature a gradually declining factor for the carbon content of electricity from the grid due to a gradual decarbonisation of the plant that feeds electricity onto it. Equally it is predicted that more of our gas will come from imports of Liquefied Natural Gas (LNG) and the embodied energy inherent in its production and transport is tending to push up the carbon emission factor for gas.

In chapter 2 we described the work of the Zero Carbon Hub in predicting these future carbon emissions factors (carbon content of fuels when used). The year-by-year predicted factors are presented again here for clarity.

Table 34. CO_2 emission factors used in calculating lifecycle CO_2 emissions.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Gas	0.198	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227
Electricity	0.517	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.501	0.501	0.501
Grid Displaced Electricity	0.529	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.501	0.501	0.501

Building Regulations have historically generated carbon emission factors for policy purposes by using average projections. For the 2010 regulations, this was a 3 year average. However the Zero Carbon Hub proposes that a 15 year average is used which allows for an assessment over the life of most typical building services (boilers, lights, etc). This produces the following possible carbon emissions factors for policy purposes in each successive policy year:

Table 35. Carbon emission factors proposed by the Zero Carbon Hub for future policy and regulation. (2010 figures illustrated for the purposes of checking Building Regulations compliance for the first phase of development).

Year	2010	2013	2016	2019	2022
Gas CO_2 emission factor	0.198	0.227	0.227	0.227	0.227
Electricity CO_2 emission factor (grid supplied and grid displaced)	0.517	0.642	0.527	0.412	0.257

Table 37 shows that the emission factor for the grid is likely to go up in the next 2 rounds of building regulations amendments and then decline in the following years.

It must be emphasised that the above is not Government policy but reflects the latest thinking from the ZCH which has been appointed to advise government on the subject and is therefore the best available current data.

Implications of carbon emission factors on achievable carbon savings from different technologies

As can be seen from the Table 35 it is anticipated that the emission factor for electricity will decline steadily with a marked drop in the 2020s. This means that electricity-producing technologies such as PV and CHP will be favoured in the short term whilst electricity-using technologies (such as heat pumps) will be favoured in the medium and long-term. The following tables highlight, for different building types, the possible carbon reductions feasible (in percentage terms relative to 2006 regulations) through the application of different technologies in different years. All data includes savings from energy efficiency.

Gas fired CHP vs Heat Pump

Table 36 compares the performance of gas-fired CHP against air-source heat pumps in a semi detached house through to 2019 when the last homes are expected to be built on the Application Site [24].

Table 36. Potential CO_2 reduction from gas fired CHP and air-source heat pumps in a semi-detached house.

Semi-detached house	2010	2013	2016	2019	2022
Energy Efficiency only	24%	24%	24%	24%	N/A
Gas fired CHP / DH	63%	69%	54%	33%	N/A
Air source heat pump, ASHP	27%	22%	33%	45%	N/A

Gas fired CHP is predicted to produce savings of up to 69% in dwellings around the time of construction of the majority of homes (around 2013 - 2016) declining through to 2019. The decline in carbon reduction from CHP is explained by the gradual decarbonisation of the grid; as the grid electricity it is displacing becomes cleaner the benefits of CHP reduce. In 2019, air-source heat pumps are predicted to produce a greater saving over the succeeding 15 year period. Since the majority of homes are to be built before 2019 it can be concluded that greater savings will be made by connecting homes to the district heating network than through the use of heat pumps at least for the first 15 years of operation.

Table 37 compares the performance of gas-fired CHP against Ground Source Heat Pumps in a naturally ventilated office.

Table 37. Potential CO_2 reduction from gas-fired CHP and ground source heat pumps in a naturally ventilated office.

Naturally ventilated office	2010	2013	2016	2019	2022
Gas fired CHP / DH	N/A%	35%	29%	20%	5%
Ground source heat pump, GSHP	N/A%	24%	29%	36%	49%

Due to the greater efficiencies of ground source systems (vs air-source) it is expected that heat pumps will be preferred in commercial buildings from 2019 onwards. This coincides with the proposed phasing of the Proposed Development which sees commercial and academic buildings constructed later than homes.

[24] A range of COPs are assumed in the analysis depending on heat pump capacity. For domestic, a COP of 2.5 is used for space heating and 1.75 for domestic hot water, based on SAP values.

Table 38 compares various low carbon heating technologies employed in the food store.

Table 38. Potential CO_2 reduction from heating technologies in a foodstore.

Food Store	2010	2013	2016	2019	2022
Energy Efficiency only	22%	N/A	N/A	N/A	N/A
Gas fired CHP / DH	24%	N/A	N/A	N/A	N/A
Ground source heat pump, GSHP	24%	N/A	N/A	N/A	N/A
Solar thermal providing 50% DHW load	22%	N/A	N/A	N/A	N/A

The results demonstrate that low carbon heating technologies are ineffectual in buildings with very low heating loads such as food stores. This is due to the lack of a significant heating load against which CO_2 reductions can be made.

Comparison with Biomass CHP and Biomass District Heating

Table 39. Potential CO_2 reduction from biomass technologies in a semi-detached house

Semi-detached house	2010	2013	2016	2019	2022
Energy Efficiency only	24%	24%	24%	24%	N/A
Gas fired CHP / DH	63%	69%	54%	33%	N/A
Biomass CHP	108%	111%	108%	104%	N/A
Biomass District Heating	63%	63%	65%	67%	N/A

Emissions savings from biomass technologies are not greatly influenced by the carbon emission factor for electricity (even biomass CHP) so that savings are consistently high for the technology in all years up to 2022.

Biomass CHP is the only heating technology capable of significantly exceeding 70% carbon compliance by itself so that all other technologies require an amount of PV on the roof to make up the shortfall.

Photovoltaic Panels

Carbon savings from the use of photovoltaic panels are also influenced by the grid CO_2 factor since it is grid electricity that is being displaced.

Table 40. Potential CO_2 reduction from PV in a semi-detached house

Semi-detached house	2010	2013	2016	2019	2022
Energy Efficiency only	24%	24%	24%	24%	N/A
Monocrystalline PV with a panel area equivalent to 50% of the roof area (15.3m2)	83%	86%	78%	68%	N/A

Like biomass CHP, photovoltaic panels are capable of exceeding 70% compliance by themselves in the semi-detached house up to 2016 due to the relatively high grid carbon emission factor. It should be noted that this is not the case for blocks of flats where the reduced roof area relative to the floor area limits the contribution that PV can make.

Solar Domestic Hot Water Panels

The output from solar domestic hot water panels is limited by the domestic hot water load. Here we have assumed that the technology can meet up to 50% of the domestic hot water demand.

Table 41. Potential CO_2 reduction from Solar Domestic Hot Water Panels in a semi-detached house

Semi-detached house	2010	2013	2016	2019	2022
Energy Efficiency only	24%	24%	24%	24%	N/A
Solar Domestic Hot Water panels meeting 50% of the domestic hot water load	37%	37%	38%	38%	N/A

Some possible compliance routes - dwellings

The following tables illustrate (using a typical semi-detached dwelling) how dwellings might reach 70% compliance either through connection to the proposed district heating system or through standalone microgeneration technologies.

The tables demonstrate that PV is the “residual technology” that makes up any shortfall in carbon saving from any proposed heating technology. This is a consistent finding from all studies into higher levels of the code for sustainable homes.

Semi Detached Home connected to district heating

Dependent on the phasing it is likely that the majority of the Applicant-owned dwellings will be connected to district heating. The following table highlights a possible strategy for meeting 70% compliance in those homes connected to the heat main.

Table 42. Potential CO_2 reduction from Gas-fired Combined Heat and Power in a semi-detached house

Semi-detached house	2010	2013	2016	2019	2022
Energy Efficiency only	24%	24%	24%	24%	N/A
Gas-fired CHP / District Heating	63%	69%	54%	33%	N/A
Residual PV required to meet 70% carbon compliance, m2	1.8m2	0.3m2	4.6m2	12.8m2	N/A

Since nearly 70% carbon compliance is possible in the early years through connection of homes to district heating it is not thought that these buildings will require large amounts of PV. As the advantages of gas-CHP start to wane in the 2019s more and more PV is required.

Semi Detached Home using micro-generation technologies

It may be more economic for some of the homes (particularly market ones) at the periphery of the Application Site further away from the energy centre to meet carbon compliance using microgeneration technologies instead of district heating. The following table gives a possible combination of microgeneration technologies that meet 70% carbon compliance in years up to 2019.

Table 43. Potential CO_2 reduction from Heat Pumps in conjunction with Solar Domestic Hot Water Panels in a semi-detached house

Semi-detached house	2010	2013	2016	2019	2022
Energy Efficiency only	24%	24%	24%	24%	N/A
Solar Domestic Hot Water Panels	37%	37%	38%	38%	N/A
Air-source heat pump and domestic hot water combined	43%	40%	48%	57%	N/A
Residual PV required to meet 70% carbon compliance, m2	6.9m2	7.3m2	6.2m2	4.4m2	N/A

Due to the poor savings from air-source heat pumps in the early years it is possible that developers will choose to install gas boilers instead and make up the shortfall with extra PV. The choices that developers make will be highly dependent on uncertain policy such as the renewable heat incentive.

Section 4: Conclusions

This Section summarises the preferred approach to the energy strategy and proposes how this strategy might evolve in the long-term. The strategy is split into the following chapters:

4.1 An Energy Strategy

Introduction

The following Energy Strategy outlines one possible approach to the provision of heating, cooling and electricity across the Application Site that would be compliant both with National and AAP policy. The chapter represents likely scenarios given current thinking about quantum of development and phasing but must be considered provisional pending detailed design.

Energy Efficiency:

Homes

From day one all homes will be built to high fabric energy efficiency standards. At present the standards proposed by the Zero Carbon Hub for the Government's 2016 Zero Carbon standard (FEES) are mandatory for achieving Code for Sustainable Homes level 5 and this standard or future standard, if changed, will be required. These homes will therefore have substantially improved U-values and air-tightness over current Building Regulations.

Some detached homes may be built to the even tougher Passivhaus standard which requires a very air-tight envelope and mechanical ventilation with heat recovery. Indeed, some developers of plots (particularly detached homes) may be encouraged to adopt this approach as part of the University's desire to monitor the performance of different energy strategies in-use. Whilst the Zero Carbon task group currently asserts that the additional cost of Passivhaus does not justify the resultant marginal CO_2 saving (according to them similar investment elsewhere would bring higher CO_2 savings), technologies may change over time; for example the cost of triple glazing and, over the phasing of the Proposed Development, the Applicant is likely to want to review the costs and benefits of the Passivhaus approach.

The overall applications proposals have been developed to provide high daylight levels throughout, minimising the need for electric lighting. Residential accommodation will be dual aspect to facilitate cross flow ventilation where possible (or necessary) to mitigate the effects of future climate change.

Non-domestic

Passive means of ventilating and cooling non-domestic buildings will be used throughout the Proposed Development. In particular, the majority of conventional office and academic accommodation will be naturally ventilated, making use of thermal mass and appropriate orientation and shading to minimise overheating. Plan depths will be kept to a minimum so that all occupants are close enough to a window to receive natural light and air. Any deep plan buildings will be restricted to single storey where roof lights can provide natural light and ventilation.

Other non-university commercial and public sector buildings such as the supermarket, hotel and primary school will also be required to adopt low energy, passive design approaches through the use of design guidelines and green leases.

Some research buildings will need to be mechanically cooled due to heat gain from large internal equipment loads such as from laboratory equipment and IT. In these buildings low energy cooling methods such as mixed mode ventilation, free cooling and ground cooling will be employed in addition to passive measures such as thermal mass, orientation and shading. The same is likely to be true of buildings along the western edge where noise levels may preclude opening windows.

Behaviour Change and Operational Carbon Management

Low carbon lifestyles will be promoted through the management of the estate. The proposed energy centre (see below) may feature an educational facility to teach residents and visitors about the sustainable technologies employed across the Proposed Development. Part of the service charge could be used to fund carbon advice to residents through the management office, and operate an energy portal on the site intranet.

The energy portal would enable residents to compare the energy performance of their home against the average across the estate. Residents that wish to do so would be able to share their energy use data with others and therefore share tips about reducing consumption.

Subject to further discussions with industry, smart metering and appliances will be trialled in homes. Residents may have variable electricity tariffs depending on the time of day and the amount of electricity being produced on-site. This could mean, for example, that washing machines “know” when to turn on depending on the output of photovoltaic panels on the roof of the home helping to increase the amount of renewable electricity used on-site rather than exported. Fridges could turn off intermittently for short periods of time to help reduce peak demands on the grid.

Electric car charging points will be installed throughout the development. The design team will liaise with an electric car charging provider to make sure that the street topology is appropriate for the use of charging points.

Heating

The majority of the Applicant’s residential buildings, including key worker accommodation, will be heated from a district heating main to be routed around the Proposed Development (exceptions may be made where the Applicant’s buildings are planned far from the route of the scheme). Some private residential accommodation will be heated using standalone gas boilers, however plots that are close to the routing of the district heating main will be encouraged to connect to it. It is likely that private residential apartments will connect since this will be the most economical means of meeting energy targets in these buildings. The same may be true of market terraced housing.

Cooling

A district cooling main will be routed from the energy centre along the radial route to serve commercial and academic buildings requiring mechanical cooling. Centralised chillers can make use of more efficient cooling towers (over the energy centre) and the ability to reject heat into the hot water systems of the student and key worker homes. This will offer substantial CO_2 savings over distributed chillers in each building.

Energy Centre

An energy centre will be built within the neighbourhood centre within a few years of the start of the project to generate heat for the district heating main. Initially, the majority of the heat will be produced by a succession of modular gas-fired combined heat and power plants with back-up heating provided by gas-fired boilers. Some heat will be provided from heat rejection from the centralised cooling system (including large amounts of heat from the supermarket refrigeration which will be covenanted to provide it).

Over time it can be expected that the heat source will change as technologies improve and as fossil fuels (such as gas) become scarcer or more expensive due to climate change legislation. Centralising the heat source and distributing through a district heating system allows the heating technology to be more easily altered than would be the case if gas boilers were distributed across the Proposed Development.

Alternative sources of heat could be biogas from waste (see A Future Vision next chapter), fuel cells, air/ground-source heat pumps or biomass-based technology if a secure sustainable resource is identified.

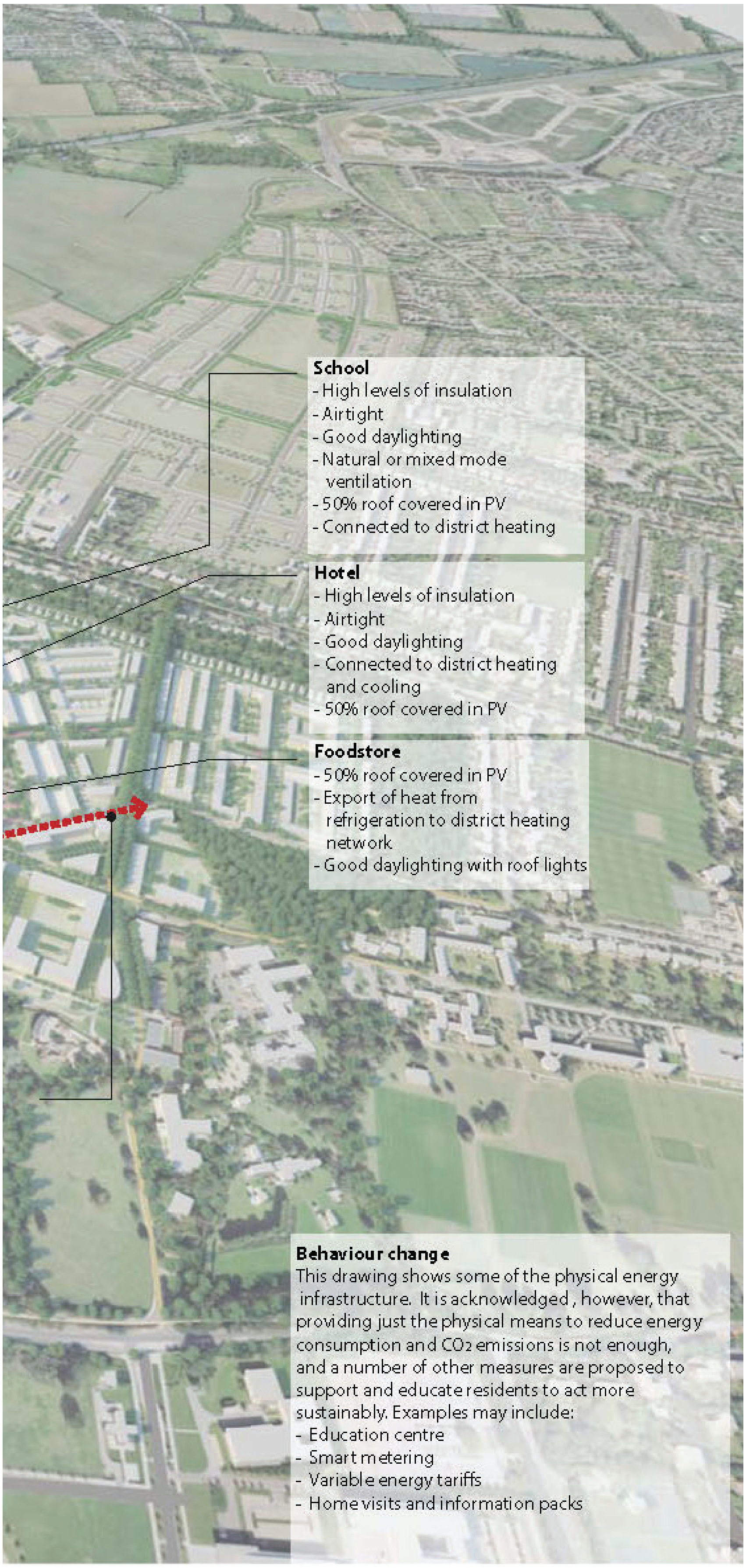
Renewable Sources of Energy

Energy efficiency and gas-fired combined heat and power will produce more than two-thirds of the carbon savings required to meet the Code for Sustainable Homes level 5. The remaining CO_2 reductions are planned to be met with an extensive installation of photovoltaic panels across the roofs of the development. The recent introduction of the Feed-in-tariff makes PV attractive as a producer of on-site renewable electricity.

As a rough rule of thumb approximately 50% of the roof area of dwellings will be covered in PV meaning that roofs will either have to be flat or orientated within 45 degrees of due South.

A large number of non-domestic buildings across the Proposed Development will be heated and cooled using ground source heat pumps, possibly networked using a low temperature district heating system. Whilst the carbon saving potential of this technology is currently limited by the fossil-fuelled power stations that supply the grid (since heat pumps are powered by grid electricity) it is anticipated that emissions from the grid will drop after 2020 as the UK moves to cleaner, high-efficiency gas power stations (possibly with carbon capture), nuclear and large scale wind. At this point heat pumps will become more favourable than gas-fired boilers. The majority of non-domestic buildings are proposed to be built after 2020 so this approach is aligned with the proposed phasing.


Low density areas
- Some areas may not be serviced by district heating network
- CO_2 reductions from standalone technologies
Detached house
- High levels of insulation
- Airtight
- Good daylighting
- Gas boiler
- PV covering 50% roof and solar thermal
Monitoring
- University is committed to monitoring and continuous improvment
- Possible trials of passive house design, and new technologies such as micro fuel cell CHP in certain areas
Research
- Naturally ventilated where feasible
- Solar shading
- Good daylighting
- Connected to cooling network where required or ground source heat pump
- 50% roof area covered in PV
- Circa 20% CO_2 saving from renewables
Flats and student accommodation
- High levels of insulation
- Airtight
- Good daylighting
- Connected to district heating network
- Some PV on roof
Energy centre
- Gas CHP (modular)
- Gas boilers for peak and back up
- Electric chillers
District heating network
- Buried insulated pipes circulating hot water for heating and hot water
- Connected to individual buildings
Cooling network
- Buried chilled water pipes
- Connected to some commercial and academic buildings



Due to the mix of building types and uses on the proposed development, the energy strategy will vary across the site.

This indicative illustration shows examples of how the low carbon aspirations can be met for different areas of the site.

4.2 A future vision

The current strategy

The energy strategy developed for the planning application proposed in this report will result in a development with significant levels of renewable and low carbon energy generation. The proposed scheme meets current and future (as currently known and defined) building regulations Part L, Code for Sustainable Homes level 5 (and level 6 CO_2 standards from 2016), and local planning policy from the AAP.

The strategy is based around technologies which are currently available and proven, and which can be integrated into the site in a phased approach, such that all phases of the development can meet the CO_2 targets. In addition, the proposed strategy presents an acceptable level of risk, both in terms of the technology (all of which have a proven track record), but also in terms of fuel supply.

Medium term options

It is likely that during the lifetime of the Proposed Development, new technologies and fuels will become available which offer advantages over the current options. An important factor to consider is the phased construction, and once the site is complete, then alternative forms of energy generation may become viable. As outlined in this report, an important technology category which may become more mature in this timeframe, and more technically viable on the complete site is biomass CHP (using either wood or waste). In light of this, a one hectare site has been set aside in the development for a potential future energy centre (biomass CHP plant). The location, in the North West corner of the Application Site, has been chosen since it has a lower land value and alternative uses are hard to envisage; the site sits on the confluence of the A14 and M11.The chosen site sits within the AQMA and detailed analysis would be required to assess the air quality impacts of future technologies.

The Applicant is committed to examining potential options for future technologies at this NW site including:

- Wood / Biomass CHP. This would need to consider the availability of fuel resource, which by this point may be imported. It is expected that in the 2020s, more reliable and secure wood fuel supply chains will be established but at what cost and where from? Biomass technologies at this site scale are currently not commercially available, and the impacts of air quality and local acceptance would need careful consideration.
- A gasification plant (wood / biomass) could be installed North West corner with the gas either piped to the Local Centre gas CHP energy centre, or alternatively treated and then injected into the national gas grid which could be beneficial for local air quality. There are currently many technical issues around gasification and gas injection due to the quality of gas produced and this would need to be examined in detail.

The current energy strategy proposes that individual dwellings constructed in the early years, and not connected to the heat network, will probably be heated using high efficiency gas boilers (with solar thermal or PV to provide additional CO_2 savings). Low temperature heating systems in these dwellings will allow a range of alternative technologies in the medium term, perhaps when the boiler needs its first or second replacement. Options include the use of air source heat pumps which may provide greater CO_2 reduction in the future with grid decarbonisation.

In addition to on-site technologies, the presence of a district heating network on the Proposed Development may open up opportunities for import or export of heat to or from the Proposed Development. At a local level, there could be potential for linking the Proposed Development to neighbouring sites such as West Cambridge, or the NIAB development to the north of Huntingdon Road. The viability of connecting to these sites will depend on the availability of suitable heat and electricity generation technology (such as biomass CHP) and the cooperation of other parties. In the current situation where heat is not governed by regulation, there are many potential risks both to the Proposed Development, and to the neighbouring sites which would need to be examined to provide confidence to all parties involved.

There may also be opportunities for connecting the Proposed Development to a larger scale system, perhaps a Cambridge wide heat network which links up other major sites across Cambridge. The development of such a heat network will require the co-operation of a number of different parties, but most importantly significant public sector support. The development of this type of scheme would typically be led by a public body such as the local council, and potentially even operated by the council in some form of joint venture with a commercial operator.

Long term options

In the long term, there could be a number of options open to the Proposed Development for evolution of the energy strategy. A range of heat generation technologies could be connected to the heat network, such as large scale fuel cell CHP, or biomass CHP. The type of technology will very much depend on what is developed over the next few decades. Indeed, the technology may not even yet have been discovered.

The greater use of electricity for heating may be preferable if significant decarbonisation of the electricity grid is achieved (potentially through a mixture of renewables, carbon sequestration, and nuclear power). Options include the use of large scale heat pumps on the district heating network, or individual heat pumps in each building. However the timing of such decarbonisation remains uncertain so the need to retain flexibility is important.

North West Cambridge: Carbon Reduction Strategy

Part B: Carbon Footprinting

Table of Contents

1 Introduction

Background

The Carbon Reduction Strategy for North West Cambridge (the Proposed Development) discusses the potential effect that the development may have on CO_2 emissions. One of the key CO_2 producing sectors, and the one on which the site design can have the greatest effect on, is the use of energy for heating and powering buildings. Part A of the Carbon Reduction Strategy addresses this sector and proposes a number of options which can help reduce emissions.

This section of the Carbon Reduction Strategy (Part B) provides a discussion of other sources of CO_2 emissions either directly or indirectly generated by the Application Site and its residents. These emissions are not regulated through building regulations, and are potentially more difficult, if not impossible, to control through the site design. However the sustainability proposals for the Proposed Development laid out in the Sustainability Statement are aimed at building a sustainable development including trying to influence the way in which residents act on the site. Some of these sustainability proposals will help residents reduce their CO_2 emissions, for example, by using more sustainable forms of transport.

This section assesses the potential carbon footprint effects by examining UK and Cambridge City carbon emissions data to establish an approximate baseline for the Application Site. . This assessment considers how the Proposed Development can be brought forward such as not to increase the per capita CO_2 emissions for the Cambridge area.

This Carbon Reduction Strategy (Part B) forms one part of a suite of documents relating to the planning application for North West Cambridge.

Method and scope

An indicative carbon emissions baseline has been established for the Proposed Development. This is reported as: (i) the total CO_2 and; (ii) per capita CO_2emissions. The sustainability and CO_2 emission reduction measures proposed for the Proposed Development [1] are compared against this baseline and an indication of the reductions in emissions are assessed.

This analysis focuses on CO_2 emissions from the following:

1. Transport related emissions
    a. Baseline assessment of transport related CO_2 emissions under business as usual case
    b. Transport strategy options and potential effect on site-wide CO_2 emissions
    c. Potential effect of transport strategy on wider off-site CO_2 reductions

2. Other "in-use" CO_2 emissions
    a. Food
    b. Waste
    c. Consumables
    d. Public services

3. Housing (Buildings) and Construction related CO_2 emissions
    a. Construction activity
    b. Design and materials

A matrix is used to examine the significance of each sector above, the potential for CO_2 savings, and the level of certainty that the measures proposed will deliver CO_2 reductions for the Application Site. Some measures can be controlled or influenced by the site design to varying extents. Emissions from

[1] All measures are explained in detail in North West Cambridge Sustainability Statement Report and supporting documents.

other sectors are largely or totally beyond the control of any development strategy but still contribute to a resident's footprint.

Therefore the analysis can provide an indication of:

- The major contributors to CO_2 emissions. Measuring these could help to plan a strategy to determine the 'quick wins'
- Potential for carbon savings (significant, medium or low) compared to the base case in each focus area / sector
- How regulated or controllable an item is: is it regulated by legislation or is it dependent only on the residents' behaviour?
- Determining the 'beyond control' items such as aviation (these may require government intervention or even international law)

Most of the assessment is based on a qualitative analysis. This is due to the challenges of allocating emissions to the Application Site and its residents and the substantial level of research which would be involved. However the transport emissions are quantified as there is a quantifiable correlation between the intended effect of the travel plan and emissions. This input has been provided by Peter Brett Associates.

Data Sources

The main data used in this study is provided by Stockholm Environment Institute (SEI) and is from the Resources and Energy Analysis Programme (REAP). The data is based on the UK local authority (NUTS4) and Government Office Region (NUTS2) data for the year 2004[2]. The per capita indicators in the dataset are the ecological footprint in global hectares, the carbon footprint in tonnes of carbon dioxide (CO_2) and the greenhouse gas footprint in tonnes of carbon dioxide equivalent (CO_2eq). These all illustrate the environmental burdens associated with the consumption activities of UK residents.

This report also discusses the National Indicators (NI) 186 data from 2008 in addition to the REAP data, to allow comparison with the UK average figures[3]. These indicators are published on a national basis allowing consistency across different authorities. They are discussed in this report to allow comparison with data which is directly to relevant to Cambridge and calculated with the input of the local councils.

[2] The REAP data was published in 2008, but based on 2004 input data, presumably due to the research nature of the work, and time taken to process the data.

[3] These two data sets are different. REAP is more comprehensive than the national indicators and has been used widely in reporting carbon footprints. We felt that it was more appropriate to use the REAP data in this study. However we also note that the national indicators are used by the local authorities and several local authorities target reductions based on NI186. Such targets exist within the Cambridge City Council Environmental Agenda and are reported in Cambridge Environment Report 2009 -2010.

2 An Overview of Carbon Footprinting

What is a carbon footprint?

In the context of the North West Cambridge Carbon Reduction Strategy assessment, the carbon footprint[4] is:

'The total set of CO_2 emissions caused directly and indirectly by the proposed development'.

A distinction is made in this section between the direct and indirect component of the carbon footprint (CF) and these are assessed separately. Indirect emissions are those that are not directly controllable by the Applicant or by site design. These include (for example) aircraft travel, and supply chains for goods and services outside the Application Site.

Why is it important? - A global context

An extract from National Footprint Accounts[5] states the following:

"Natural resource wealth and material consumption are not evenly distributed worldwide. Some countries and regions have a net demand on the planet greater than their respective bio-capacity, while others use less than their available capacity. Humanity as a whole, however, is not living within the means of the planet. In 2006, humanity's total Ecological Footprint worldwide was 17.1 billion global hectares (gha); with world population at 6.6 billion people, the average person's Footprint was 2.6 global hectares. But there were only 11.9 billion gha of biocapacity available that year, or 1.8 gha per person. This overshoot of approximately 40 percent means that in 2006 humanity used the equivalent of 1.4 Earths to support its consumption. It took the Earth approximately a year and four months to regenerate the resources used by humanity in that year."

Ecological footprint information is a method of explaining how we rely on the Earth's resources. If the world's population has a total ecological footprint which is less than the total land area available, then we are living off the earth's interest. However, if the total ecological footprint is greater than the available land area, then we are living unsustainably.

Even though the population of some countries currently averages at less than one planet, the global population currently requires more than one planet. The UK has one of the highest ecological footprints in the world, lower than some comparable countries (such as the USA and Australia), but considerably higher than other developed nations with a similar high quality of life such as Italy and Japan[6].

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[4] There are other indicators that measure the environmental burden of the Application Site. These are ecological footprint which takes a more comprehensive view on environmental impact and takes into account other issues such as water and resource depletion and also Global Warming Potential (GWP) which takes into account other greenhouse gases as well as carbon dioxide. These three indicators are directly proportional. The ratio between the GWP footprint and carbon footprint is approximately 2.3 and the ecological footprint is proportional to Carbon Footprint. The Carbon footprint is thought to be appropriate for this study as it provides simplicity and clarity.

[5] National Footprint Accounts, Global Footprint Network. www.footprintnetwork.org

[6] General Footprint Report by Stockholm Environmental Institute.

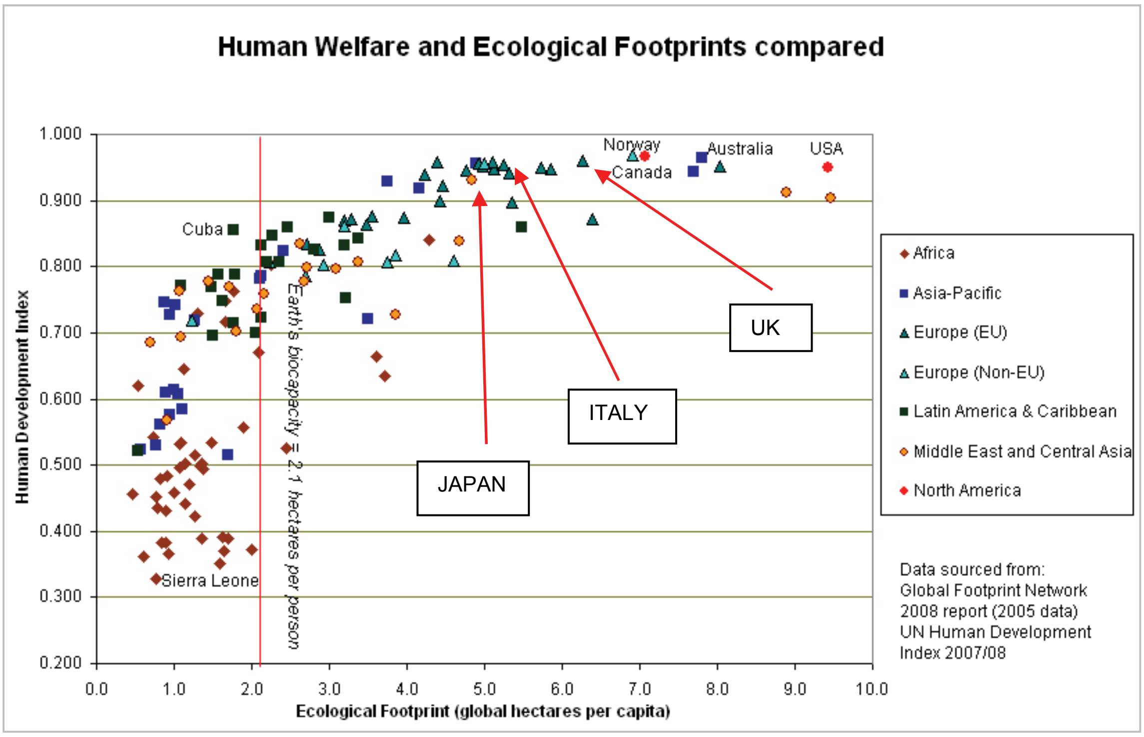

Figure 1 Ecological footprint versus development index[7]. UK's ecological footprint is 5.45 global hectors per capita (gha). Ecological footprint is closely linked to the carbon footprint data hence this graph is also a representation of the carbon footprint performance of the countries.

The concept of an ecological footprint is a simple way of understanding how sustainably we are living. By equating people to land area, it is simple to understand whether we are using too many resources and living in an unsustainable manner. The concept of a carbon footprint is more difficult to understand as there is no direct tie between a physical characteristic such as land area. However there is a good correlation between ecological footprint and carbon footprint with a similar breakdown between sectors. Throughout the rest of this report, we refer to carbon footprints.

[7] The Human Development Index (HDI) is a statistic used to rank countries by level of "human development". The statistic is derived from data on life expectancy, education and per-capita GDP (as an indicator of standard of living) collected at the national level. The concept was originated by United Nations Development Programme with the core idea of shifting the focus from economic development to human well-being. The HDIs have been used since 1990 by the United Nations Development Programme for its annual Human Development Reports.

3 UK, Cambridge, and Northwest Cambridge Carbon Footprint Analysis

Comparison of Cambridge with the UK average

The UK CF is approximately 12 tonnes CO_2/capita based on the (SEI) REAP data. This data also shows that the East of England average is slightly higher at 12.6 tonnes CO_2/capita. There could be a number of reasons for this, but a likely explanation is the rural nature of the region resulting in higher transport use.

Despite the higher regional average, Cambridge City is slightly lower than the national average with around 11.7 tonnes CO_2/capita. This is perhaps to be expected due to the efficiencies of living in an urban environment with the corresponding reduction in transportation demands and efficient supply of goods and services.

The UK Government target[8] is an 80% reduction in GHG emissions by 2050 from 1990 levels. This means that if every individual made equal savings, then a person's CF would need to be reduced to around 2.5 tonnes CO_2/capita by 2050. This requires CO_2 reductions to be made in all sectors.

Table 1 represents a breakdown of the Cambridge City Ecological and CF. According to this breakdown, the majority of the emissions come from housing and transport (56%). These two sectors can be influenced most, as these would be within the remit of the North West Cambridge Sustainability Strategy and scheme design. Therefore there is an opportunity to reduce the CF of the Application Site when compared to the base case (Cambridge CF).

Table 1. Breakdown of carbon and ecological footprint for Cambridge (based on SEI REAP data).

CO_2 emissions sector	PER CAPITA			TOTAL FOOTPRINT	
	Ecological Footprint (gha/capita)	Carbon Footprint (tonnes CO_2/capita)	Fraction of total (%)	Total Ecological Footprint (gha)	Total Carbon Footprint (Tonnes CO_2)
Housing	1.14	3.12	27%	144,204	395,172
Transport	1.03	3.38	29%	129,911	427,753
Food	1.28	1.14	10%	162,247	144,152
Consumer Items	0.67	1.32	11%	84,652	167,520
Private Services	0.30	0.76	6%	37,843	96,447
Public Services	0.59	1.58	13%	75,054	199,557
Capital Investment	0.12	0.36	3%	15,730	44,936
Other	0.01	0.07	1%	938	8,339
TOTAL	**5.14**	**11.73**		**650,580**	**1,483,876**

However there is a limit to how much the CF of the Application Site can be reduced. There will be limits to the savings which can be made for buildings and transportation. The latter in particular can only be influenced partially, because many of the transport needs of residents will be off-site and outside the range at which North West Cambridge can influence local transport measures. In addition, the other sectors where there may be some influence such as food and consumer items can be influenced only slightly. The remaining sectors would be largely outside the boundaries of the North West Cambridge Sustainability Strategy. These include public and private services and capital investment and interventions on the national (or regional to local) level are required to have an effect on these sectors.

[8] Climate Change Act 2008. According to Tyndall Centre, Hansen 2008 report, we need 90% reduction.

Therefore some emissions cannot be influenced by the North West Cambridge Strategy no matter how robust and ambitious the strategy is. This is because these items are simply beyond the control of any development strategy yet these are crucial to the community's wellbeing- public and private services cannot be avoided (such as schools, hospitals, waste management, maintenance of the infrastructure etc).

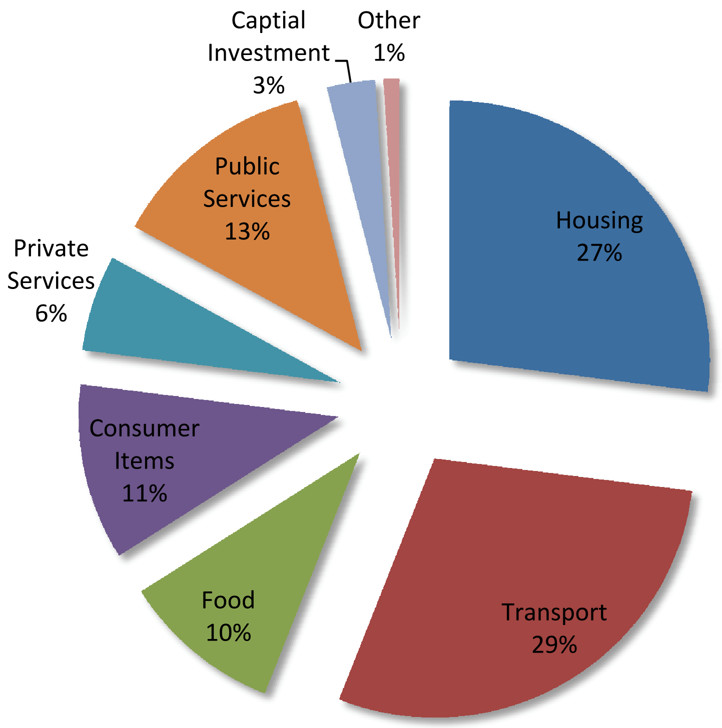

Figure 2. Breakdown of the carbon footprint for Cambridge City by sector.

If we consider that there is potential for influencing buildings (strong influence), transportation (partial influence) food and consumer items (weak influence), then it is likely that in total, less than 50% of the CF of a resident of the Application Site can be influenced by the site design and operation.

However, unrelated to the Proposed Development and its sustainability aspirations, the city has its own targets to reduce carbon emissions overall including emissions from public services and infrastructure. This is discussed in the final section (NI 186 data) and indicates a tendency towards a reduction in emissions within sectors that are outside of the Application Site boundaries and control.

A key way of reducing carbon emissions, and the NI 186 indicator, is to move to lower carbon forms of energy. This will partially be achieved on site in the case of the Proposed Development, with the proposals for low and zero carbon forms of energy. However national scale energy generation is likely to have the largest effect, especially with a transition to a low carbon electricity grid making use of renewable technologies, nuclear energy, and carbon capture and storage. As electricity is used in all buildings and processes and could increasingly be used for transport and heating the effect of a decarbonised grid will be seen across all sectors.

4 Proposed measures for the Application Site and influence on the carbon footprint

Assessing the influence of North West Cambridge

This section assesses the contribution that the Proposed Development can make to reducing a resident's CF. A matrix is used (Table 2) which provides a breakdown of the Cambridge CF data and compares this to the Application Site. The purpose of this exercise is to use the Cambridge City data as a benchmark and assess the overall performance of the Proposed Development by examining the sustainability measures that are proposed in related categories. One other purpose of this exercise is to examine the significance of each sector and the sub sectors so that the following can be discussed and determined:

- Which sectors and the sub sectors can any strategy for the Proposed Dvelopment influence? What is within control?
- What is the significance of the sectors and the subsectors in terms of CF when compared to the overall emissions?
- How much does the Proposed Development reduce the CF from those sectors, does it explore the opportunities to their full extent where it can make a difference?
- What is the level of certainty in influencing (reducing) the CF?
- Which sectors and subsectors are beyond the scope of the Proposed Development hence cannot be influenced to reduce the CF?
- What is the significance of these sectors that are beyond the scope of the Proposed Development and therefore cannot be influenced?

The first column of the matrix breaks down the SEI REAP data further for each emissions sector to give sub-sectors. The second column provides a list of measures which are proposed for the development and which may have an effect on CO_2 emissions. The magnitude of the effect in each sector can be assessed by comparing the measures included in the Proposed Development in this column to the breakdown data of the Cambridge City in the first column. This is discussed in the next column and the reduction in CF is provided qualitatively. A score of significant, medium or low is given. Further discussions take place in the next column of 'Measures Outside the Proposed Development's Control' and this explains further which sectors cannot be easily, or at all, influenced by the development.

Further detail on the transportation emissions is provided in Section 6 and the Appendices.

Table 2. Breakdown of CF by sector, and the effect which the North West Cambridge proposals may have on CO_2 emissions.

Emissions Sector	Breakdown of Cambridge City Carbon Footprint	Measures considered for the Application Site	Carbon Footprint of the Proposed Development compared to Cambridge City	Interventions / measures beyond the control of any development strategy (i.e. requires national intervention)	Further potential CO_2 reduction effects due to the Proposed Development
HOUSING (27% of the total CF in Cambridge)	**27% of total CF in Cambridge** **Breakdown:** direct fuel use by houses (40%) electricity; gas & other fuels distribution (37%) housing - construction and materials (15%) Other (refurbishment, maintenance, repair etc) (8%)	**Energy Use (in-use):** • Very high levels of energy efficiency • Urban layout and building orientation to maximise daylighting and minimise summertime overheating • All homes to be zero carbon post 2016 using low and zero carbon energy installations and allowable solutions offsets. • Measures to encourage behaviour change: Smart meters- monitoring and comparing the energy use (via community website) **Buildings (construction activities and materials):** • Material selection is geared towards - Pre-used, recycled and re-usable materials; - Local materials and supply chains - Potential for recycling at the end of life - Consideration of embodied carbon and use of materials such as timber which lock in carbon. • Assessment of embodied energy and CO_2 • Minimal transfer of materials to or from the site as a result of groundworks • Early electrification of site to minimise demand for generators and reduce noise and CO_2 emissions • Monitoring on-site energy use during construction phase with efforts made to minimise these	**Reduction in CF:** SIGNIFICANTThe Applicant has set ambitious targets to minimise the direct fuel use in dwellings. All dwellings will meet the Code for Sustainable Homes level 5 standard , and post 2016, will be zero carbon. 77% of this sector (2.4 tonnes /capita) is for domestic fuel and power, and so with the zero carbon standard, the CF will be around **2.4 tonnes p.a./capita** lower). In addition there is a strong move towards minimising the energy use from construction activities and materials, but the savings from this are likely to be lower than for housing fuel use as the potential to reduce the effect from this sector is limited.	**Energy infrastructure:** Carbon emissions related to gas and electricity supply at a national infrastructure level cannot be influenced. Most of this infrastructure is at an off-site scale including national generation and distribution. **Material Selection:** Materials selection will be based on a number of design criteria, therefore it may not be possible for all materials to meet all of the aspirations including local sourcing, embodied CO_2, recyclability	Maximising the energy savings from buildings by encouraging further **behaviour change**: • Raising interest and awareness with residents and building operators. • Sustainability information pack for households to raise awareness and educate. • Use of the community website to compare energy use with others to encourage competitive behaviour change. • Use of educational facilities: demonstrations, displays, forums, information sharing between residents. • Smart metering All the above is likely to encourage the residents to reduce energy consumption in their houses and businesses.

Emissions Sector	Breakdown of Cambridge City Carbon Footprint	Measures considered for the Application Site	Carbon Footprint of the Proposed Development compared to Cambridge City	Interventions / measures beyond the control of any development strategy (i.e. requires national intervention)	Further potential CO_2 reduction effects due to the Proposed Development
TRANSPORT (29% of total CF in Cambridge)	**29% of total CF In Cambridge** **Breakdown:** Private vehicle fuel use (direct fuel use) (31%) Air Transport (24%) Operation of personal transport equipment (13%) UK residents abroad (8%) Water transport (6%) Purchase of vehicles (5%) Railway transport (5%) Road transport (3%) Others (5%)	The Application Site is well-located with respect to improving the sustainability of transport. The proposed measures on the site combined with the location of the Proposed Development and layout will enable maximum use to be made of sustainable and low CO_2 transportation modes. The travel framework proposes a number of measures to improve the sustainability of transportation, both on, and off the site. **Measures which will reduce CO_2 include:** • Inclusion of a sustainable and comprehensive mix of uses on site such as to reduce the need to travel to work, to buy provisions or in order to enjoy leisure time; and Inclusion of on-site hotel facilities such that academic or research facilities at the Development or at West Cambridge or Girton do not need to travel great distances • Provision of 1,500 key worker housing units to accommodate University staff, researchers and visiting academics locally, where the wide choice of non-car forms of transport would assist both in reducing journey distances and car usage. • A target of a maximum 40% car use for journey to work trips. • Reduced car-parking (compared with similar developments). • Infrastructure for public transportation, cycling and walking, minimising the need of private car use. • Safe, attractive and appropriate routes for both pedestrians and cyclists through a network of car-free segregated routes. • Cycle training, on-site cycle facilities, pool bicycles provision. • Car club and car share schemes, electric charging points.	**Reduction in CF:** LOW Private vehicle use is responsible for a large proportion of a Cambridge resident's CF. Therefore by reducing car use below that of a typical Cambridge resident, emissions from private transportation can be reduced. Cambridge already has very low car use (44% of residents using a car to travel to work) and therefore whilst the Proposed Development is proposing lower levels of use, the saving is still likely to be relatively small. The analysis on transportation for this report (section 6) suggests that the travel plan will reduce overall transport emissions by around 8% or the overall footprint by about 2%. Carbon emissions from other modes of transport including non-local road, rail, water, and air are unlikely to be influenced by the Proposed Development. Therefore the reduction in carbon footprint could be small to medium.	**Air Transport:** Proposing measures to reduce air travel does not seem possible hence this method of transport cannot be influenced easily. Although education could play a role in raising awareness, this is down to the personal choice of the residents. In addition air transport may be higher than the national average due to having some overseas academic residents on site. Overseas residents may be likely to visit their families abroad once or twice a year by taking long haul flights. Provision of video conferencing facilities for use by academics and residents could assist minimising demand for travel **Road, Rail, Water:** The modes of transport cover transportation of people and goods off the site. The opportunities for the Proposed Development to influence these is extremely limited.	Maximising the public transport use and walking and cycling by further **behaviour change**: Raising interest and awareness: Cambridge already has a reputation for public transport use and cycling therefore residents may be more familiar and inclined to use green transport measures Advice and support in low carbon lifestyles, including transportation, and the provision of low carbon transport infrastructure will support behaviour change and have a wider effect in the Cambridge area.

Emissions Sector	Breakdown of Cambridge City Carbon Footprint	Measures considered for the Application Site	Carbon Footprint of the Proposed Development compared to Cambridge City	Interventions / measures beyond the control of any development strategy (i.e. requires national intervention)	Further potential CO_2 reduction effects due to the Proposed Development
FOOD (18% of total CF in Cambridge)	**18% of total CF In Cambridge** **Breakdown:** Catering Services (34%) Beverages (12%) Meat and meat products (excl. poultry) (11%) Fruit and vegetables (7%) Capital investment food (7%) Fruit and vegetables (7%) Poultry meat (5%) Others (7%)	The environmental effect of food consumption at the Proposed Development is largely beyond the control of any development related strategy. Residents may purchase some or all of their food remotely from the Application Site. Food which is available from the proposed food store is likely to be similar to other stores of the same company and not necessarily locally sourced. However a number of measures are proposed which aim to promote local sustainable food production: • 2.6 ha of allotments available to residents of the Application Site. • Fruit trees where possible in communal garden areas. • A regular farmers market in the local centre for local food suppliers. • Support for an on-site food cooperative . • Use of some local food by the catering facilities on the site including the school, hotel, academic and commercial buildings. • Provision of information on local food suppliers through the community website.	**Reduction in CF:**LOW Although there are a number of measures in place which may help reduce CO_2 emissions, the overall reduction in CF is likely to be low due to off-site food supply which is outside the control of the Proposed Development. Many residents may not participate in the food measures proposed for the Application Site and therefore would maintain a baseline food CF. Therefore the carbon footprint effect of the measures will probably be limited. If a 10% reduction could be made in this sector, then the annual reduction in CF is circa 0.2 tonnes CO_2 / year.	**Catering Services** It is beyond the remits of this strategy to provide sustainable catering services as this would depend on many external factors. However energy use in catering facilities (in buildings) can be influenced through lease arrangements. **Meat, meat products and beverages** Likewise carbon impact associated with beverages, and meat products are harder to influence as these are totally outside of the control of this site. **Off-site purchase and consumption** A large fraction of a resident's food purchase and consumption may take place off the Application Site, and therefore there is no influence over this except for raising awareness.	Minimising the carbon impact of food consumption by further **behaviour change**: Introducing a farmers market and opportunity for selling the food that is produced locally likely to have positive effect to the choices people make. Provision of information through the community website may help influence purchasing decisions. Education to primary school pupils, including local food production at the school, may help change future attitudes to food production resulting in future CO_2 reductions.

Emissions Sector	Breakdown of Cambridge City Carbon Footprint	Measures considered for the Application Site	Carbon Footprint of the Proposed Development compared to Cambridge City	Interventions / measures beyond the control of any development strategy (i.e. requires national intervention)	Further potential CO_2 reduction effects due to the Proposed Development
PRIVITE SERVICES , PUBLIC SERVICES and CONSUMER ITEMS (30% of the Carbon Footprint of Cambridge)	**In total 30% of the Carbon Footprint in Cambridge** **Breakdown:** Private Services[9] (6%) Public Services[10] (13%) Consumer Items[11] (11%)	These three sectors are presented under one section as the Proposed Development has the least influence in these sectors. Although there are some measures in place, public and private services and consumer items are not within the merits of the strategy and cannot be influenced nor can it be controlled easily. However following is proposed in the strategy: For Public services: **Hygiene and health:** Providing local medical facilities in low impact buildings; providing facilities to incentivise walking and cycling; providing allotment to grow local organic food. **Education:** Build new school to have low - zero emissions; facilitate walking/cycling/taking the bus (and walking bus) to school; make school an exemplar project promoting "green" living **Recreation & Leisure:** Improve recreation facilities in the area; provide green space, providing sports facilities in the form of a gym, green gyms, and/or sports pitches.	**Reduction in CF:**LOW/NONE Although there are some measures in place this section is hardest to control and influence, and difficult to attribute savings to the Proposed Development. This is because this section largely depends on the interventions in Local or National level. Public services fall in with the Local Authority premises largely and Cambridge City has its own National Indicator target as set out in Cambridge Environmental Report[12]. Yet the Proposed Development's Sustainability Strategy and the measures in the strategy cannot influence the emissions from public services. Private services will cover a vast range of services from outside the site with little influence apart from changing resident's behaviour and increasing awareness.	All of the items in this section are hard to influence and beyond the scope of the sustainability strategy for the Proposed Development.	Minimising the carbon impact by further by **behaviour change**: Due to the measures in place residents may be positive choosers when buying products, these include buying locally sourced products, products with low environmental impact etc.

[9] Capital Investment Private Services 27%, Recreational & cultural services 14%, Insurance 13%, Telephone & telefax services 9%, Accommodation services 8%, Water supply and miscellaneous dwelling services 6%, Education 5%, Financial services 5%, Social protection 5%, Other 8%

[10] Public administration (central) 28%, Health & vet services (central) 24%, Capital Investment Public Services 16%, Public administration (local) 12%, Education (local) 9%, Social work activities (local) 6%

[11] Clothing 17%, Furniture; furnishings; carpets etc. 15%, Other recreational equipment etc. 12%, Audio-visual; photo & info. processing equipment 10%, Personal care 8%, Personal effects 6%, Glassware;

[12] Cambridge Environmental Report 2009-10

Discussion

Table 2 provides an indication of how the design and operation of the Proposed Development may reduce a resident's CF, and determines which elements may be influenced by the Sustainability Strategy for the Proposed Development and which elements cannot be influenced. A column is provided to discuss some further elements implemented in the Proposed Development's sustainability plan. These are largely anticipated to encourage behavioural change and indirectly work towards reducing the CF of the Proposed Development.

The analysis shows that some sectors can be influenced significantly, some only slightly and there are three sectors wholly or mainly beyond the influence of any development related strategy.

Housing is the sector where the Proposed Development has the opportunity to make the biggest difference. The scale of the effect is significant because the site has ambitious targets for developing low and zero carbon homes, with all homes from 2016 being net zero-carbon, resulting in around 2.4 tonnes per person reduction for these homes.

There may also be opportunities for making savings in the transportation sector, and a number of measures are proposed to encourage the greater use of sustainable forms of transport. However the savings are limited due to (a) a large component of transport emissions arising from off-site transport, and (b), Cambridge already having low levels of car use, making further improvements more challenging.

These sectors are followed by food, services and consumer items. Although there are some measures in place, the effect (reduction) is likely to be low as most of the items in these sectors are down to the personal choice of the residents or a necessity with no means of control (i.e. public services such as hospitals and schools). Governmental intervention may be required to reduce the CF of some of these items.

Finally some measures are likely to be completely beyond the influence of any development related strategy An example is aviation where current trends are seeing a steady increase in passenger miles and CO_2 emissions. Unless people change their behaviour and attitude to flying, or penalties are used to reduce aviation such as higher taxes or charges, then this trend is likely to continue. Provision of video conferencing facilities may reduce the need for academic travel.

In summary there appears to be a 50:50 divide between the items that can potentially be influenced and the items outside the sphere of influence of the Proposed Development. The Proposed Development includes measures in all the potential areas where the sustainability (and CO_2 footprint) of the site can be improved, even if the end result on CF for some of these sectors may be minimal.

Overall the Application Site does not increase the per capita CF of Cambridge City, as per capita emissions are likely to be lower than the average. The site is probably too small to make a significant effect in reducing the emissions of the Cambridge City yet if there were many sites in the City with similar sustainability targets the CF of the City would be reduced on a per capita basis.

Figure 3 below illustrates the level of influence that the Proposed Development may have over each of the CO_2 emission sectors.

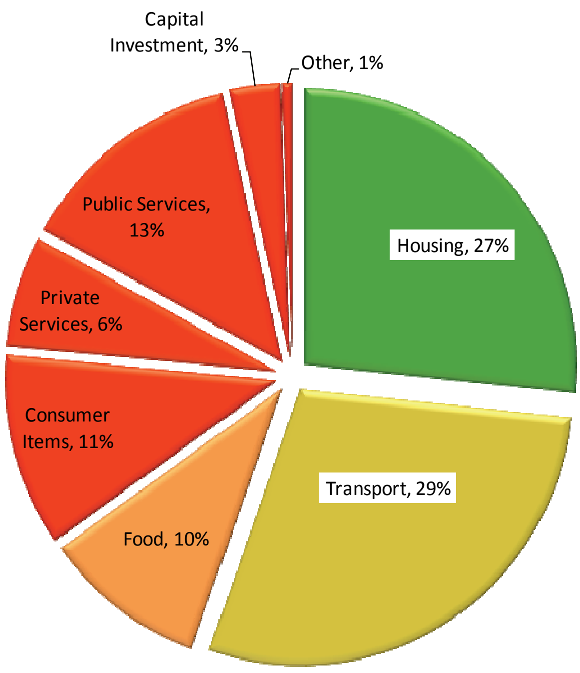

Figure 3. Influence of the Proposed Development on the different CO_2 emission sectors. Green indicates a high level of influence and red a low or zero level of influence.

5 Intangible measures contributing to CO_2 reduction

Behaviour change

Some aspects of carbon footprinting which are crucial to a development's overall environmental performance may not be easily integrated into the urban infrastructure and the buildings hence may appear to be less controllable. These largely include the residents' behaviour towards various aspects of daily life, and the consumption habits which directly result in environmental footprint and CO_2 emissions:

Education and raising awareness: The Proposed Development will promote 'sustainable living' overall through being a living demonstration of a sustainable community, or a 'living experiment' for ongoing research and monitoring. New and innovative technologies and systems will be on-show for residents and visitors to explore, assisted by easily accessible information and open days. For example, energy and drainage infrastructure will not be hidden but displayed in certain areas for people to view. These will be linked to a public art strategy enabling residents to both learn and enjoy looking at these features. Opportunities will also be taken to provide linkages between University research and the Proposed Development, in particular the monitoring of resource use (energy, waste, water etc) across the Application Site.

Community engagement: Where a site has community spirit and involvement good behaviour can be encouraged and influenced more easily as the residents will have the chance to talk, discuss and learn from each other. This will be one of the important elements of this Proposed Development.

Having a community website will aim to enhance social interaction to 'share' in general. As well as cultural and social activities, the website will allow the residents to share knowledge and ideas, host a car sharing group, sell, swap or recycle goods, organise and announce the local food production, farmer market etc, and compare household energy use.

Information and monitoring: In addition the community website combined with the installation of measurement and monitoring devices (energy displays, smart meters) will enable extensive monitoring of the energy and CO_2 emissions. The information will be available in real-time displays for residents to view, with an option for them to compare their consumption with other residents in an interactive environment.

Food purchase: The local centre will be available to be used for hosting farmers markets and food fairs aimed at local producers and suppliers. The foodstore in the local centre will also be encouraged to support these schemes, and to promote local food sales itself.

6 Transportation CO_2 emissions

Introduction

This section presents a summary of analysis conducted by Peter Brett Associates as part of their work in conducting the Transport Assessment and developing the Travel Plan for the Proposed Development.

The analysis is based on the outputs from traffic modelling, and therefore assesses CO_2 emissions associated with road transportation use to and from the Application Site. Due to the transport modelling including the effects from various measures in the Travel Plan, including the promotion of walking, cycling, and public transport use, the modelling provides an estimate of CO_2 reduction as a result of these measures.

The full CO_2 emissions associated with transportation for visitors and residents on the proposed development will be influenced by many factors and forms of transport which are beyond the control of any development related strategy. For example, just one or two foreign holidays involving flights could more than double a resident's transportation CO_2 emissions. Such trips are considered to be extra-ordinary and s completely beyond the control of any development related strategy . This section, therefore, focuses on typical daily trip generation. in assessing CO_2 emissions.

Base case

Analysis of travel modes and projected journeys suggests that there will be around 6,300 passenger car unit trips to and from the site a day for the base case scheme, with an average journey length of 22.7 km [13]. Using standard conversion factors from DEFRA, this gives an annual CO_2 emission of 22.0 ktonnes CO_2 per year.

Reductions on North West Cambridge

By including the measures proposed in the Travel Plan within the transport modelling, the number of journeys is reduced to around 5,000 trips to and from the site. Assuming the same journey length, the total CO_2 emissions are now 17.2 ktonnes per year.

CO_2 savings from the proposed Travel Plan

The measures proposed in the Travel Plan suggest that CO_2 emissions will be reduced from the base case by around 5.5 ktonnes per year, representing a 25% reduction. It is important to remember that this includes both journeys to and from the site, and therefore is a reduction for both residents of the Proposed Development, and also visitors from other areas.

Section 4 of this report examines the overall carbon footprint using the SEI methodology. Transportation represents around 29% of the carbon footprint of a typical resident, and road transportation and associated emissions are around 47% of this (or 14% of the total). Therefore a 16% reduction represents circa 3.5% reduction in the overall carbon footprint.

Full details of the analysis are provided in the Appendices.

[13] A passenger car unit (PCU) is a method of expressing different forms of transportation such as buses, cars, delivery vehicles, etc as cars for simplicity.

7 Lessons from UK's first 'zero carbon' site BedZED

Introduction to BedZED

The Beddington Zero Energy Development, (BedZED), is the UK's first and best-known 'eco-village' developed by the Peabody Trust housing association and Bioregional. It is located in Sutton in South London and the design focuses on creating highly sustainable homes, including a green transport plan, high efficiency passive building design, sustainable construction materials and the promotion of green lifestyles.

BedZED comprises 100 homes, community facilities and enough workspace for 100 people. Residents have been living at BedZED since 2002. This example is chosen as it has been in use for 8 years and there has been extensive monitoring of the site. Hence the BedZED development could provide valuable lessons for the Proposed Development. The following discussion is based on reporting from 2009[14].

Results from monitoring

Monitoring shows that BedZED households use on average 2,579 kWh of electricity per year (45% lower than the average in Sutton) and 3,526 kWh heating (from gas) per year (81% less than the average in Sutton). As a result the CO_2 emissions from home energy use are only 23% of the UK average (although the average does include a large number of inefficient older homes).

Water consumption is also low, with an average of 72 litres of mains water per day, topped up by 15 litres of recycled or rainwater being used by each person per day. This is less than half of the local (and national) average of circa 150 – 160 litres per person per day.

A high recycling rate is achieved with 50% of waste by weight being recycled. Overall, there was a 68% reduction in waste sent to landfill compared with the Sutton average at the time of reporting. This rate of recycling is achieved by the provision of separate recycling containers in each house, composting bins, and high resident awareness. For comparison the current figure for Cambridge City is around 40%, but averages around 50% across the county (National Indicator 192).

A car club is provided on site and public transport and cycling figures are higher than the national average. Road transport (car use) is less than half of the national average.

However despite all of the successes of BedZED and the measures incorporated, the ecological footprint of the 'average' BedZED resident remains high at 4.67 global hectares (equivalent to needing 2.6 planets of resources) and the carbon footprint is 9.9 tonnes per person. The monitoring notes that one environmentally conscious resident has managed to reduce this footprint to 6 tonnes or an ecological footprint of three global hectares (equivalent to 1.7 planets). This shows that there is an opportunity to reduce the effect further but this requires additional behaviour change by residents.

Whilst BedZED has enabled residents to reduce their CF, primarily from direct energy use, the reduced CF is still significantly higher than an 80% national CO_2 reduction would require to meet UK 2050 targets. Therefore despite the cutting edge design and approach to the buildings and community, the overall effect has been relatively small due to a large proportion of the CF being due to off-site emissions which cannot be controlled.

One source of off-site emissions identified in monitoring of BedZED is the use of public and private sector services and goods. Whilst some residents may "act sustainably" in their selection of services and goods, most residents will still require the same level of supply, and in many cases (particularly with public sector services such as healthcare) there is no scope to "select" low CO_2 options.

The second source identified in the monitoring work was the use of air travel. Residents of BedZED on average fly 10,063km / year which equates to 1.9 tonnes of CO_2 (20% of total CF). This figure is three times higher than the average in Sutton. There could be many reasons for this yet none of these

[14] BedZED Seven Years On. Bioregional. 2009.
www.bioregional.com/files/publications/BedZED_seven_years_on.pdf

can be influenced or controlled easily. Therefore this source of emission while having a major impact will always be one of the least controllable.

8 Cambridge City Targets

This section of the report discusses the Cambridge City carbon performance and the targets. As mentioned in the introduction, these are slightly different from the rest of the analysis and data used in this report. This is because the data is based on the national indicators, developed locally by Cambridge City Council, and compiled and published by the Department of Energy and Climate Change (DECC).

Local Authorities have a crucial role in achieving the Government's climate change objectives. They have great opportunities through their powers and responsibilities (such as providing housing, transport, services, etc) and therefore can have significant influence over emissions in their local areas and in aggregate, the UK.

Carbon dioxide emissions data for Local Authority areas is captured by the National Indicator 186 (NI 186). The average CF, according to this methodology across the country (all local authorities) is 7.83 tonnes CO_2/person[15]. This indicator measures the emissions resulting from energy use in homes and workplaces and vehicle fuel use across Cambridge and excludes aviation emissions. There has been a reduction of 4.4% since 2005 but the target for 2010 is an 11% reduction from a 2005 baseline. According to Cambridge Climate Change Strategy & Action Plan in 2008[16] there is a commitment to meet this target within the means of Cambridge City Council's Influence. (Cambridge is not able to influence all of the activities which result in NI186 figures nevertheless has an important role as being the planning and housing authority for the city.)

Table 3. Summary of Cambridge City and National NI 186 indicator based on 2008 data.

	Industry and Commercial (kt CO_2)	Domestic (kt CO_2)	Road Transport (kt CO_2)	Total (kt CO_2)	Population ('000s, mid-year estimate)	Per Capita Emissions (tonnes)	% per capita reduction since 2005
Cambridge	436	236	98	770	119	6.5	4.4%
UK Local Authority Average	1155	999	696	2,849	61,398 (UK)	7.50	5.5%

Based on the data in Table 3 the average CO_2 emissions per person for domestic consumption in Cambridge is around 1.99 tonnes . However the approximate annual emissions for the Proposed Development for domestic and commercial (assuming fully built in 2010 and with current emissions factors) are proposed to be circa 14,650 tonnes per year. With an increase in population of circa 8,590 residents, the average footprint of a resident of the Proposed Development for domestic AND commercial / academic facilities is 1.7 tonnes per person. (Note that this is not a direct comparison due to the difficulty in allocating NI 186 industrial and commercial emissions with the population. However the comparison demonstrates that if the Application Site emissions are all allocated to the increase in local population due to the Proposed Development, then the average footprint is significantly lower).

The comparable CO_2 footprint for a resident on the Application Site, based on this additive calculation, is therefore much less than an existing Cambridge resident, resulting in an overall reduction in the city's NI 186 indicator. This does of course make the simple assumption that there is not a significant expansion of commercial and industrial energy use outside of the Application Site, but even if this did expand in proportion to the population increase

[15] This figure is comparable with a simple average: taking total UK emissions (GHG) of 481 Mt (DECC 2009) and 62 million people gives a footprint of 7.75 tonnes per person. UK emissions figures (and NI figures) do not include imported emissions (such as goods and services imported from abroad). The REAP data does include these and hence has a higher footprint. The REAP data is the more comprehensive measure if we want to look at the "true" footprint.
[16] Cambridge Environment Report – 2009 /2010:

(assuming no change to more energy intensive industry), the average CO_2 emissions per capita will still remain lower.

9 Summary

Summary

This report provides a brief overview of what the carbon footprint may be for a resident of the Proposed Development, and how the proposals for the development may effect the carbon footprint. The average footprint of a Cambridge City resident (according to analysis by the Stockholm Environment Institute), is around 11.7 tonnes CO_2/year. This is lower than the UK average of 12 tonnes CO_2/year and the East of England average of 12.6 tonnes CO_2/year.

The carbon footprint of an average person is composed of a number of sectors. Housing and transportation account for just over half, with food, consumer items, private services, public services, and other sectors accounting for the rest. There are clearly sectors which the Proposed Development can heavily influence, the built environment having the strongest potential, followed by transportation to a smaller extent. However a number of the sectors have little or no tie-in with the development proposals, and the scope for reducing emissions in these sectors through the development proposals is minimal.

The largest potential reduction in carbon footprint is from the construction of “zero carbon” homes post 2016, providing a reduction of circa 2.4 tonnes CO_2 per person (prior to 2016, the savings per person will be around 1.2 tonnes per person if meeting Code for Sustainable Homes level 5). Whilst not all of these reductions will be achieved on site, the equivalent CO_2 reductions will be made through Allowable Solutions (i.e., carbon offsets).

There is also potential for large CO_2 reductions in the transport sector. However the exact effect will depend on how residents respond to the transport strategy, and their lifestyle (for example, aviation use for business or holiday). The proposals for promoting limited private vehicle use and increasing levels of public transport use, encouraging cycling and walking through design of routes, and provision of charging points for electric vehicles should have a large effect on local transportation (albeit perhaps not significantly beyond the average current Cambridge resident). However these gains might be outweighed by longer distance transportation. This was found to be true at BedZED during the monitoring work. The analysis for the Proposed Development suggests that around 25% reductions in CO_2 emissions from car use will be achieved through the travel plan measures proposed.

Out of the remaining sectors, food potentially offers some scope for reduction of CF, through the provision of food growing land on site, options for a farmers market and local food cooperative, and encouragement for the food store to participate in selling locally produced food. There is however very little which can be done to force residents to embrace these aspects of sustainable food, and the effect is likely to be relatively low, especially in the short term. A 10% reduction in the CF of food results in a 0.2 tonne reduction per year for the average resident.

Based on this analysis, therefore, the CF of a resident at the Proposed Development may be reduced to around 9 tonnes CO_2 per year (three quarters of the average Cambridge CF), largely through the introduction of zero carbon homes. Whilst there is a significant emphasis on promoting changes in transport use for the site, resulting in an overall reduction in road transport emissions of 25%, the overall effect on CF is limited to around 3.5%.

Further gains can be made on the CF through a process of behaviour change. This can help to reduce emissions further in all sectors by making people aware of the consequences of their decisions. Many of these savings may be in sectors which are largely “off-site” such as consumer items, but they will all contribute to a reduction in CF.

In conclusion, the strategy proposed for the Proposed Development will ensure that residents at the Proposed Development do not have higher per capita CO_2 emissions than the average for the Cambridge area. They should ensure that the CF of an average resident at the Proposed Development will be well below the current Cambridge average, but further reductions, especially if an 80% reduction is to be achieved by 2050, will require significant changes to many other CO_2 emitting sectors influenced at a local, national, or international level.

Appendices

Appendix: Transport CO_2 emissions

This section including the technical analysis has been written by Peter Brett Associates, alongside the development of the Transport Assessment and Travel Plan for North West Cambridge.

Introduction

International and national commitments - such as the Kyoto Protocol and the Climate Change Act - seek a reduction in greenhouse gas generation by the UK of 80% by 2050, with a series of lesser targets for the interim years. Transport currently generates approximately 5% CO_2 emissions globally but in the UK is responsible for around one quarter of the total UK energy consumption and CO_2 emissions.

Travel demand management strategies can be used to help reduce the number of vehicle trips, with a corresponding reduction in the generation of CO_2. The Transport Assessment for the Application Site has quantified the transport effect of the completed site in terms of person trips made in 2026 by each mode for the following two scenarios:

- the Base Case – person trips made from the Proposed Development assuming the residential and employment land use travel patterns reflect the current business as usual situation in Cambridge, ie, without the imposition of the proposed travel demand management measures; and
- the Future Case – trips made from the Proposed Development assuming the imposition of the travel demand management measures aimed at reducing car use for the residential and employment land uses. .

References to these two scenarios – the Base and Future Cases – are maintained in this assessment to refer to the Without and With travel demand management measure scenarios.

This Carbon Dioxide Generation Impact Assessment has quantified the CO_2 implications of the travel demand management strategy for the Proposed Development for the 2026 scenario, by comparing the Car Driver trip generation within the above Base and Future scenarios.

Whilst the CO_2 generation from typical daily movements - including travel to work, education and retail, as well as post and food deliveries - are included within this assessment, this assessment does not consider the CO_2 generation arising from trips such air travel, or holiday trips – these trips are considered to be extra-ordinary and ephemeral, hence are beyond the scope of this assessment. This assessment therefore considers only the CO_2 generation saved in terms of the normal daily trip generation reduction associated with the Proposed Development.

Methodology

The Transport Assessment has considered the transportation effects of the Proposed Development with reference to two approved highway models:

- the North West Cambridge Development option tests from the highway authority's highway model, the Cambridgeshire Sub-Regional Model (CSRM); and
- Peter Brett Associates' Person Trip Model.

These transport models predict any change in travel patterns associated with the Proposed Development and the surrounding transport network characteristics, and therefore, form the ideal tools to measure the effect of the Proposed Development travel demand management strategy - and from these, the comparative CO_2 generation.

The following methodology has been applied to assess the total CO_2 generated by motor vehicle travel in each case each day:

i. the residential; and employment land use car driver numbers are obtained from the 12 hour Person Trip Assessment Base or Future Case (providing the 5-day – ie weekday - flows);

ii. a factor is applied to convert the 5-day 12 hour flows to 7-day 24 hour flows – ie, the average weekly flows;

iii. the average distance travelled per vehicle to / from the Proposed Development has been taken from the Cambridge Sub-Regional Model;

iv. the total distance travelled each day has been calculated by applying this average distance travelled per vehicle to the total 24 hour 7-day flows;

v. the CO_2 generated per kilometre has been obtained from the 2010 Guidelines to the DEFRA / DECC Green House Gas Conversion Factors for Company Reporting;

vi. the total CO_2 generated per day has been calculated by applying the CO_2 generated per kilometre to the total distance travelled each day.

More details are provided in the following sections.

Base total distance travelled

The CSRM has modelled the trips generated by each area with reference to the existing and proposed land uses, and their relative potential attractions and productions. These areas are referred to as Zones, and generally reflect similar land uses, access points or a planning application. The vehicle trips are considered as “passenger car units”, a weighted average reflecting the typical range of vehicles.

The outputs from the North West Cambridge Development option tests reflect the Base situation. Information has been extracted by the operator of the model for the peak hours - for the AM peak period, 8:00 to 9:00, and the PM peak period, 17:00 to 18:00. This output is shown in Table A1:

Table A1: Output from the CSRM model of development trips for the Base Case.

	Base case - AM	**Base case - PM**
PCU trips from NWC zone	768	992
PCU kms from NWC zone	17,196 km	22,165 km
Average trip distance from NWC zone	22.4 km	
PCU trips to NWC zone	841	787
PCU kms to NWC zone	20,026 km	17,674 km
Average trip distance to NWC zone	23.2 km	
Average journey length	22.7 km	

PCU – passenger car unit

The CSRM has concluded that the average journey length travelled by each vehicle associated with the development is 22.7km. The model does show a minor difference in distance travelled between the AM and PM peak hours, presumably reflecting the differing travel patterns relating to the productions and attractions of the varying land uses throughout the day.

Whilst the car distance-travelled calculated by the CSRM may be representative of car travel during the peak hour situation, this may represent an over-estimate of the distance travelled throughout the remainder of the day given the excellent sustainable credentials of this development.

Peter Brett Associates Person Trip Model estimates the total number of trips to the Proposed Development during 12 hours of a weekday by all modes – walking, cycling, bus, car driver and car passenger. The “Base Case” output for cars is listed in Table A2.

Table A2: Output from the PBA Person Trip Model assessment of Base development trips

	AM Peak		PM Peak		12 hour	
	Arr	Dep	Arr	Dep	Arr	Dep
Residential Car Driver Trips	217	697	538	248	2,849	3,317
Employment Car Driver Trips	586	42	80	464	2,503	2,241
Total	**803**	**739**	**618**	**712**	**5,353**	**5,558**

Extracted from Peter Brett Associates North West Cambridge Transport Assessment Table 5.4 and PBA Person Trip Analysis Spreadsheet

Reference has been made to local automatic traffic count data to provide a factor from 5-day 12 hour flows (as per these models) to 7-day 24 hour flows. The count, on Huntingdon Road West of Whitehouse Lane, was commissioned by the University in October 2009, and provided a local factor of 1.16. Applying this factor to the above 5-day 12 hour flows gives a 7-day 24 hour total trip generation from the residential and employment land uses of the Proposed Development in the Base situation of **6,328** trips both arriving and departing each 24 hour period.

Assuming each trip travels the 22.7km reported by the CSRM, the total Base Development vehicle-distance movement within an average 24 hour period would be around **287,291**km. Whilst explicable as a peak hour travel to work figure for those living sufficiently far from their place of work to make the private car their preferred mode of transport, this is considered (given the sustainability characteristics of the Proposed Developments and the nature of its likely residents and workforce) to be an over-estimate for average trip vehicle movement distance for 12 hour flows for the Proposed Development.

Development Travel Management Strategy

The aim of a development travel demand management strategy will be to reduce travel by car, and consequently the CO_2 emissions related to transport. A number of key principles have been used to ensure that the Proposed Development transport strategy is sustainable. The transport strategy therefore makes best use of the following key supporting factors:

i. the location of the development;

ii. the mixed land uses within the development;

iii. a strong culture within the City of Cambridge for not travelling by car;

iv. the exemplary record of the University in delivering sustainable travel choices and a successful travel plan within its facilities across Cambridge.

The key transport strategy elements for the site are:

i. Land Use;

ii. Walking and Cycling Strategy;

iii. Parking Strategy (cars and cycles);

iv. Public Transport Strategy;

v. Travel Demand Management (including the Travel Plan);

vi. Vehicle Access Strategy.

Whilst these components are described fully in the Transport Assessment, the effect of these is considered further.

Future distance travelled

The distance travelled in the Future situation has been assessed in a similar manner to the Base Case, but with reference to the Future Case Person Trip Model results. For the purposes of this assessment, it has been assumed that the average distance travelled by vehicles to the development in the Future Case would remain the same as per Table 1. This means that where cars are still used, the types of journeys remain the same.

Reference has also been made to Peter Brett Associates' Person Trip Model to estimate the total number of trips to the Development during 12 hours of a weekday by all modes for the "Future Case". The Future Case output is listed in Table A3.

Table A3: Output from the PBA Person Trip Model assessment of Future development trips

	AM Peak		PM Peak		12 hour	
	Arr	Dep	Arr	Dep	Arr	Dep
Residential Car Driver Trips	199	571	430	170	2,320	2,726
Employment Car Driver Trips	481	33	66	344	1,839	1,647
Total	**680**	**604**	**496**	**514**	**4,159**	**4,373**

Extracted from Peter Brett Associates North West Cambridge Transport Assessment Tables 11.1 and 2, and PBA Person Trip Analysis Spreadsheet

The same local automatic traffic count data factor of 1.16 is applied to the 5-day 12 hour flows to provide the 7-day 24 hour flows. The 7-day 24 hour total trip generation from the Proposed Development would be an average of **4,949** two way trips both arriving and departing in the Future situation.

Assuming each trip travels the 22.7km reported by the CSRM, the total Future Development vehicle-distance movement within an average 24 hour period would be around **224,684**km.

Reduction in CO_2

Accepting that the total distance travelled by Development vehicles in the Base situation is **287,291**km, and the equivalent Future situation is **224,684**km, the Travel Demand Management Strategy would result in a total reduction of **62,607**km per day. .

To detail the CO_2 output generated by this movement, a value of CO_2 per kilometre travelled needs to be defined. The value that has been used has been extracted from the 2010 Guidelines to DEFRA / DECC's Green House Gas Conversion Factors for Company Reporting, Annex 6, Table 6e, the 'Average Car' CO_2 output of 0.21 kg of CO_2 per kilometre travelled has been used

To assess the yearly CO_2 generation, the number of 7-day 24 hour flows has been factored to an annual level by multiplying the daily output by 365. The annual CO_2 generated by the development in the Base and Future situations, and the annual saving implied by the sustainable aspects of this development, are shown in Table A4.

The figures for average and total vehicle trip distances and for CO_2 emissions are in a variety of respects pessimistic assessments:

- they assume an average vehicle trip at any time of day will correspond to 22.7km - this is a high figure considering that it applies a travel to work figure to all vehicle trips throughout every day;
- an average derived from travel to work trips for a working day peak hour is applied 7 days a week, 365 days a year;
- it is assumed that the average vehicle in 2026 will have the same emissions characteristics as an average vehicle in 2010;
- these figures make no allowance for savings inherent in the components, location and culture of the Proposed Development being likely to result in residents and workers being more likely to travel by sustainable modes of transport than if the Proposed Development were never brought forward.

Table A4: Annual transport related CO_2 emissions from the Proposed Development.

	Daily distance travelled (km)	Daily CO_2 Output (kg CO_2)	Annual CO_2 Output (kg CO_2)
Base development scenario	287,291	60,331	22,020,815
Future Development scenario	224,684	47,184	17,222,160
Reduction in distance travelled	62,607		
Kilograms of CO_2 saved through improved travel associated with the development		**13,147**	**4,798,655**

It is concluded that the Travel Demand Management Strategy would result in a reduction of **62,607**km per day distance travelled by Car, with a resulting total saving of **4,798,655**kg of CO_2 per year. This is a saving of around 16% from the base case.

"Beyond Control" situations

Whilst any developer may be committed to delivering a quality development and transport strategy, there is obviously no certainty that any future occupants will heed this with regard to their travel choices or lifestyle decisions

In the case of the Proposed Development, the University has more ability than most developers to influence these movements by maintaining ownership of the majority of the residential accommodation (for the Key Worker and Student Accommodation), as well as controlling and policy the parking provision for the majority of the development.

The Development Framework Travel Plan will monitor the resulting travel patterns, and will seek to control vehicle generation from the site to agreed targets. The Framework Travel Plan contains a series of contingency measures to be agreed to be implemented should these targets not be met.