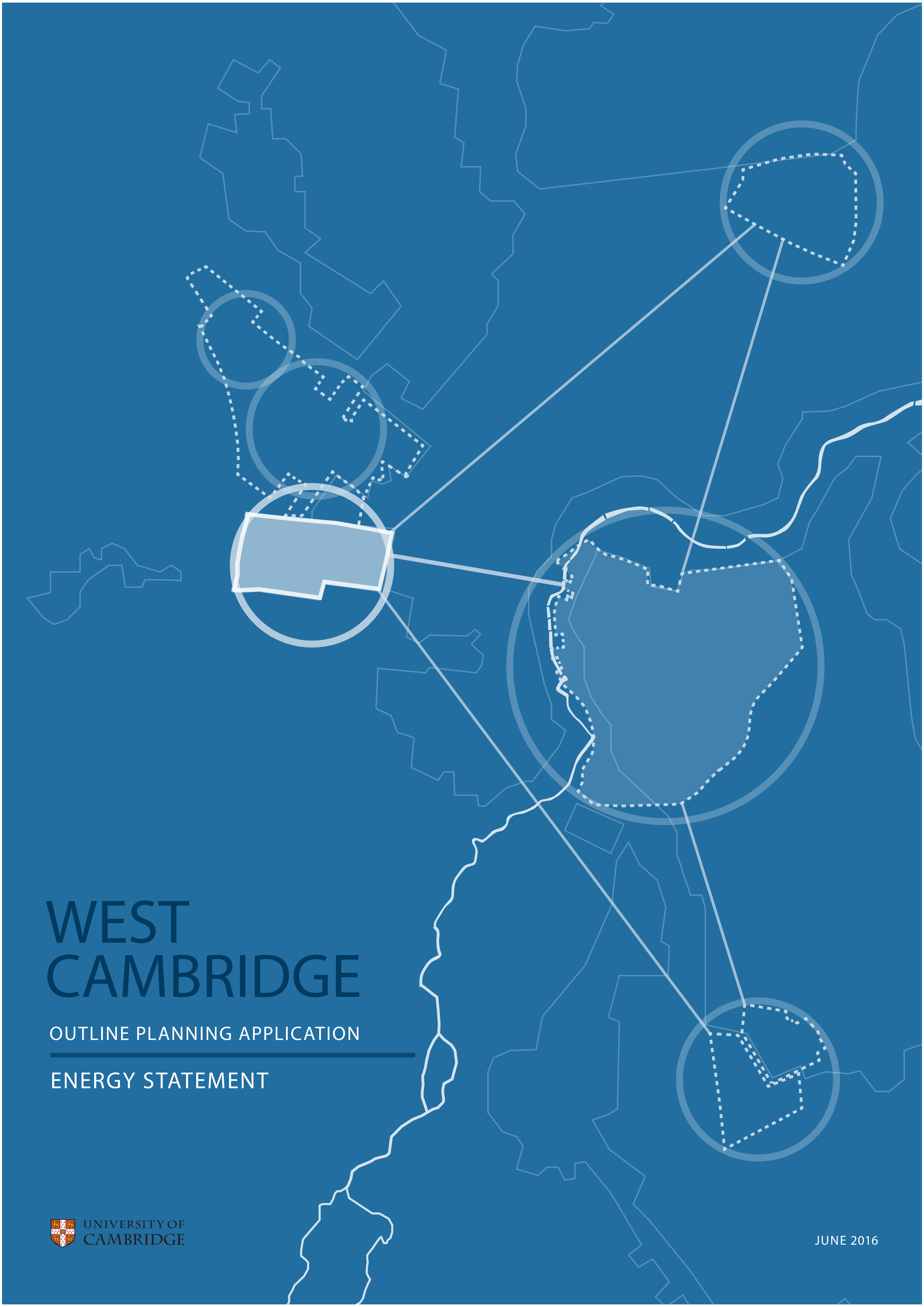

WEST CAMBRIDGE

OUTLINE PLANNING APPLICATION

ENERGY STATEMENT

UNIVERSITY OF
CAMBRIDGE

JUNE 2016

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Acronyms

AD	Anaerobic digestion
ASHP	Air source heat pumps
CCGT	Combined Cycle Gas Turbine
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent (includes emissions from CH_4 and N_2O expressed as CO_2 equivalent emissions)
DECC	Department of Energy and Climate Change
DH	District Heating
EPBD	European Energy Performance of Buildings Directive
FiT	Feed in Tariff
GIA	Gross Internal Area
GSHP	Ground Source Heat Pumps
HEFCE	Higher Education Funding Council for England
kW	Kilo Watt (1,000 Watts)
kWh	Kilo Watt Hour (1,000 Watt Hours)
LZC	Low and Zero Carbon (technologies)
MW	Mega Watt (1,000,000 Watts)
MWe	Mega Watt electric
MWh	Mega Watt Hour (1,000,000 Watt Hours)
PV	Photovoltaic panel
RDF	Refuse Derived Waste
RHI	Renewable Heat Incentive
UoC	University of Cambridge
WSHP	Water Source Heat Pumps

EXECUTIVE SUMMARY

Executive Summary

Introduction

This energy statement has been prepared in support of an outline planning application for the comprehensive development of the West Cambridge site. The University of Cambridge (“the Applicant”) has undertaken a re-masterplanning of the site with a view to establish a long term vision and strategy for its development. The masterplan will provide around 383,300m^2 of new gross internal built up area for academic facilities, commercial research and shared facilities to be delivered in a phased manner (“the proposed development”), in addition to approximately 123,000m^2 of existing accommodation.

The proposed development at West Cambridge offers the University a unique opportunity to provide flexible space while creating a high quality, well connected built environment, supporting the commercialisation of knowledge through entrepreneurship and collaboration with industry.

The application site is located to the west of Cambridge City centre. It sits on land to the south of Madingley Road, between the M11 to the west, Clerk Maxwell Road to the east and bordered on the south by path to Coton.

Policy context

Local statutory requirements, as outlined in Cambridge City Council’s Draft Local Plan 2014, which is expected to supersede the Adopted Local Plan 2006, require new developments to maximise opportunities for energy efficient building design and efficient energy supply using local low and zero carbon technologies. With regard to the on-site carbon reduction target, the Draft Local Plan 2014 (incorporating Proposed Modifications December 2015) requires all buildings to achieve the minimum energy requirements associated with BREEAM 'Excellent' from 2016 onwards.

In the near future, Part L of the Building Regulations is expected to be incrementally revised to deliver a nearly zero energy standard in 2021 to meet the requirements of the European Energy Performance of Buildings Directive. At the same time, the University has set ambitious CO_2 reduction targets across its estate in the short to medium term. National policy and other drivers will in most likelihood mean that the targets will continue to become more stringent in the future. The energy strategy for the site has been developed within this overall context and offers resilience and flexibility to respond to future changes in policy environment and future technological advances.

Preferred energy strategy

The preferred energy strategy has three components

1. Energy efficient building fabric
2. Efficient energy supply infrastructure on site
3. Low and zero carbon technologies

Energy efficiency

All buildings are to be designed with high fabric energy efficiency standards, for example, meeting or exceeding Part L 2013 requirements without recourse to LZC technologies. In particular, consideration will be given to passive means of ventilation and cooling (such as through the use of narrow floor plates and suitable building layouts), design of windows and external shading, good levels of thermal performance, energy efficient lighting design and controls, zoning of building areas to optimise energy use, and the use of heat-recovery technologies for specific building uses (such as laboratory buildings).

Some research buildings will need to be mechanically cooled due to the level of heat gains from laboratories and IT equipment. 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 high thermal mass, suitable orientation and external shading.

Higher levels of energy efficiency performance will be explored at the detailed design stage, in particular for future phases as technological advancements or economic considerations make higher standards viable.

In addition, all buildings will be designed to minimise the risk of summer overheating by minimising unwanted heat gains, optimising thermal mass and accounting for anticipated future temperature increases in the ventilation strategy. Consideration will also be given to site level measures to minimise the impact of the urban heat island effect including adequate vegetative cover, and green/ cool roofs.

Design guidelines and green leases will be used to ensure passive approaches and energy efficiency standards are integrated within the proposed commercial accommodation on site.

Efficient energy supply infrastructure on site

A site-wide district heating (DH) network is proposed which will be developed in stages in response to the phasing of development within the masterplan. The DH network will be connected to the majority of buildings on site where a suitable heat load exists, including both existing and where possible new accommodation.

A site-wide DH network is well suited to the site given its scale, density and the CO_2 reduction targets set under local and national policy. Such a centralised system will offer economies of scale by aggregating baseload demand across the site and providing efficiencies in operation. As the electricity grid decarbonises, the DH network will also offer more flexibility to switch to advanced technologies in the future, compared to individual building-level systems. The network will be designed for future low temperature operation to facilitate this. A low temperature system would assist with CHP efficiency, allow integration of heat pumps, allow the capture of waste heat and help to reduce thermal losses.

Buildings developed prior to the commencement of the heat network will be designed for future connection to the DH network and will be connected once the network is operational. Interim boiler plant will be provided which is either temporary, or becomes part of the site wide network. The strategy may be reviewed on a case-by-case basis where an alternative approach can deliver comparable long term benefits, which will include the early phase of engineering

The University will review the connection strategy of each building or inset masterplan to ensure that the scheme is optimally integrated including collecting waste heat from the building where available, for use on the network.

All new buildings will have low temperature heating systems installed (flow temperatures less than 70 degrees C). A central energy centre will provide heat to the network. The proposed location for the energy centre is on the western boundary of the site as shown in Figure 1. The location minimises the visual impact of the energy centre and its flue by integrating it within the adjacent multi-storey car park structures. The energy centre building will be built as part of Phase 1 of the site. The generation plant within the energy centre will be modular allowing the equipment to be installed in phases; however, it is expected there will be some redundancy in initial years (i.e. plant may be oversized for the needs of the site in the initial years).

Alongside a DH network, the potential for private wire systems and/or Licence Lite arrangements[1] will be explored to allow the University to make greater use of electricity generated on site, either from CHP or renewable electricity systems. These do not affect the carbon calculations presented here, but do allow for efficient local use of electricity.

Low and zero carbon technologies

The following conclusions are drawn based on the low and zero carbon technologies (LZC) options appraisal:

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[1] Licence Lite offers an option to reduce some of the financial and technical barriers to being a licensed supplier by allowing a new supplier to enter into a commercial arrangement with a third party licensed supplier (TPLS). The TPLS carries out compliance for certain part of the supply licence on behalf of the Licence Lite supplier.

- Gas CHP is a mature technology that can provide a low carbon solution for the foreseeable future during times of high carbon grid electricity, and will be the first wave of heat supply technology in the central energy centre. It will be sized to provide baseload demand, and as the technology is fairly modular, it will be installed in phases as the masterplan is gradually built out. In the medium to long term, the technology is expected to continue to provide CO_2e savings during peak demand periods when it will most likely offset grid electricity from carbon intensive gas CCGT[2] power plants.
- In the medium term, large air / water/ ground source heat pumps could be used as a second source of heat for the network as the electricity grid decarbonises (mid to late 2020s). These could provide baseload heat at times of low grid CO_2e intensity (i.e. periods with excess renewable electricity from wind or other technologies), and to charge the thermal store. The heat pumps could be located in the central energy centre or within individual buildings, while still being connected to the heat network, depending on availability of potential heat sources such as space for an array of ground boreholes, extracted air from laboratory buildings or the lake in the southern part of the site. Suitable guidance will be incorporated in the design codes / development agreements to ensure that opportunities are maximised when individual plots are taken forward for detailed design.
- Cooling will be provided either via GSHPs, electric chillers or, where relevant, a heat-driven absorption chiller located in individual buildings. The cooling demand on site is not projected to be significant enough to warrant a district cooling network. There are usually no CO_2 benefits of using absorption chilling unless a waste heat source is available.
- PVs offer a mature, flexible and modular technology option, and therefore opportunities to integrate these on roofs and ground-mounted structures (e.g. canopies car parking) will be maximised.
- Other building scale systems, such as small scale wind turbines or solar thermal, are likely to provide relatively small savings and are less flexible, but will be considered on a case-by-case basis at detailed design stage.

It is therefore proposed that the energy centre will include gas CHP engines as the initial low carbon heat source. The gas CHP engines will provide baseload heat and will be supplemented by gas boilers for back up and peak heating demands. Air source and/or ground source heat pumps may be used in future as a second source of heat for the network. The approach would also allow for other technologies to be adopted if these develop rapidly, for example the use of Hydrogen and fuel cells, which are currently not viable to use.

The proposed energy centre area of about 2000 m^2 together with allowance for a 3 storey building allows for space provision to install heat pumps in the future. The introduction of additional thermal storage will allow greater use of heat pumps in times of low carbon supply (possibly winter nights), and store this for the following day. This may require additional storage to the 600m^3 proposed for the initial CHP based scheme and the precise requirements for which will be assessed in due course.

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[2] Combined Cycle Gas Turbine

Figure 1: Proposed district heating network

Table 1: Summary of gas CHP energy generation

Parameter	Quantity	Units
Annual heat demand for buildings connected to DH network (excluding distribution losses)	42	GWh/yr
Peak demand – heat	32	MW
CHP working hours (assumed)	17	hrs/day
CHP working hours (assumed)	5:00 to 22:00	
Annual CHP gas demand	77	GWh/yr
Peak boiler gas demand	15	GWh/yr
CHP estimated heat generation	31	GWh/yr
CHP heat generation as % of overall demand	Approx 70%	
Estimated top up boilers heat generation	13	GWh/yr
Distributed boiler plant used on network (existing)	Up to 8-9	MW
Energy centre boilers capacity	Up to 32	MW
Estimated thermal store volume	Approx 600	m^3
CHP electricity generation	29	GWh/yr

At the building level PV panels are proposed to cover 50% of the building's roof area[3]. In instances where space is needed for plant and access, 50% of the available roof area will be targeted for PVs. Benchmark PV performance has been set at 850 kWh/ kWp with a module efficiency of at least 15%. At detailed design stage the incorporation of PV into other structures, such as car park roofs and canopies, will also be considered.

Estimated energy and CO_2 savings

The following tables outline the estimated energy demand, on-site energy generation, and associated CO_2e emissions following implementation of the energy strategy outlined above. The calculations pertain to one way in which the site could develop based on the current application proposals.

Table 2: Estimated energy demand and on-site generation

Electricity	MWh/yr	%
Total predicted site -wide electricity demand (excludes CHP electricity demand)	88,000	100%
Estimated electricity generated by gas CHP	29,000	33%
Estimated total electricity generation from PVs[4] and CHP	35,135	40%
Heat	**MWh/yr**	**%**
Total predicted site -wide heat demand	43,000	100%
Estimated total heat generated by gas CHP	31,000	72%

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[3] The figure allows for space between panels. The net area of PV panels is targeted to be 25% of the building footprint.

[4] The figures are calculated based on 50% of the roof area being covered by PVs. The figure will however vary depending on the available roof space, after taking into account space needed for plant and access.

Table 3: Energy and CO_2e reduction after application of gas fired CHP and PVs

	With energy efficiency	Remaining demand after energy efficiency and gas-CHP	Remaining demand after energy efficiency, gas-CHP and PV	% change
Annual gas consumption apportioned to existing buildings(MWh/yr)	13,120	19,870	19,870	51%
Annual gas consumption apportioned to new accommodation (MWh/yr)	37,580	57,530	57,530	53%
Total site-wide annual gas consumption (MWh/yr)	**50,700**	**77,400**	**77,400**	**53%**
Annual net electricity demand apportioned to existing buildings* (MWh/yr)	33,430	27,140	26,140	-22%
Annual net electricity demand apportioned to new accommodation (MWh/yr)	54,800	32,090	26,960	-51%
Total site-wide annual net electricity demand (MWh/yr)*	**88,230**	**59,230**	**53,100**	**-40%**
Associated primary energy consumption from existing buildings (MWh/yr)	118,640	107,570	104,480	-12%
Associated primary energy consumption from new accommodation (MWh/yr)	214,070	168,690	152,940	-29%
Total primary energy (MWh/yr)	**332,710**	**276,260**	**257,420**	**-23%**
Associated annual CO_2e emissions from existing buildings (tonnes)	20,190	18,380	17,860	-12%
Associated annual CO_2e emissions from new accommodation (tonnes)	36,560	29,080	26,420	-28%
Total site- wide annual CO_2e emissions (tonnes)	**56,750**	**47,460**	**44,280**	**-22%**

* After accounting for on-site generated electricity

Note that the usage of gas increases for the gas CHP case, because gas is used on site to generate electricity and heat. This increase in gas use is more than compensated for in CO_2 terms by the reduction in imported grid electricity.

The application of site-wide district heating and combined heat and power is estimated to result in annual carbon savings of around 9,300 tonnes (rounded figure) or about 16% over the energy efficient base case. Overall gas CHP and PVs are expected to deliver a 22% reduction in site-wide CO_2 emissions, and a 23% reduction in primary energy consumption.

For new accommodation on site, the strategy is estimated to deliver a 28% reduction in CO_2 emissions and 29% reduction in primary energy consumption relative to the energy efficient baseline.

It is important to note that these estimates are based on current CO_2 emissions factors used to demonstrate compliance against Part L of the Building Regulations[5]. In comparison, 15-year projected average CO_2 emission factors, typically used for long term policy development, are relatively lower for electricity and somewhat higher for

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[5] Current CO_2 emission factors are 0.216kgCO_2/kWh for natural gas and 0.519kgCO_2/kWh for electricity

gas[6]. This means that inevitably there would be a difference in expected near term savings (which are likely to be high) and longer term savings which will largely depend on rate of decarbonisation of the electricity grid. Similarly primary energy factors for grid electricity are also expected to drop over time.

Compliance with the minimum energy requirements for BREEAM 'Excellent' rating would require individual buildings to demonstrate an Energy Performance Ratio (EPR) of greater than 0.375. The EPR takes into account the modelled performance of the building (relative to a notional building complaint with Part L of the Building Regulations) based on three parameters – energy demand for heating and cooling, primary energy consumption and CO_2 emissions. The estimated percentage reduction figures for CO_2 emissions and primary energy for new accommodation on site indicate that on average a typical new building would achieve an EPR in the region of 0.5. The percentage reduction figures will however tend to vary across buildings (depending on the building use and form) and the precise levels of energy efficiency and/or renewables energy provision will be fine-tuned at detailed design stage to ensure compliance.

Connection to neighbouring sites

The viability of linking up the district heating network to North West Cambridge was reviewed when developing the masterplan for North West Cambridge. The review concluded that the scale of each site is large enough to justify separate energy centres with little benefit to be gained from combining energy centres with a gas CHP based system. In particular, any benefits were outweighed by the cost of installing the heat main linking the two sites.

A 'smart' system for the future

The proposed energy strategy maximises opportunities for renewable and/or low carbon energy generation on site in line with current local planning policies. It also provides flexibility to respond to anticipated future changes to Building Regulations Part L and the wider policy environment.

Of fundamental importance to the future flexibility and viability of the strategy is the use of a low temperature heat network, which will be suitable for current and future heat sources. An innovative approach being considered for the site in the medium to long term is 'grid balancing'. As the electricity grid decarbonises through increased renewable generation, the heat network (along with the gas-CHP, heat pumps, and on-site thermal store) could be optimised to act as part of a smart system, alternating between the two on-site generation sources under certain grid conditions to help balance loads on the electricity grid and to maximise CO_2e savings. However the timing of such decarbonisation remains uncertain so the need to retain flexibility is important.

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 relevant CO_2 targets. It is likely that during the lifetime of the development, new technologies and fuels will become available which offer advantages over the current options. The proposed district heating network will also offer greater flexibility to switch to advanced technologies in the future compared to individual building-level systems. In addition, the viability of new building integrated technologies and or higher energy efficiency standards will be re-appraised at detailed design stage and key stages during the development phase.

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[6] For instance SAP 2012 gives a 15-year projected CO_2 factor of 0.381kgCO_2/kWh for electricity and 0.22 for gas. Source: http://www.bre.co.uk/filelibrary/SAP/2012/Emission-and-primary-factors-2013-2027.pdf

WEST CAMBRIDGE ENERGY STATEMENT

Structure of the Document

This energy statement is structured into three sections:

- Section 1 describes the proposed development and defines the minimum targets and standards that apply following a review of relevant policy and legislation.
- Section 2 summarises the technical analysis conducted. This incorporates an assessment of the baseline conditions and a feasibility assessment of low carbon technologies and measures.
- Section 3 describes the preferred energy strategy and proposes how this strategy might evolve in the long-term.

1 Background and Policy Review

1.1 Introduction

The West Cambridge site forms an integral part of the University of Cambridge's ("the Applicant's") current academic and commercial research facilities. The University is undertaking a re-masterplanning of the site ("the Proposed Development") with a view to establish a long term vision and strategy for its comprehensive development. The masterplan will provide around 383,300m^2 of new gross internal built up area for academic facilities, commercial research and shared facilities to be delivered in a phased manner ("the proposed development") in addition to approximately 123,000m^2 of existing accommodation. The proposed development at West Cambridge offers the University a unique opportunity to provide flexible space while creating a high quality, well connected built environment, and supporting the commercialisation of knowledge through entrepreneurship and collaboration with industry.

The site is located to the west of Cambridge City centre. It sits on land to the south of Madingley Road, between the M11 to the west, Clerk Maxwell Road to the east and bordered on the south by the for path to Coton.

This document sets out the preferred energy strategy for the application Site in support of an outline planning application. The calculations in this report pertain to one way in which the site could develop based on the current application proposals.

1.2 Policy review

1.2.1 National climate change and energy legislation

The Climate Change Act (2008)

The Climate Change Act sets a legally binding target for reducing UK carbon dioxide (CO_2e) emissions by at least 80% by 2050 compared to the 1990 baseline. The Act is supported by the UK Low Carbon Transition Plan (2009), which sets out UK's approach to meeting these carbon reduction commitments. To deliver this act, the first four carbon budgets, leading to 2027, have been set in law. These require a 35% reduction by 2020 and a 50% reduction by 2025 over 1990 levels. These legally binding targets will further drive the development of future UK policy and regulations aimed at reducing CO_2e emissions. These targets require significant reductions in CO_2e emissions from existing energy users, and minimal additional emissions from new energy users.

National Planning Policy Framework (NPPF), 2012

The National Planning Policy Framework (NPPF) came into force in March 2012. The document consolidated more than two-dozen previously issued Planning Policy Statements (PPS) and Planning Policy Guidance Notes (PPG) for use in England. The NPPF has a significant impact on local planning policy in respect of sustainability. It states that "development that is sustainable should go ahead, without delay – a presumption in favour of sustainable development that is the basis for every plan, and every decision".

Building Regulations Part L

Part L of the Building Regulations sets maximum limits for CO_2 emissions from buildings as well as providing minimum efficiency standards for fabric and building services. Part L is revised every few years to become more stringent. Initial phases at West Cambridge will have to attain at least the minimum standards required by Part L 2013, and other phases will need to meet future versions when announced.

In July 2015, the government announced its decision to postpone the proposed 2016 update to Part L of the Building Regulations. Therefore there is considerable uncertainty around the timing for future revision/s to Part L and the expected trajectory for further tightening of energy and carbon performance standards. It is expected that future revisions of Part L will also need to take into account the European Energy Performance of Buildings Directive (EPBD) that requires that all new buildings to be "nearly zero-energy" from 2020 onwards.

1.2.2 Local planning policy

Cambridge City Council's Draft Local Plan, 2014

The main local policy that is expected to be guiding the masterplanning proposals is the Cambridge City Council's *Draft Local Plan 2014*, which is expected to supersede the *Adopted Local Plan 2006*. Both documents have specific policies relating to sustainable development and policies focussing on the development of the West Cambridge site. There is also a Supplementary Planning Document (SPD) on Sustainability for the 2006 Local Plan, which mandates a 10% CO_2 emission reduction through renewable technologies, though low and zero carbon technologies (LZCs) such as natural-gas combined heat and power (CHP) may partially contribute to this target. The requirements of the SPD are addressed in this document.

For new non-residential developments, the *Draft Local Plan 2014* (incorporating Proposed Modifications December 2015) requires the following targets to be achieved, where technically or economically viable:

Year	Minimum BREEAM rating	On-site carbon reduction	Water efficiency
2014	Very Good	In line with 2013 Part L	Full credits for category Wat 01 of BREEAM
2016 onwards	Excellent	In line with the minimum requirements associated with BREEAM 'excellent'	Full credits for category Wat 01 of BREEAM

In addition, major proposals are required to investigate the potential for connecting to or instigating district heat networks where viable, along with future-proofing the buildings for future connection where possible. This supports the City's aim of developing city-wide heat networks and making use of low carbon heat sources.

It should be also noted that the *Draft Local Plan 2014* makes allowance for the use of, or development of, alternative sustainability assessment frameworks in place of BREEAM. This is discussed further in the West Cambridge Sustainability Statement.

1.2.3 University of Cambridge commitments and policies

Estate-wide CO_2e emission reduction targets

HEFCE (The Higher Education Funding Council for England) has set a sector-wide CO_2e emission reduction target, requiring a 34% reduction by 2020 from the 1990 baseline. The University of Cambridge is aiming for an absolute reduction of 34% in scope 1 and 2 emissions against 2005 levels by 2020 for activities not attributable to scientific or technical research, and a relative 34% reduction in CO_2e emissions associated with scientific and technical research expressed as tCO_2e per £ spent on research.

BREEAM standards

University policy requires all non-domestic buildings to achieve a BREEAM rating of ‘Excellent’ or equivalent. Where this cannot be achieved, as a minimum, the energy section must achieve the level of performance required for an ‘Excellent’ rating.

Policy on thermal comfort

The University aims to provide a comfortable working environment for staff and students, and to comply with health and safety requirements while minimising CO_2e emissions and costs arising from the operation of heating systems. The University aims to maintain internal temperatures in buildings within the range of 19 to 21°C during their core operational hours. Full air conditioning or local cooling is not the standard throughout the University Estate. It is installed in specific instances for the general comfort and wellbeing of individuals or any group of individuals (such as identifiable academic need, regulation or code of practice for specific activities, or where excessive high internal temperatures are likely with no other practicable means or reducing heat gains).

1.3 Defining minimum targets and standards

The review outlined above provides a high level summary of energy policies that have guided the minimum standards and the overall energy strategy for the development. It is important to recognise that the future trajectory for tightening of energy and/or carbon performance standards under Part L of the Building Regulations is still unclear, and as a result, both national and local policy is likely to change/ evolve during the timeframe over which the development is phased. Rating schemes, such as BREEAM may also alter their standards / assessment procedures to align with the national methodologies.

The review however highlights a number of parameters that must be considered fundamental to the site energy strategy. In summary:

A. All buildings to be designed with high fabric energy efficiency standards to meet or exceed the prevailing Building Regulation Part L standards.

B. A BREEAM rating of ‘Excellent’ will require all buildings to have an Energy Performance Ratio (EPR) greater than or equal to 0.375. This EPR is calculated based on three parameters, namely the building's modelled heating and cooling demand, primary energy consumption and CO_2e emissions, relative to a reference building defined under the Building Regulations Part L. Typically an EPR of 0.375 would require a 7% improvement over 2013 Part L across all three parameters although there is flexibility in terms of overachieving one of the parameters and underperforming on the other.

C. The site-wide sustainability framework also sets an ambition to develop at least two buildings on site to BREEAM ‘Outstanding’ rating. This will require an EPR of 0.6 or better, typically requiring about 15% improvement in operational energy demand, primary energy consumption and CO_2e emissions compared to 2013 Part L baseline.

2 Technical assessment and feasibility analysis

This section summarises the technical analysis conducted for the West Cambridge site, from assessing the energy use and associated baseline CO_2e emissions through to a feasibility assessment of a range of measures and technologies aimed at reducing these emissions in order to comply with local and national policy. The section is split into the following sub-sections:

- Site opportunities and constraints
- Building design and energy efficiency
- Projected energy consumption and CO_2e emissions after energy efficiency measures
- Low and zero carbon technology options

2.1 Site opportunities and constraints

2.1.1 Opportunities

The masterplanning of West Cambridge site offers a number of opportunities that have been taken into consideration when developing the overall energy strategy:

- **Large development site:** The size and scale of development, which includes existing and new buildings, allows larger and more efficient site-wide systems to be considered that can potentially offer greater economies of scale than smaller building scale systems.
- **Comprehensive re-masterplanning exercise:** The re-masterplanning exercise for the West Cambridge site provides an opportunity to integrate passive design principles and advanced fabric performance standards within new accommodation on site. The re-allocation of land could allow the development of centralised energy plant, reducing the need for plant in separate buildings.
- **No historic buildings constraints:** The site is predominantly modern in nature, and does not suffer from the historic building and heritage constraints of many of the other University sites.

2.1.2 Constraints

The site also poses a number of potential constraints that have informed the development of an energy strategy. These include:

- **Existing buildings on site:** There are already a number of buildings on-site, some of which will remain and be embedded within the new masterplan. Their current energy demands and supply need to be considered when developing a future strategy for the overall site, as systems may need to be integrated or excluded as required.
- **Long term phasing:** The phasing of the site over many years means that a strategy needs to meet the needs of each phase whilst maximising the benefits provided by the overall scale of the site. This requires a phased strategy which may include some redundancy in the earlier years.
- **Uncertain future build out:** The strategy needs to be flexible to allow a range of building types and scales to be connected without requiring subsequent infrastructure modification. The strategy also needs to be flexible to cope with changes in grid electricity supply and CO_2e intensity.

2.2 Building design and energy efficiency

2.2.1 Energy efficiency principles

The following aspects will be considered and prioritised at detailed design stage for all new buildings on site.

- **Narrow floor plates:** Plan depths will, where practicable, be kept less than 16m to allow for cross ventilation and good daylighting. Deep plan buildings where required will aim to include design features such as atria so that daylight and natural ventilation can be maximised.
- **Passive means of ventilating and cooling:** In particular, office and academic accommodation will be naturally ventilated, making use of thermal mass, appropriate orientation and shading to minimise overheating. Some research buildings will need to be mechanically cooled due to heat gains from large internal equipment loads such as 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.
- **Appropriate window design and solar shading:** Consideration will be given to design of windows and shading to allow for good ventilation, maximise wintertime heat gain while minimising unwanted solar gains in summer, and maintaining adequate daylight levels.
- **Highly insulated and air-tight building fabric:** All buildings to be designed with good levels of thermal performance (U-values and air-tightness), in order to meet Part L 2013 requirements through energy efficiency alone. Higher levels of energy efficiency performance are to be explored at detailed design stage, in particular for future phases as technological advancements or economic considerations make higher standards viable.
- **Energy efficient lighting design and controls:** All lighting to have a luminous efficacy of at least 50 lamp lumens per circuit watt, with motion sensors and daylight sensors, where applicable. Time control to turn off selected lighting for certain periods (for example between midnight and 6 am) will also be considered.
- **Zoning of building areas:** This will allow energy use to be optimised and allow for parts of a building or certain processes loads to be shut down when not in use. Provision will be made for “kill” switches to shut off non-essential services in parts of the building
- **Variable speed pumps and fans:** Variable speed pumps and fans will be specified to optimise energy use in response to demand.
- **Optimising air-change rates for specific building uses:** This is particularly relevant to the laboratory buildings on site. Often very high air-change rates are specified for labs, which may not always be necessary depending on intended use. A review of appropriate rates will be made at detailed design stage for all laboratory buildings.
- **Assessment of need and review of technologies for fume cupboards:** A review of technologies will be carried out to optimise energy use, subject to a risk assessment. Heat recovery with plastic heat exchangers and automatically descending sashes are now available and will be reviewed for laboratory buildings.
- **Specifying equipment with the highest energy rating:** Where relevant, procurement of equipment is to consider energy efficiency as one of the key performance metrics, e.g. ‘A’ rated fridges and other laboratory equipment.

These energy efficiency principles will be enforced through the use of design guidelines and possibly green leases for non-university commercial buildings.

2.2.2 Climate change adaptation principles

Climate change is expected to result in hotter drier summers leading to concerns of overheating in buildings and water shortages, as well as more extreme weather in all seasons leading to risks of flood or storm damage. From an energy strategy viewpoint, the overheating risks within the buildings will be most important to address. This includes building design considerations as well as measures to mitigate the impact of the urban heat island effect.

A range of responses within the site masterplan and in the brief for individual buildings are proposed to minimise the adverse impacts associated with climate change.

At a site level, consideration will be given to the following features at the detailed design stage with a view to mitigating the urban heat island effect:

- **Increasing tree and vegetative cover:** Trees and vegetation lower surface and air temperatures by providing shade and through evapotranspiration. Landscaping will be incorporated with a view to delivering benefits in terms of a cooler external environment, without creating excessive water demands.
- **Installing green roofs:** Green roofs provide shade and remove heat from the air through evapotranspiration, reducing temperatures of the roof surface and the surrounding air. Provision of green roofs will need to be balanced against other competing uses for roof space such as PVs and plant.
- **Using cool pavements:** A cool pavement refers to one using paving materials that reflect more solar energy, enhance water evaporation, or have been otherwise modified to remain cooler than conventional pavements. They can be created with existing paving technologies (such as asphalt and concrete) as well as newer approaches such as the use of coatings or grass paving.

By adopting primarily natural ventilation strategies that will minimise the heat rejected to the immediate building surroundings from plant, will additionally help to counter the heat island effect.

At building level, buildings will be designed with high albedo to minimise unwanted heat gains. Glazing levels will be set and shading optimised to reduce summertime solar heat gain. Glazing with a low G-value will be specified[7]. The optimum G-values will be determined when individual buildings are modelled and will depend on the orientation and intended functions.

Consideration will be given at detailed design stage on how thermal mass (such as exposed concrete ceilings) can be deployed to reduce overheating risk. The ventilation strategy at building level will look at a combination of natural ventilation for open plan offices, mixed-mode ventilation for areas with more variable loads such as meeting rooms, and active cooling for spaces such as IT hubs. Although inner city arguments against natural ventilation in terms of noise disturbance and poor air quality should not apply at the West Cambridge site, the impact of higher external summer temperatures in the future will need to be considered to arrive at the optimum solution.

The UK Climate Impacts Programme (UKCIP) at the University of East Anglia has provided future weather scenarios 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[8]. 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.

Modelling of individual buildings will be carried out at detailed design stage to quantify the impact of future higher external summertime temperatures so that the proposed environmental strategy for each building is able to cope with current and future temperatures. Design guidance will be developed which provides details on the assessment procedure, methodology, and test conditions.

The climate change adaptation principles proposed at building level for West Cambridge are summarised in Table 4 below.

Table 4.Proposed climate change adaptation measures to increase the likelihood of buildings being able to cope with future increased summer temperatures.

Building Type	Building-level climate change adaptation measures
Naturally ventilated non-domestic buildings	Naturally ventilated non-domestic buildings will inherently need to include measures to reduce internal temperatures from the outset in order to avoid the need for air-conditioning. These include • Appropriate orientation

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[7] The G-value of a window is a measure of the solar transmittance

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

Building Type	Building-level climate change adaptation measures
	• Cross ventilation • External shading • Thermal mass • Window design to ensure appropriate ventilation rates It is however acknowledged that these buildings may need to be retrofitted with cooling by 2050. Therefore these 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.
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 mentioned above in order to minimise the use of active cooling.

2.3 Projected energy demand and CO_{2e} emissions after energy efficiency measures

2.3.1 Typical building uses on site

The modelling to estimate the baseline energy demand and emissions for the site are based on the following proposed uses:

- Around 232,400m^2 (GIA) of academic facilities including around 61,000m^2 of existing floor area;
- Around 186,500m^2 (GIA) of commercial research facilities (office space, laboratories and workshops) including around 34,000 m^2 of existing floor area;
- Around 18,500m^2 (GIA) of shared teaching and meeting facilities;
- Around 11,000m^2 of space for restaurants and cafes;
- Around 1,700m^2 nursery including 650m^2 of existing floorspace;
- Around 3,800m^2 (GIA) of data centre development, including around 1,900 m^2 of existing floor area;
- Around 84,500m^2 (GIA) of multi-storey car parks, all new development;
- Around 28,000m^2 (GIA) of community space and residential development, with around 14,000m^2 of new residential accommodation and around 4,000m^2 of new community space.

These areas include existing buildings which will remain or be refurbished (e.g. Roger Needham building) but exclude any buildings proposed to be demolished. Commercial areas include current and future buildings.

2.3.2 Approach to benchmarking of energy use

Drawing on work conducted for the North West Cambridge site, metered data from buildings has been used to benchmark energy consumption, rather than data from modelling using the methodology specified under Part L. The latter does not often accurately reflect in-use energy consumption. Using measured building data will enable an understanding of the actual loads taking into account user behaviour and unregulated energy uses.

Where possible, therefore, building data has been obtained from well-designed, energy efficient buildings from the last decade and considered to be representative of the current state of the art. Where relevant, data has also been obtained from recently built University buildings as these are likely to best represent the way in which the University occupies and uses its buildings.

2.3.3 Energy consumption benchmarks for typical building uses

Table 2 below summarises the energy consumption benchmarks that have been applied to estimate the energy demand for the site after energy efficiency measures have been adopted.

Table 5.Energy consumption benchmarks after energy efficiency

	Heat Demand, kWh/m^2	**Electricity Demand (including demand for cooling), kWh/m^2**	**Comments**
Desk-based research - Energy consumption benchmarks from two recently completed University ‘desk-based’ research use			It is assumed that all commercial and academic desk-based research is carried out in conventional office space and that this will either be naturally ventilated or mixed mode. Hauser Forum data chosen as representative of office space at West Cambridge.
Faculty of Education (completed in 2005)	66	88	
Hauser Forum	48	67	
Benchmark used (Hauser Forum)	**50**	**67**	
Medium intensity laboratories - Energy consumption benchmarks for laboratory buildings from different sources (including from West Cambridge)			Energy use in laboratories tends to be heavily dominated by process loads from laboratory equipment, which is sometimes left running 24 hours per day and is not regulated under building regulations. Energy consumption can therefore vary widely depending on the exact use of the building. 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. There may also be extensive use of fume cupboards leading to high air-change rates, and therefore heating.
Centre for Mathematical Sciences	97	168	
Mott Building, Physics	94	546	
CAPE	55	420	
William Gates Building	38	129	
Materials Science and Metallurgy	21	42	
HEEPI “Good”	78	93	
Benchmark used (Average of selected buildings)	**77**	**195**	
High intensity laboratories - Energy consumption benchmarks for laboratory buildings from different sources (including from West Cambridge)			Physics of Medicine is the most recent high intensity laboratory to be built on the West Cambridge site. Its benchmark figures are in the good-typical range of HEEPI figures, and take into account its plug-in loads and high air-change rates.
Existing Vet School	208	379	
Physics of Medicine	216	226	
Benchmark used (Physics of Medicine)	**224**	**226**	
Cavendish III			Figures provided by the University
Benchmark used	**50**	**550**	
Humanities and others – Energy consumption figures from the University of Cambridge’s Sidgwick Site			This category incorporates other academic spaces that are not included

	Heat Demand, kWh/m^2	**Electricity Demand (including demand for cooling), kWh/m^2**	**Comments**
Faculty of English	96	75	in desk-based research buildings.
Alison Richard Building	84	157	
Benchmark used (Average of Sidgwick Site)	**113**	**89**	
Sports centre with swimming pool – Figures taken from CIBSE TM46			TM46 benchmarks used as no other more appropriate reference consumption figures are available for these buildings.
TM46 Sports Centre	**281**	**95**	
TM46 Swimming Pool	**961**	**245**	
Cycle hub – Figures taken from CIBSE Guide F			CIBSE Guide F benchmark used as most appropriate for the cycle hub changing facility. Figures are shown as kWh/m^2 for changing facility (and in brackets as kWh per total cycle hub floor area assuming 20% of this is the changing facility).
CIBSE Guide F “Sports Ground Changing Facility” Good practice	**141** **(28)**	**93** **(19)**	
Primary School/ Nursery			The benchmark figures are taken from previous research into nursery consumption figures for the North West Cambridge site, and the subsequent modelling of the Lot 7 nursery on the North West Cambridge site.
DCSF, Energy and water benchmarks for maintained schools; 10th percentile, i.e. best practice, 2002 - 2003	61	18	
CIBSE TM46 Schools (note: includes secondary schools)	150	40	
North West Cambridge Lot 7 Nursery energy usage prediction	65	30	
Benchmark used (Lot 7 Nursery)	**65**	**30**	
MSCP			TM46 benchmarks used as no other more appropriate reference consumption figures are available for these buildings.
TM46 Multi-storey Car Park	**0**	**4.6**	
Street Lighting			This benchmark figure was taken from the modelling for North West Cambridge, and verified by AECOM’s lighting team.
North West Cambridge Benchmark	**0**	**0.25 W/m^2**	

2.3.4 CO$_{2e}$ emission factors used for the calculations

Carbon Dioxide equivalent (CO$_2$e) emission factors are a measure of the amount of carbon dioxide and other greenhouse gases released by an activity (commonly in units of kg CO$_2$e/kWh). Calculations on site-wide CO$_{2e}$

emissions are based on current CO_2 emissions factors used to demonstrate compliance with Part L 2013 as shown in Table 6.

It is worth noting that emissions associated with the use of grid electricity are expected to change dramatically in the coming years as the mix of technologies (coal, gas, wind, nuclear) used to generate electricity changes. Projected 15-year average CO_2 emission factors, typically used for long term policy development, are relatively lower for electricity and somewhat higher for gas. For instance, SAP 2012 gives a 15-year projected CO_2 factor of 0.381kgCO_2/kWh for electricity and 0.22 for gas[9].

This will have an important bearing on both the baseline emissions as well as the savings realisable over time through the adoption of alternative technologies, such as heat pumps or combined heat and power. Progressive grid decarbonisation would mean that, in the early phases of the proposed development, technologies displacing grid electricity, such as gas-fired CHP, will be favourable (since they are partly replacing coal which has a high CO_2e intensity). In the medium to long-term (2025 and beyond), technologies that use low carbon grid-electricity, such as heat pumps, will gradually become more favourable.

The proposed approach to calculating CO_2 emissions baseline and savings in technologies is however consistent with the current approach to demonstrating compliance with Part L of the Building Regulations.

Table 7.CO_2e emission factors used in calculating site-wide emissions baseline and projected savings

	Building Regulations Part L 2013 emission factors
Mains gas	0.216 kg CO2e/kWh
Electricity	0.519 kg CO2e/kWh

2.3.5 Estimated energy consumption and CO_{2e} emissions

The phasing of the proposed development at West Cambridge means that the energy demand for the site will increase gradually over time from current levels to when the site is fully built out. The predicted energy consumption and associated CO_2e emissions for each of the phases and the fully built-out site are provided in Table 8 below. These figures include both the existing buildings that will be retained and new development proposed on site. The energy demand is calculated based on best practice levels of energy efficiency (using benchmarks identified in section 2.3.3) and 85% efficient conventional gas heating.

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[9] Source: http://www.bre.co.uk/filelibrary/SAP/2012/Emission-and-primary-factors-2013-2027.pdf

Table 8: Summary of estimated baseline energy consumption and CO$_2$e emissions for West Cambridge

	Annual energy demand (MWh/yr) including implementation of best practice energy efficiency measures				**Associated annual CO$_2$e emissions (tCO$_2$e)**		
	Existing buildings	**New accommodation**		**Total**	**Existing buildings**	**New accommodation**	**Total**
		University	Commercial				
Phases 0 & 1							
Electricity demand	33,430	24960	3720	62,110	17,350	14,880	32,240
Heat demand	11,150	4950	3220	19,320	2,830	2,080	4,910
Phase 2							
Electricity demand	-	15060	3860	18,920	-	9,820	9,820
Heat demand	-	13200	2680	15,880	-	4,040	4,040
Phase 3							
Electricity demand	-	3690	3510	7,200	-	3,740	3,740
Heat demand	-	5280	2620	7,900	-	2,010	2,010
TOTAL							
Total electricity across all phases	**33,430**	**43,710**	**11,090**	**88,230**	**17,350**	**28,440**	**45,800**
Total heat across all phases	**11,150**	**23,430**	**8,520**	**43,100**	**2,830**	**8,130**	**10,960**

The total site-wide CO$_2$e emissions are estimated to be around 56,700 tCO$_{2e}$, of which new developments account for around 36,500 tCO$_{2e}$ per annum. The figures show that whilst electricity is the largest annual demand, there is also a significant thermal demand predicted.

The annual electricity demand for multi-storey car parks (MSCPs) and street lighting is estimated to be in the region of 325MWh/yr and 80MWh/yr respectively. Combined, these contribute less than 0.5% of the total electricity demand for the site, and around 0.35% of the total predicted carbon dioxide emissions. As these emissions are negligible in comparison to the occupied buildings, these have been ignored for the current analysis.

The site-wide energy demand figures above form the baseline after the application of energy efficiency measures. Further energy and CO$_2$e savings would be realised through the use of low and zero carbon energy supply technologies. These are described and quantified in the next sub-section.

2.4 Low and zero carbon technology options

2.4.1 Summary of LZC technology appraisal for West Cambridge

It is acknowledged that reliance on fossil fuels for the West Cambridge site must be minimised through the use of lower carbon sources of energy. This sub-section examines the appropriateness of a number of low and zero carbon sources of energy. This analysis partially draws on existing work by AECOM examining the technical and economic potential of low and zero carbon technologies across the University's estate. The findings from the options appraisal are summarised in Table 5 below, and discussed in more detail in Appendix 2.

Table 9: Summary of suitability of low and zero carbon technologies for West Cambridge

Technology	Suitability	Comments
District heating network (DH)	Suitable	District heating networks provide the infrastructure needed to distribute heat from a range of low and zero carbon energy sources to individual buildings across a site. The scale and density of the West Cambridge site is well suited to a district heating network. The technology is mature and reliable, but can incur a high capital cost. The heat source needs to provide economic savings which helps fund the network.
Communal gas CHP connected to district heating (DH) network	Suitable	Gas CHP (Combined heat and Power) is a mature technology that can deliver significant CO_2e reductions when connected to a site-wide heating network. Progressive gird decarbonisation can potentially erode some of the savings in the medium to long term, although there will be periods where gird carbon intensity remains high and gas CHP would continue to provide savings. Consideration needs to be given to future-proofing the site to accommodate other complimentary technologies as and when they become viable from a CO_2e mitigation perspective.
Communal biomass boilers connected to DH network	Technically suitable, but high risk solution	Whilst technically suitable, there is significant risk associated with future availability and cost of fuel, whilst also ensuring sustainability of fuel source. There are also concerns over transport movements and their impact on sensitive research uses at this site, and also concerns around air quality due to flue gas emissions.
Biomass CHP connected to DH network	Technically suitable, but high risk solution	Although biomass CHP can deliver substantial CO_2e reductions, the technology at the scale required for the proposed development is currently considered to be immature / pre commercial and there are many examples of scheme which are performing poorly. There are also the wider concerns over the availability and future cost of fuel as with biomass boilers.
Heat pumps connected to district heating network	Suitable for later phases as electricity grid decarbonises	Heat pumps could operate as a low carbon source in times of excess low carbon electricity available from the grid, although the technology is unlikely to save CO_2 during periods of peak demand. Centralised systems connected to a heat network would allow economies of scale and the potential to capture secondary heat from borehole extraction, ground stores, or other large ground collection systems. Heating systems in individual buildings and the DH network would need to be designed to operate at low temperatures to allow efficient operation of heat pumps.
Anaerobic digestion (AD)	Not suitable due to quantity of organic waste required	Large scale AD is not considered suitable for the development due to the large feedstock requirements and concerns over transport movements and the potential impact on sensitive research uses at this site. AD also requires a large area of land. The University has previously examined AD for a number of sites and concluded that it is not feasible.
Large scale wind turbines	Not suitable	Large scale wind is not considered suitable due to the requirements for buffer zones between the turbines and buildings/ roads and the potential visual impact.
Small scale wind turbines	Not suitable	There could be opportunities for incorporating small scale wind turbines on some parts of the site. However the performance is likely to be poor due to the urban nature of the site, resulting in negligible CO_2e savings relative to the baseline even with a large number of turbines. The suitability is to be reviewed when designing future phases of development, if technological

Technology	Suitability	Comments
		innovations result in turbines being available that are more suited to the urban environment. However it is likely that the contribution to site wide CO_2e savings will remain negligible.
Solar Photovoltaic panels (PV)	Suitable for all buildings	PV has very few limitations and could be installed on the roofs of most buildings. There may however be constraints around exporting electricity not used on site to the grid. The maturity of the technology means this is a relatively low risk solution. The maximum contribution is obtained if roof slopes can be designed to be predominantly south facing. In practice, competing uses, such as green roofs and plant space, limit the amount of roof area available for PV. Financial support is available through Feed-in-Tariffs (FITs), which (although not guaranteed in the medium to long term) can reduce technology lifecycle costs during the initial phases of development.
Solar thermal panels	Suitable for buildings not connected to heat network; limited CO_2e saving potential	The maturity of the technology means this is a relatively low risk solution. Solar thermal panels generate domestic hot water that generally conflicts with the baseload demand CHP systems are sized to supply. Nevertheless they could be installed in buildings with a sufficient hot water demand and which are not connected to a heat network. Due to the limited demand for hot water in comparison with other building loads, the proportion of CO_2e emissions offset by this technology is likely to be small. Financial support is available through the Renewable Heat Incentive (RHI) for installations smaller than 200kWth.
Building level gas fired CHP	Suited to large buildings with significant heat load	Gas fired CHP could be appropriate for individual buildings with large heating loads. However greater efficiencies are likely to be available for larger scale systems supplying multiple buildings via a district heating network.
Building level heat pumps	Suitable for later phases as electricity grid decarbonises	The technology is expected to become suitable from a CO_2e abatement perspective as the electricity grid decarbonises in the future. Building scale heat pumps could make use of extracted air as a heat source, thereby improving their efficiency, in particular for lab buildings that would be designed with a high air exchange rate. Specific applications could make use of other heat sources such as the lake in the south of the site. Heating systems would need to be designed to operate at low temperatures to allow efficient operation of heat pumps.
Building level biomass boilers	Not suitable	In addition to the concerns highlighted for site-wide biomass heating/ CHP systems, individual biomass boilers are not considered suitable 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.

2.4.2 Current technologies used for existing buildings on site

The following buildings at West Cambridge are known to have some low carbon and zero (LZC) technologies:

- The Hauser Forum building has a ground source heat pump with 94kW heat and 58kW cooling capacity. The Broers research building, developed as part of the Hauser Forum, has similar systems but is privately operated and not controlled by the University Estate department.

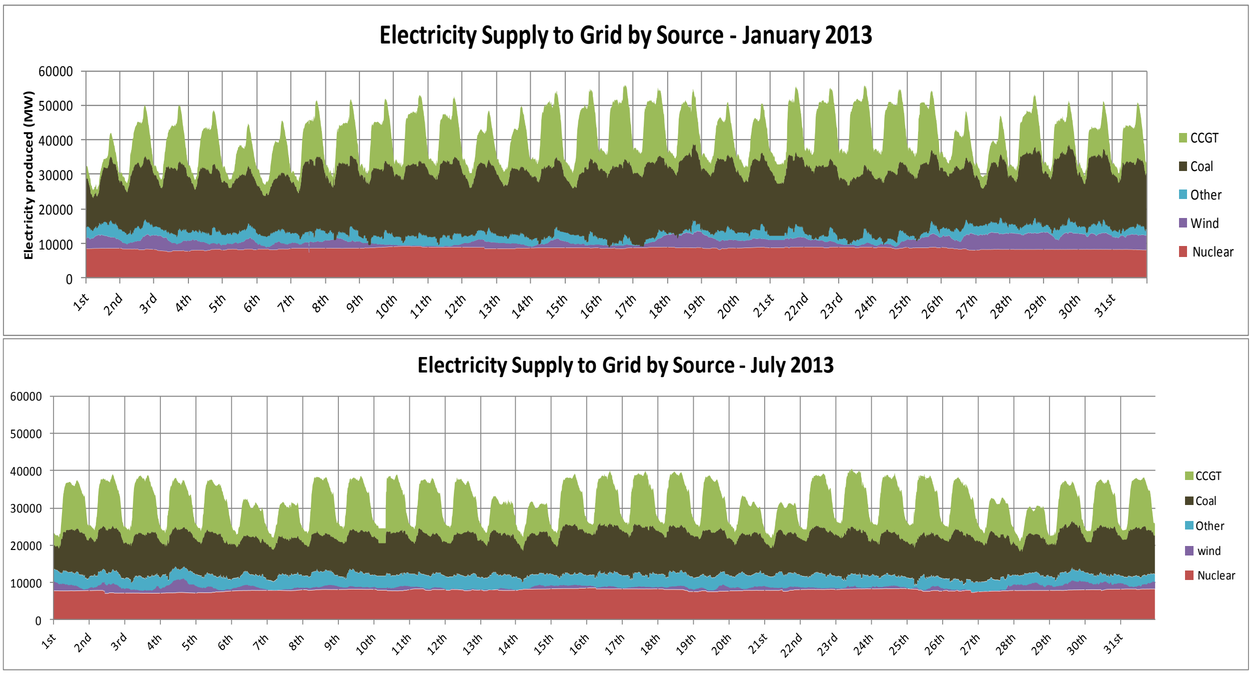
- The Institute for Manufacturing has a 220kW biomass boiler which provides heat input to the VRF air source heat pumps.
- The Veterinary school has two 150kW biomass boilers.
- The Sports Centre has a 78.75kW PV on-roof array.
- The Materials Science & Metallurgy building has a 24kW on-roof PV array.

These systems are all relatively small in scale and not sufficient to influence decisions for the wider site strategy.

2.4.3 Optimising CO_{2e} emissions savings over the building lifecycle

Electricity generation on the national grid is expected to significantly change over the next few decades. It will move from high carbon fossil generation, to a mix of nuclear, increased renewables, fossil fuel generation with carbon capture and storage (CCS), and some non-CCS gas generation for peak load following. This means that on average the grid will become lower carbon, but that it will have different levels of CO_2e emissions at different periods depending on the electricity demands, and the amount of renewable electricity available at that point. This section outlines the conceptual approach that could be adopted to optimise CO_2e emissions from the site over time. Additional research and discussions with stakeholders will be required to refine this approach further.

Modelling conducted by AECOM demonstrates that despite the current grid mix comprising a range of technologies, the operating "marginal" technology is currently gas CCGT[10] and coal. Figure 2 shows current grid electricity generation for sample months in 2013. Nuclear acts as baseload (it does not modulate in relation to demand) and renewables produce electricity when available (in particular windy periods). This means that any on-site electricity production will be offsetting higher carbon fossil fuel generation. Under this circumstance, gas fired CHP will save large amounts of CO_2e relative to grid electricity.


Electricity Supply to Grid by Source - January 2013

Electricity Supply to Grid by Source - July 2013

Figure 2: Current grid electricity generation for sample months in 2013.

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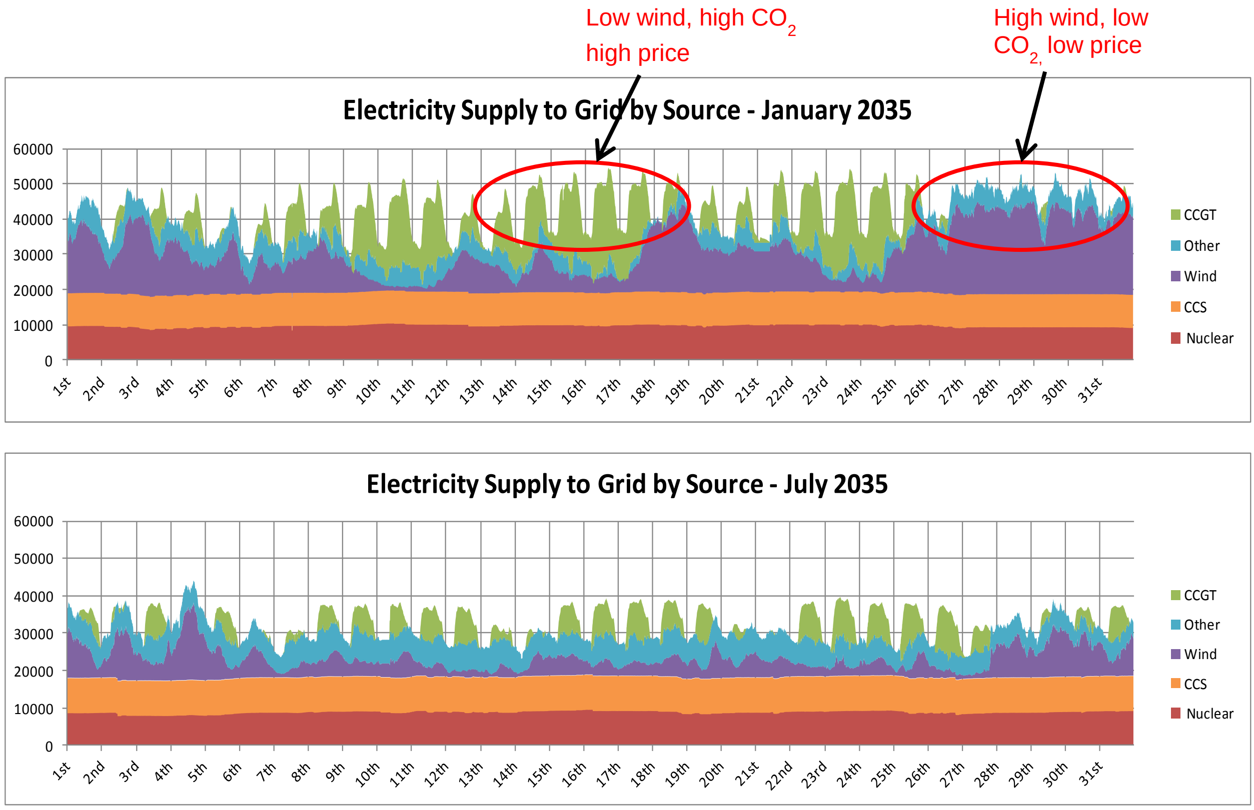
[10] Combined Cycle Gas Turbine

Over time, as the electricity grid decarbonises through increased renewable generation, and potentially some CCS generation, there will be periods when fossil fuel generation (high carbon) will be the operating marginal, but also periods where there is excess renewable or low carbon electricity (low carbon). Gas CHP will still save CO_2e against the former, whilst electricity consuming systems (for example heat pumps) could make use of the low carbon electricity in times of excess.

Figure 3 shows a projection in 2035 with periods of high carbon operating marginal and periods of low carbon operating marginal.

The price of electricity can be used as an indicator of the operating marginal. In high carbon periods fossil fuel generation will be used having high fuel costs, thus resulting in higher cost electricity (as seen in peak periods). In low carbon periods with excess renewable electricity, there will be a low price, and even negative price if the alternative is to pay generators to stop generating.



Low wind, high CO_2 high price

High wind, low $CO_{2,}$ low price

Figure 3: Projected periods of high and low carbon operating marginal in 2035

By operating a combination of heat pumps and gas CHP on a district heating network, it could be possible to optimise the generation source under certain grid conditions so that CO_2e savings are maximised, both now and in the future, and the economics can potentially be improved.

In this circumstance the heat network effectively acts as part of a smart system by providing balancing for the electricity grid. The introduction of large amounts of thermal storage could allow greater use of heat pumps in times of low carbon supply (possibly winter nights), and store this heat for the following day.

The approach outlined is based on the likely changes to the UK energy systems, and the ever greater need to consider the balance between demand and supply. The concept has been reviewed with David Mackay (ex-Chief Scientific Advisor to DECC, who has been highly influential at a national level), and is seen as a suitable solution.

The concept is innovative as a complete system, but all the individual components are tried and tested, and therefore represent an overall low risk strategy.

3 Proposed energy strategy

This section outlines the proposed energy strategy for West Cambridge and proposes how this strategy might evolve in the medium to long term. The preferred strategy reflects current thinking on quantum of development on site, phasing, technology viability, as well as anticipated changes in the wider regulatory context. It will be reviewed at detailed design stage and at key stages during the build-out phase.

3.1 Key considerations

The following key considerations have informed the choice of technologies and the energy strategy for the masterplan:

- The strategy should be capable of delivering significant CO_2e savings to enable compliance with anticipated improvements to Part L of the Building Regulations, in particular expected revisions in response to the European Energy Performance of Buildings Directive (EPBD) that requires that all new buildings are designed to be “nearly zero-energy” from 2020 onwards. In addition, the strategy should provide a substantial contribution to the University’s aims for carbon reduction and enable the fulfilment of its Environmental and Carbon Reduction policies, which is critical in light of the major expansion plans that the University has for the future.
- The strategy should provide low lifecycle costs per tonne CO_2e saved.
- The strategy should consider both current and future electricity grid CO_2e emissions savings as the grid is expected to decarbonise in coming years.
- The strategy should allow for the significant changes which are expected in the UK energy systems, and provide a smarter solution. It should provide flexibility and allow the University to plan ahead so as to benefit from potential new innovation and technological advances in future with minimum cost and avoiding major future infrastructure changes and disruption.
- The strategy should result in lower energy costs for the University.
- The strategy should offer an innovative solution which could support the overall sustainability and reputational ambitions for the site.

3.2 Proposed energy strategy

The proposed energy strategy for the West Cambridge site has three components:

1. Energy efficiency
2. Efficient energy supply infrastructure on site
3. Low and zero carbon technologies

These are described in more detail in the sub-sections below.

3.2.1 Energy efficiency

All buildings will be designed with high fabric energy efficiency standards, for example, meeting or exceeding Part L 2013 requirements without recourse to LZC technologies. In particular, consideration will be given to:

- passive means of ventilating and cooling, where viable
- narrow floor plates and other design features for maximising natural ventilation and daylight
- building layouts, design of windows and external shading to ensure good ventilation, adequate daylight, high winter heat gain while minimising unwanted solar heat gains at other times
- good levels of thermal performance (U-values and air-tightness)

- energy efficient lighting design and controls
- zoning of building areas to optimise energy use
- optimising air-change rates and consideration of heat-recovery technologies for specific building uses such as laboratory buildings
- reducing overheating risk under projected 2050 conditions using passive measures, wherever feasible, including consideration of both building and site level measures

Some research buildings will need to be mechanically cooled due to heat gains from laboratory and IT equipment. 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 and shading.

Higher levels of energy efficiency performance will be explored at the detailed design stage, in particular for future phases as technological advancements or economic considerations make higher standards viable.

Design guidelines and green leases will be used to ensure passive approaches and energy efficiency standards are integrated within commercial accommodation on site.

3.2.2 Efficient energy supply infrastructure on site

A site-wide district heating (DH) network is proposed which will be developed in stages in response to the phasing of development within the masterplan. The DH network will be connected to the majority of buildings on site where a suitable heat load exists, including both existing and new accommodation.

A site-wide DH network is well suited to the site given its scale, density and the CO_2 reduction targets set under local and national policy. Such a centralised system will offer economies of scale by aggregating baseload demand across the site and providing efficiencies in operation. As the electricity grid decarbonises, the DH network will also offer more flexibility to switch to advanced technologies in the future, compared to individual building-level systems. The network will be designed for future low temperature operation to facilitate this. A low temperature system would assist with CHP efficiency, allow integration of heat pumps, allow the capture of waste heat and help to reduce thermal losses.

Buildings developed prior to the commencement of the heat network, or where new development cannot be connected to the network in the initial years (for instance, where located at the edge of the site and infill development is only planned to be delivered in future phases) will be designed for future connection to the network. Such development will be required via a lease or development agreement to provide space for a heat exchanger and design the space heating systems to be compatible with the site-wide DH network. Interim boiler plant will be provided which is either temporary, or becomes part of the site wide network. The strategy may be reviewed on a case-by-case basis where an alternative approach can deliver comparable long term benefits.

At this stage it is proposed that the Civil Engineering building will be developed using such an alternative high fabric efficiency and low carbon approach that maximises the use of local waste heat. This decision takes into account both the phasing of the building, which is due for completion before the site-side DH network will become operational, and the availability of local ‘building use specific’ low carbon opportunities. The University will review the connection strategy of each building or inset masterplan to ensure that the scheme is optimally integrated including collecting waste heat from the building where available, for use on the network.

All new buildings will have low temperature heating systems installed (flow temperatures less than 70 degrees C).

A central energy centre will provide heat to the network. The proposed location for the energy centre is on the western boundary of the site as shown in Figure 4. The location minimises the visual impact of the energy centre and its flue by integrating it within the adjacent multi-storey car park structures. The energy centre building will be built as part of Phase 1 of the site. The generation plant within the energy centre will be modular allowing the equipment to be installed in phases; however, it is expected there will be some redundancy in initial years (i.e. plant may be oversized for the needs of the site in the initial years).

Alongside a DH network, the potential for private wire systems and/or Licence Lite arrangements[11] will be explored to allow the University to make greater use of electricity generated on site, either from CHP or renewable electricity systems.

3.2.3 Low and zero carbon technologies

The following conclusions are drawn based on the low and zero carbon technologies options appraisal outlined in the preceding sections:

- **Gas CHP is a mature technology that can provide a low carbon solution for the foreseeable future during times of high carbon grid electricity**, and will be the first wave of heat supply technology in the central energy centre. It will be sized to provide baseload demand, and as the technology is fairly modular, it will be installed in phases as the masterplan is gradually built out. In the medium to long term, the technology is expected to continue to provide CO_2e savings during peak demand periods when it will most likely offset grid electricity from carbon intensive gas CCGT[12] power plants.
- **In the medium term, large air / water/ ground source heat pumps could be used as a second source of heat for the network as the electricity grid decarbonises** (mid to late 2020s). These could provide baseload heat at times of low grid CO_2e intensity (i.e. periods with excess renewable electricity from wind or other technologies), and to charge the thermal store. The heat pumps could be located in the central energy centre or within individual buildings, while still being connected to the heat network, depending on availability of potential heat sources such as space for arrays of boreholes, extracted air from laboratory buildings or the lake in the southern part of the site. The viability of heat pump systems for individual buildings should take into account the availability of such heat sources and system efficiencies that can be achieved relative to a centralised system. Suitable guidance will be incorporated in the design codes/ development agreements to ensure that opportunities are maximised when individual plots are taken forward for detailed design.
- **Cooling will be provided either via GSHPs, electric chillers or, where relevant, a heat-driven absorption chiller located in individual buildings.** The cooling demand on site is not projected to be significant enough to warrant a district cooling network. There are no CO_2e benefits of using absorption chilling unless a waste heat source is available. Consideration of the most suitable technology needs to be given on a case-by-case basis.
- **PVs offer a mature, flexible and modular technology option**, and therefore opportunities to integrate these on roofs and ground-mounted structures will be maximised.
- Other building scale systems, such as small scale wind turbines or solar thermal, are likely to provide relatively small savings and are less flexible, but will be considered on a case-by-case basis at detailed design stage.

It is therefore proposed that the energy centre will include gas CHP engines as the initial low carbon heat source. The gas CHP engines will provide baseload heat and will be supplemented by gas boilers for back up and peak heating demands. Air source and/or ground source heat pumps may be used in future as a second source of heat for the network.

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[11] Licence Lite offers an option to reduce some of the financial and technical barriers to being a licensed supplier by allowing a new supplier to enter into a commercial arrangement with a third party licensed supplier (TPLS). The TPLS carries out compliance for certain part of the supply licence on behalf of the Licence Lite supplier.

[12] Combined Cycle Gas Turbine

Figure 5: Proposed district heating network

3.2.4 Energy supply – CHP illustration

Figure *6* below shows the outputs from the modelling carried out for a gas CHP system connected to a site-wide district heating network. The analysis has been carried out on a monthly basis using load profiles estimated in section 2.3.3.

The North Block residential building is not assumed to be connected and therefore excluded from the analysis due to its low demand level. The data centre is excluded as well as multi-storey car parks and the Schoefield building on the north-west corner of the site, due to its remote location and low energy demands.

Further analysis will be carried out at detailed design stage to inform the specifications for the energy centre and associated plant. An example of the type of plant which could potentially be used is three 2.6MW (heat) CHP engines, such as the Jenbacher Type 6. In addition, back-up / peak load boilers would be located at the energy centre, and also potentially some distributed in existing buildings where viable. It is expected that the CHP plant would operate in a modular way, with one engine operating throughout the year, a second in the shoulder months and winter, and the third in winter only. This is highly indicative, and alternative configurations may be more suitable pending further detailed analysis.

Table 10: Summary of CHP energy generation

Parameter	**Quantity**	**Units**
Annual heat demand for building connected to DH network (excluding distribution losses)	42	GWh/yr
Peak demand – heat	32	MW
CHP working hours (assumed)	17	hrs/day
CHP working hours (assumed)	5:00 to 22:00	
Annual CHP gas demand	77	GWh/yr
Peak boiler gas demand	15	GWh/yr
CHP estimated heat generation	31	GWh/yr
CHP heat generation as % of overall demand	Approx 70%	
Estimated top up boilers heat generation	13	GWh/yr
Distributed boiler plant used on network (existing)	Up to 8-9	MW
Energy centre boilers capacity	Up to 32	MW
Estimated thermal store volume	Approx 600	m^3
CHP estimated electricity generation	29	GWh/yr

A large thermal store will also be required to act as a buffer for the CHP system, and for future flexibility to allow for heat pumps to be included as a second heat generation technology in the energy centre. At this stage, an indicative 600m^3 is proposed based on being able to store around 10% of the typical daily winter heat load.

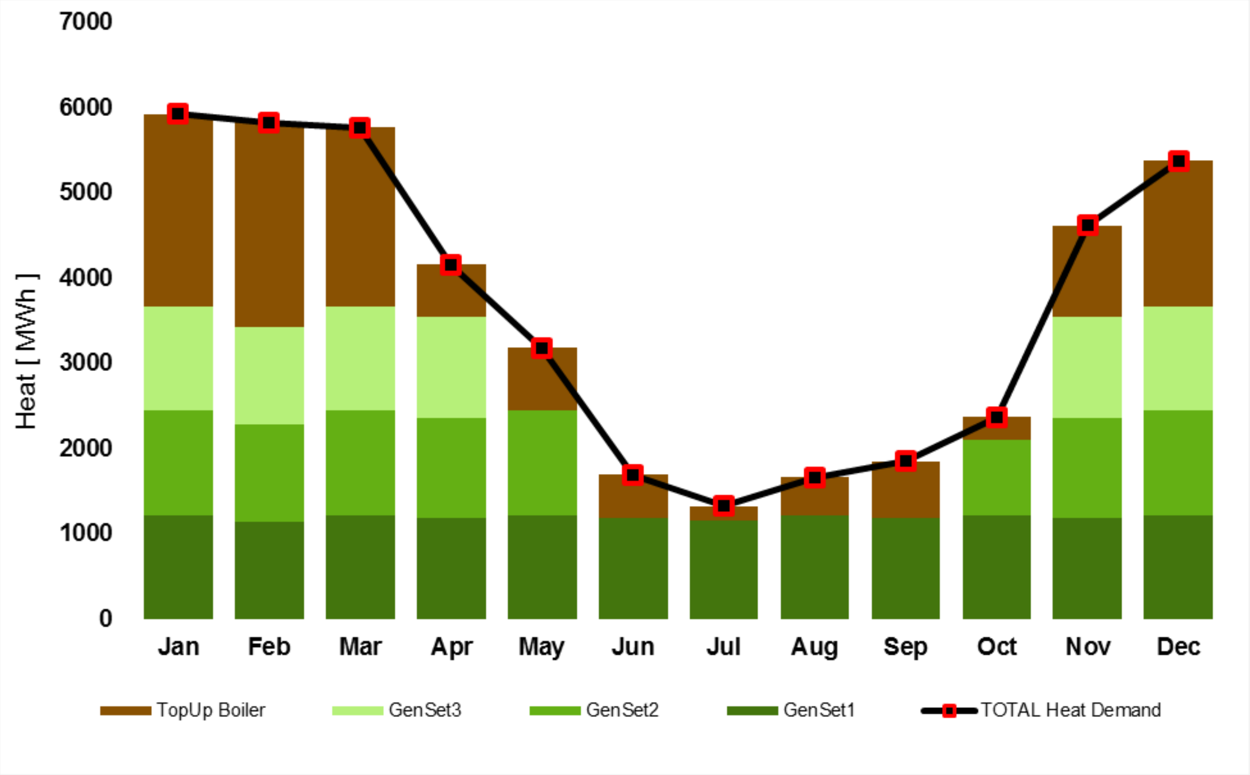

Figure 6*: Results from monthly modelling of the heat supply plant.*

3.2.5 Energy supply – heat pumps illustration

It is proposed that air source and/or ground source heat pumps are used as a second source of heat for the network. There may be some potential for including a small capacity of heat pumps in the near term, but it is more likely that they will be installed in the medium term (mid to late 2020s) as the electricity grid decarbonises. These could either be located in the central energy centre or within individual buildings but connected to the heat network.

Specifically, consideration will be given to:

- Using the lake on the south as a heat source for water source heat pumps to provide low grade heat for the sports centre and/ or feed excess heat into the network.
- Air source heat pumps recovering heat from exhaust ventilation air from laboratory buildings.
- Heat pumps recovering waste heat from the existing data centre, using the next refurbishment cycle as the trigger point to install cooling technologies that make it easier and more economical to capture waste heat.

The proposed energy centre area of about 2000m^2 together with the proposed allowance for a 3-storey building allows for space provision to install heat pumps in the future.

The introduction of large amounts of thermal storage will allow greater use of heat pumps in times of low carbon supply (possibly winter nights), and store this for the following day. This may require additional storage to the 600m^3 proposed for the initial CHP based scheme, the precise requirements for which will be assessed in due course.

3.2.6 Energy supply – PV panels illustration

The potential for PV panels to be installed on the roofs of buildings, and on ground mounted structures (e.g. car park/cycle park shading) is to be maximised though the will need to be balanced against other competing uses such as green roofs and/or HVAC plant. Approximately 50% of the roof area on site is proposed to be covered with PV arrays[13]. In instances where space is needed for plant and access, 50% of the available roof area will be targeted for PVs. Benchmark PV performance has been set at 850 kWh/kWp, with a module efficiency of at least 15%. Existing commercial buildings, that is, Schlumberger, BAS, and Aveva buildings are excluded from these targets.

At detailed design stage the incorporation of PV into other structures, such as car park roofs and canopies, will also be targeted. Table 11 below provides a summary of the PV potential for West Cambridge.

Table 11: Estimated PV generation at West Cambridge

	PV generation (MWh/yr)			**% (MWh)**	**tCO2e/yr from electricity**			**% saving (CO_2e)**
	Existing buildings	**New buildings**	**Total**		**Existing buildings**	**New buildings**	**Total**	
Total predicted electricity demand for the site	33000	55000	88,000		17,130	28,550	45,680	
Estimated PV generation from existing PV on-roof arrays[14]	85	0	85	0.10%	-45	0	-45	0.10%
Estimated additional PV generation potential[15]	920	5130	6,050	6.87%	-480	-2660	-3,140	6.87%
PV generation on buildings excluding multi-storey car parks	920	4570	5,490	6.24%	-480	-2375	-2,850	6.24%
PV generation on multi-storey car parks	0	560	560	0.63%	0	-290	-290	0.63%
Estimated maximum electricity demand which could be served by PV (new and existing)	**1005**	**5130**	**6,135**	**6.97%**	**-525**	**-2660**	**-3,185**	**6.97%**

Note: All figures, including cumulative aggregated figures, have been rounded

3.2.7 Site summary illustration after energy efficiency measures and LZC technologies

The following tables outline the estimated energy demand, on-site energy generation, and associated CO_2e emissions following implementation of the energy strategy outlined above. Given the uncertainty around the pace of decarbonisation of the electricity grid, the likely CO_2e reduction benefits that could potentially accrue from heat pumps operating in conjunction with gas CHP in the medium to long term have not been assessed at this stage.

Table 12: Estimated energy demand and on-site generation

Electricity	**MWh/yr**	**%**

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[13] The figure allows for space between panels. The net area of PV panels is targeted to be 25% of the building footprint.

[14] Estimated as 67,000 kWh and 20,000 kWh from the Sports Centre and Materials Science PV array respectively, based on average generation efficiency of 850 kWh per kWp

[15] The figures are calculated based on 50% of the roof area being covered by PVs. The figure will however vary depending on the available roof space, after taking into account space needed for plant and access.

Total predicted site -wide electricity demand (excludes CHP electricity demand)	88,000	100%
Estimated electricity generated by gas CHP	29,000	33%
Estimated total electricity generation from PVs and CHP	35,135	40%
Heat	**MWh/yr**	**%**
Total predicted site -wide heat demand	43,000	100%
Estimated total heat generated by gas CHP	31,000	72%

Table 13: Energy and CO_2e reduction after application of gas fired CHP and PVs

	With energy efficiency	Remaining demand after energy efficiency and gas-CHP	Remaining demand after energy efficiency, gas-CHP and PV	% change
Annual gas consumption apportioned to existing buildings(MWh/yr)	13,120	19,870	19,870	51%
Annual gas consumption apportioned to new accommodation (MWh/yr)	37,580	57,530	57,530	53%
Total site-wide annual gas consumption (MWh/yr)	**50,700**	**77,400**	**77,400**	**53%**
Annual net electricity demand apportioned to existing buildings* (MWh/yr)	33,430	27,140	26,140	-22%
Annual net electricity demand apportioned to new accommodation (MWh/yr)	54,800	32,090	26,960	-51%
Total site-wide annual electricity demand (MWh/yr)*	**88,230**	**59,230**	**53,100**	**-40%**
Associated primary energy consumption from existing buildings (MWh/yr)	118,640	107,570	104,480	-12%
Associated primary energy consumption from new accommodation (MWh/yr)	214,070	168,690	152,940	-29%
Total primary energy (MWh/yr)	**332,710**	**276,260**	**257,420**	**-23%**
Associated annual CO_2e emissions from existing buildings (tonnes)	20,190	18,380	17,860	-12%
Associated annual CO_2e emissions from new accommodation (tonnes)	36,560	29,080	26,420	-28%
Total site- wide annual CO_2e emissions (tonnes)	**56,750**	**47,460**	**44,280**	**-22%**

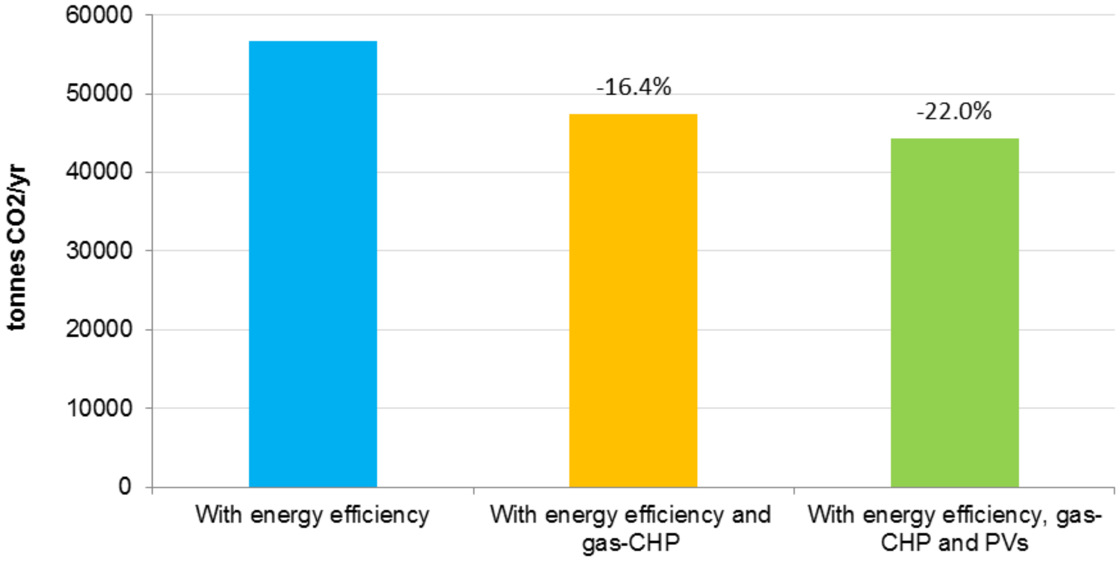
* After accounting for on-site generated electricity

The application of site-wide district heating and combined heat and power is expected to result in annual carbon savings of around 9,300 tonnes (rounded figure) or about 16% over the energy efficient base case. Overall gas CHP and PVs are expected to deliver a 22% reduction in site-wide CO_2e emissions, and a 23% reduction in primary energy consumption

For new accommodation on site, the strategy is estimated to deliver a 28% reduction in CO_2 emissions and 29% reduction in primary energy consumption relative to energy efficient baseline.

As discussed previously, this estimate is based on current CO_2 emissions factors used to demonstrate compliance against Part L of the Building Regulations. In comparison, 15-year projected average CO_2 emission factors, typically used for long term policy development, are relatively lower for electricity and somewhat higher for gas[16]. This means that inevitably there would be difference in expected near term savings (which are likely to be high) and longer term savings which will largely depend on rate of decarbonisation of the electricity grid.

Figure 7: Estimated annual CO_2e emission for the fully built-out site at each stage of the energy hierarchy



The site-wide percentage reduction figures in Table 3 indicate that on average a typical new building on site would achieve an EPR in the region of 0.5 thereby exceeding the minimum energy requirements for compliance with BREEAM ‘Excellent’ rating[17]. The figures for primary energy and CO_2 emission savings will however tend to vary across buildings (depending on the building use and form) and the precise levels of energy efficiency and/or renewables energy provision will be fine-tuned at detailed design stage to ensure compliance.

3.2.8 Connection to neighbouring sites

The viability of linking up the district heating network to North West Cambridge was reviewed when developing the masterplan for North West Cambridge. The review concluded that the scale of each site is large enough to justify separate energy centres with little benefit to be gained from combining energy centres with a gas CHP based system. In particular, any benefits were outweighed by the cost of installing the heat main linking the two sites.

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[16] For instance SAP 2012 gives a 15-year projected CO_2 factor of 0.381kgCO_2/kWh for electricity and 0.22 for gas. Source: http://www.bre.co.uk/filelibrary/SAP/2012/Emission-and-primary-factors-2013-2027.pdf

[17] Compliance with the minimum energy requirements for BREEAM ‘Excellent’ rating would require individual buildings to demonstrate an Energy Performance Ratio (EPR) of greater than 0.375. The EPR takes into account the modelled performance of the building (relative to a notional building complaint with Part L of the Building Regulations) based on three parameters – energy demand for heating and cooling, primary energy consumption and CO_2 emissions.

3.3 Development phasing

The site energy infrastructure will be developed in stages in response to the phasing of development within the masterplan. An indicative phasing plan is as follows:

- The energy centre building will be built as part of Phase 1 of the site, allowing for future expansion and modification.
- The generation plant within the energy centre will be modular (i.e. gas-CHP, thermal stores and peak load boilers), allowing the equipment to be installed in phases as the masterplan is gradually built out. However, it is expected there will be some redundancy in initial years (i.e. plant may be oversized for the needs of the site in the initial years).
- Space allowance will be made for heat pumps to be installed at a later date in the energy centre and/or close to sources of secondary heat.
- The DH network will be developed in stages largely aligning with the three development phases. Further refinement of the DH phasing strategy will happen as the design progresses.
- New development that cannot be connected to the energy centre in the initial years (for instance, where located at the edge of the site with infill development is only planned to be delivered in future phases) will be required via a lease or development agreement to provide space for a heat exchanger and design the space heating as a low temperature system to allow the building to be connected to the heat network in due course. Temporary boiler plant may be required in the intermediate period.

PV installation phasing will follow the development of individual buildings.

3.4 Potential impacts

There are a number of impacts which need to be considered as a result of the energy strategy, and in particular the energy centre.

As part of the EIA[18] and Sustainability Framework implementation, air and noise pollution, and visual impacts have been considered. The energy centre and proposed plant has been included in this assessment.

The aggregation of heat sources into one combined energy centre means that flue gas emissions which would otherwise have been dispersed across the site from a number of individual boilers are concentrated in one place. In addition, NOx emissions from CHP units can be high. For these reasons, a specialist air quality assessment has been conducted to assess the impact on local air quality. This concludes that there are no predicted exceedances of air quality strategy objectives as a result of emissions from the energy centre, and a stack height of 8m above building parameter plan height is sufficient to disperse emissions to acceptable limits. Refer to Chapter 11 of the EIA for more details.

Energy centre noise can arise from both air intakes for boilers and CHP, and from the flues. Noise and vibration assessments carried out as part of the EIA concludes that any adverse impact could be mitigated through location and orientation of plant, acoustic screening, and specification of the plant itself. The need for noise attenuation measures and the most appropriate locations for intakes to limit impact on receptors will be assessed further at the detailed design stage.

Another potential issue may be vibration from the CHP engines. This is of particular importance if vibration sensitive users are to be located nearby. As the energy centre is a separate building, and as the CHP will be fitted with isolation equipment as standard at source, the issue of vibration is not expected to be a problem.

An important aspect to consider is the potential visual impact of the energy centre. This can be minimised through two primary measures:

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[18] Environmental Impact Assessment

- The stacks from the energy centre may be in a setting where a number of other buildings (e.g. labs) have stacks and other similar structures on the roofs. They could therefore “blend in” with careful design. There may be potential to lower the stacks if required although implications on reduced efficiency and higher cost of flue gas cleaning would need to be considered;
- The energy centre building/compound itself can be easily screened through careful design, or the building could be designed to be prominent as a signature building to “celebrate” the energy strategy.

In general, it is thought that an energy centre could be “in keeping” with the scientific and engineering elements of the site and designed appropriately to enhance the site’s environment.

3.5 A ‘smart’ system for the future

The proposed energy strategy maximises opportunities for renewable and/or low carbon energy generation on site in line with current local planning policies. It also provides flexibility to respond to anticipated future changes to Building Regulations Part L and wider policy environment.

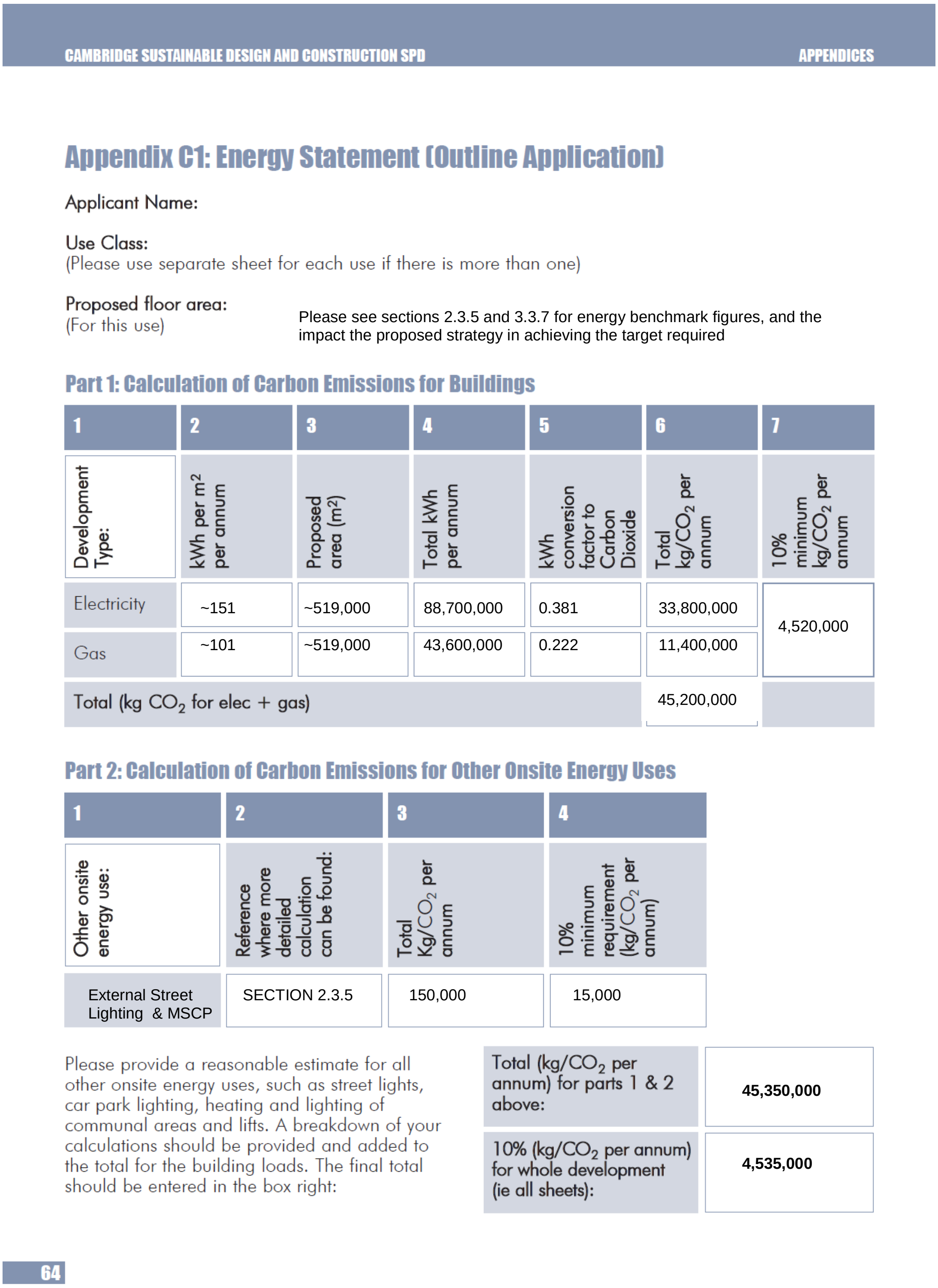
Of fundamental importance to the future flexibility and viability of the strategy is the use of a low temperature heat network, which will be suitable for current and future heat sources. An innovative approach being considered for the site in the medium to long term is ‘grid balancing’. As the electricity grid decarbonises through increased renewable generation, the heat network (along with the gas-CHP, heat pumps, and on-site thermal store) could be optimised to acts as part of a smart system alternating between the two on-site generation sources under certain grid conditions to help balance loads on the electricity grid and to maximise CO_2 savings. However the timing of such decarbonisation remains uncertain so the need to retain flexibility is important.

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 relevant CO_2 targets.

It is likely that during the lifetime of the development, new technologies and fuels will become available which offer advantages over the current options. The proposed district heating network will also offer flexibility to switch to advanced technologies in the future compared to individual building-level systems. In addition, the viability of new building integrated technologies and or higher energy efficiency standards will be re-appraised at detailed design stage and key stages during the development phase.

APPENDICES

Appendix 1: Cambridge Sustainable Design and Construction SPD Appendix C1: Energy Statement (Outline Application)



Appendix C1: Energy Statement (Outline Application)

Applicant Name:

Use Class:
(Please use separate sheet for each use if there is more than one)

Proposed floor area:
(For this use)

Please see sections 2.3.5 and 3.3.7 for energy benchmark figures, and the impact the proposed strategy in achieving the target required

Part 1: Calculation of Carbon Emissions for Buildings

1	2	3	4	5	6	7
Development Type:	kWh per m^2 per annum	Proposed area (m^2)	Total kWh per annum	kWh conversion factor to Carbon Dioxide	Total kg/CO$_2$ per annum	10% minimum kg/CO$_2$ per annum
Electricity	~151	~519,000	88,700,000	0.381	33,800,000	4,520,000
Gas	~101	~519,000	43,600,000	0.222	11,400,000	
Total (kg CO$_2$ for elec + gas)					45,200,000	

Part 2: Calculation of Carbon Emissions for Other Onsite Energy Uses

1	2	3	4
Other onsite energy use:	Reference where more detailed calculation can be found:	Total Kg/CO$_2$ per annum	10% minimum requirement (kg/CO$_2$ per annum)
External Street Lighting & MSCP	SECTION 2.3.5	150,000	15,000

Please provide a reasonable estimate for all other onsite energy uses, such as street lights, car park lighting, heating and lighting of communal areas and lifts. A breakdown of your calculations should be provided and added to the total for the building loads. The final total should be entered in the box right:

Total (kg/CO$_2$ per annum) for parts 1 & 2 above:	**45,350,000**
10% (kg/CO$_2$ per annum) for whole development (ie all sheets):	**4,535,000**

Appendix 2: Low and zero carbon technology options appraisal in detail

This applicability of ‘heat only’ and ‘combined heat and power’ (CHP) technologies that can be connected to a site-wide district heating (DH) network is discussed in Appendix 2a below. The findings from the options appraisal for stand-alone and building-level technologies are set out in Appendix 2b.

Appendix 2a: Site-level technologies connected to a district heating (DH) system

District heating schemes comprise a network of insulated flow and return pipes transporting hot water (and in some instances, steam), usually buried beneath roads, which are connected to an energy centre containing the heat supply plant. 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).

CHP systems provide a higher overall efficiency than that achieved by grid electricity and individual building heating systems. CHP generates electricity but also makes use of the wasted heat that would usually be emitted to atmosphere with a conventional power plant supplying electricity to the grid. Since the electricity is generated closer to where it is needed, losses in transmission and distribution are also reduced.

CHP systems are usually sized to provide the base heat load during the summer months. 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 CHP maintenance. By smoothing the fluctuations in heat demand using thermal storage, the fraction of heating provided by a CHP system can be increased, resulting in greater overall CO_2e savings.

Gas CHP connected to DH network

Description:

This is a relatively mature technology with a wide range of gas-engine CHP systems available. The engines are often installed in a modular configuration to enable the system to respond to seasonal heat demand variations and maximise operational efficiencies. Spark ignition gas-engines are the most common technology for small and medium scale CHP schemes. 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 it can approach 40% for larger engines of 5 MW. The overall efficiency of gas-engine CHP systems is greater than 80% where all the extracted heat is effectively used.

Potential advantages:

- mature technology with reliable, working applications throughout the world including in the UK
- scale of the technology allows for a phased modular build-out, which means that the installation can be optimised to incrementally meet the needs of the different development phases
- although a fossil fuel based technology, it is expected to continue to save CO_2 emissions for at least the life of the first installed engines based on recent data published by DECC on the marginal emissions factors for electricity displaced by gas CHP.[19]

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[19] Emissions factor for displaced electricity is forecasted to be approximately 350-400 g/kWh from 2012 through to 2025, reducing to 250-300 g/kWh from the late 2020s onwards as the penetration of low-carbon technologies increases. Source: LCP, Modelling the impacts of additional Gas CHP capacity in the GB electricity market, Dec 2014.

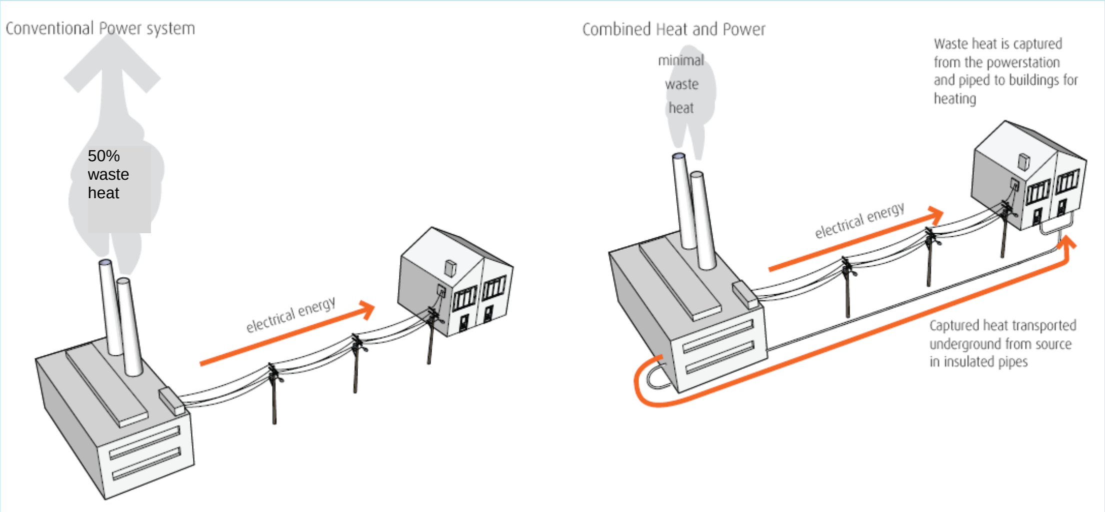

Figure 8. The operation of Combined Heat and Power (CHP)

Potential risks and disadvantages:

- relies on a finite fossil fuel resource (gas) and therefore cannot be the long term energy solution for the proposed development

Conclusions:

Gas CHP is a mature technology that can deliver significant CO_2e reductions in the short to medium term when connected to a DH network. In the medium term, other complimentary technologies need to be considered for connection to the DH network, with gas CHP continuing to be one of the components of smart energy infrastructure on site.

Potential energy and CO_2e savings:

It is estimated that gas-CHP could supply around 70% of the proposed development's annual heat demand. Where the majority of the buildings on site are connected to the district heating network, then the installed gas-CHP capacity would be in the region of 7- 8 MWe.

Projected site-wide CO_2e savings calculated using Building Regulations Part L 2013 emission factors for electricity are estimated to be around 9,200 tonnes per annum. This equates to a 16% saving relative to baseline CO_2e emissions after energy efficiency.

Biomass boilers connected to DH network

Description:

These systems typically consist of single (or multiple boilers) located in an energy centre with an automatic feed mechanism transferring the feedstock to the burner. Biomass boilers are best suited to meeting a steady baseload, and thermal storage can be used to increase the fraction of heat met. Additional backup gas boilers are normally installed to provide peak heating loads and back-up capacity.

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.

Resource/ fuel availability:

Feedstock for biomass boilers can vary, with lower cost feedstock such as wood chip or waste wood being the preferred option for larger schemes with district heating networks owing to increases in the price of virgin wood in recent years. The price that energy schemes will pay for biomass fuel in the future is dependent on demand, which is predicted to continue to grow in the medium to long term as existing policies are made stringent and new policies are introduced to deliver against national 2050 CO_2e reduction targets.

A report published by the Forestry Commission (2010) indicates that even sources of waste food are increasingly becoming exhausted. By 2017 potential demand for recovered (waste) wood is forecast to be almost 36% greater than potential availability, resulting in UK becoming a net importer of biomass fuel.[20] 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 considerably. In addition there are questions about the long term sustainability of imported biomass owing to concerns around deforestation, loss of habitat and/or diverting resources away from food production.

Straw from farms is another biomass based fuel, though less ideal for space-constrained urban areas. Straw is currently often re-ploughed into the land because of its high nutrient content, and collection poses additional cost and time-burden to the farmer. Anglian Straw Limited, a dedicated company set up to source straw for the 38MW straw power station based near Ely currently collects most of the locally available straw resource leaving very little available for other schemes. 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 more land being taken up for development. Because of limited availability and other competing uses for straw, it is not considered to be a viable option for the West Cambridge site.

Another potential source 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 that handles the county’s black bin waste. After abstraction of recyclables the plant produces large amounts of a compost-like fraction with a calorific value of around 8 MJ/kg (source: Donarbon). Discussions were undertaken with the operators of Donarbon, the Dickerson Group, to assess the viability of supplying RDF to the North-West Cambridge site for use in a RDF fuelled CHP application. Initial calculations suggested the plant could produce fuel with a yearly heating value of around 220 GWh or 220,000 MWh, of which the estimated heating demand for the North West Cambridge site is approximately 40,000 MWh. This leaves sufficient spare capacity to cater to the heating demand at West Cambridge. A key issue, however, is the low calorific value of the fuel, which would result in a relatively higher number of deliveries to site and higher space requirements for on-site storage compared to some other biomass fuels.

Potential advantages:

- established and mature technology, with widespread use both in the UK and Europe
- can provide large CO_2e reductions through the provision of low carbon heat for space heating and hot water
- renewable technology that can potentially form part of a long-term energy strategy for the site, subject to sustainable fuel source being available locally
- larger-scale centralised biomass boilers can be fitted with flue cleaning equipment to minimise air pollution
- technology currently attracts payments under the Renewable Heat Incentive (RHI) per kWh of energy generated; tariffs levels and availability are not guaranteed in the medium to long term

Potential risks and disadvantages:

- fuel supply is a considerable risk with uncertainties as to the future availability and cost, in particular, sustainably sourced fuel
- space needed for fuel storage and access for delivery vehicles is a potential downside; this would be a

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[20] Wood Fibre Availability and Demand in Britain 2007 to 2025. John Clegg Consulting Ltd. 2010.

particular concern with multiple energy centres on site or with fuels having low calorific value

- air quality concerns with smaller scale boilers (in multiple energy centres or for individual buildings) that do not have flue cleaning equipment installed
- biomass heating not an efficient use of finite biomass resource, and provides lower CO_2e savings compared to using the fuel in an alternative technology such as biomass CHP

Conclusions:

Biomass boilers can provide considerable CO_2e savings, but there are significant concerns around the future availability and cost of biomass fuel, local air quality, and the impact of transport movements on sensitive research uses on this site. The technology is therefore not considered suitable for this site.

Potential energy and CO_2e savings:

Not applicable

Biomass CHP connected to DH network

Description:

The term “biomass CHP” covers an array of technologies and processes which may be used to convert 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).

Biomass CHP technologies primarily fall into two types:

- **Gasification systems:** The biomass fuel is gasified and then burnt in a gas CHP system. The gasifier partially oxidises the biomass (or other carbon rich fuel) at between 700°C and 1000°C to produce a hydrogen rich syngas, 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.
- **Steam turbine systems:** The fuel is combusted to generate steam and drive a turbine. 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 that 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. 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.

Resource/ fuel availability:

Please refer section on ‘biomass boilers’ above.

Potential advantages:

- relatively efficient means of using biomass fuel to save CO_2e, with greater savings being achieved than in a heat only application
- where all of the waste heat can be effectively used, biomass CHP provides the greatest CO_2e saving of all

site-wide options

- technology currently attracts payments under the Renewable Heat Incentive (RHI) per kWh of energy generated; tariffs levels and availability are not guaranteed in the medium to long term

Potential risks and disadvantages:

- biomass CHP technologies at the small scale required for the proposed development are immature and highly risky at present; there are few commercial installations operating at this scale and many are experiencing operational difficulties; many systems are still considered prototype and in development
- technology not as modular as gas-CHP, and will result in significant heat dumping in the initial years as the development is built out
- fuel supply is a considerable risk with uncertainties as to the future availability and cost, in particular, sustainably sourced fuel
- space needed for fuel storage and access for delivery vehicles is a potential downside; this would be a particular concern with multiple energy centres on site
- air quality concerns with smaller scale systems that do not have flue cleaning equipment installed

Conclusions:

Given the risk around technology maturity as well as future availability and cost of fuel, the technology is not considered suitable for the site.

Potential energy and CO_2e savings:

Not applicable

Heat pumps connected to DH network

Description:

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 system operating at higher temperature. The ratio of heat produced to input electricity required is known as the Coefficient of Performance (CoP), which provides an indication of the system efficiency. The "coefficient of performance" is governed by the "heat in" and "heat out" temperatures, with higher efficiencies achieved when there is a lower temperature gradient across them. For this reason it is important to optimise the building space heating system to operate on as low a temperature as possible, through the use of under floor heating or large radiators.

The relatively high CO_2e 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_2e and cost with other fuels such as gas and oil. At present, the average CO_2e intensity of grid electricity is about 2.5 times higher than that of boilers using natural gas (after accounting for boiler efficiency). This means that a CoP of at least 2.5 is required for the heat pump to give a positive CO_2e benefit. However, as the grid reduces in CO_2e intensity with increased renewable and low carbon generation, heat pumps are expected to gradually become more favourable on a CO_2e basis.

Heat pumps can be used to provide both heating in winter and cooling in the summer months, and can also efficiently cater to simultaneous heating and cooling demand in different areas/ building uses.

There are three main types of heat pump systems of interest to West Cambridge; ground source heat pumps, air source heat pumps and water source heat pumps.

Ground source heat pumps (GSHPs) make use of the relatively constant ground temperature throughout the year, typically around 10°C in the UK. The thermal energy can be extracted from the ground using three basic methods:

- horizontal pipe loops laid under the surface, requiring around 250 m^2 of ground collector area per 5kW loop; most suited to low density sites and smaller heat loads applications
- vertical boreholes requiring significantly less ground area and therefore more suited to urban locations; boreholes can either be closed or open loop
  - a closed pipe loop orientated vertically in a borehole typically 70 - 100m deep that can sometimes be combined with foundation piles in new buildings;
  - an open loop system pumping groundwater to the surface to extract thermal energy before pumping it into a separate rejection well

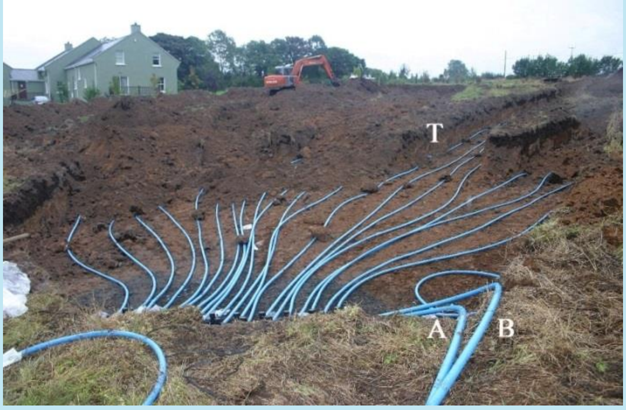

Figure 9: Image showing installation of surface collector loops for a ground source heat pump system prior to being covered and landscaped.

The CoPs of GSHP systems are typically 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. 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 make use of the external air to extract heat. ASHPs are significantly lower costs due to the absence of ground works, and can be installed on most buildings with minimal space requirements. 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. The performance of the system can be improved when combined with a relatively higher temperature heat source, such as ventilation exhaust air.

Water source heat pumps (WSHPs) extract heat from a body of water such as a lake or river. The COPs can be increased relative to ASHPs due to the good heat transfer coefficients of the water.

Potential advantages:

- relatively mature technology
- centralised systems offer economies of scale to capture heat from large ground collection systems or other sources
- can provide both heating in winter and cooling in the summer months where a separate DH cooling network is installed; this will also improve efficiencies for GSHPs
- where the CO_2e intensity of the grid is sufficiently low, can provide large CO_2e reductions compared with fossil based systems
- technology currently attracts payments under the Renewable Heat Incentive (RHI) per kWh of energy generated for systems with a CoP greater than 2.9; tariffs levels and availability are not guaranteed in the medium to long term

Potential risks and disadvantages:

- when connected to the central DH network, the network will need to be designed to operate at lower temperatures to maximise efficiency

- low temperature systems would require additional top-up heating for hot water
- existing buildings will require retrofitting to operate on a low temperature system or alternatively will have to local boiler plant for top-up
- ASHPs offer little or no CO_2e savings compared to gas-fired boilers with current gird carbon intensity; field trials (in domestic installations) have indicated CoPs are generally lower than planned or claimed by manufacturers[21], often resulting is even higher CO_2e emissions and energy costs than gas boilers
- borehole based GSHPs offer relatively higher CoP than ASHPs, but have higher upfront costs; geotechnical studies and drilling costs mean that larger systems are generally more economic
- horizontal loop GSHPs have limited application given the density of heat loads at West Cambridge

Conclusions:

In the medium term (post 2025), heat pumps could operate as a low carbon source in times of excess low carbon electricity in the grid, although the technology is unlikely to save CO_2e during periods of peak demand when the grid is supplied with electricity from gas[22] and coal power plants. Therefore the site energy systems need to be designed to ensure that heat pumps can be easily retrofitted in the future.

Centralised systems connected to a heat network would allow economies of scale and the potential to capture secondary heat from borehole extraction, ground stores, or large ground collection systems.

Potential energy and CO_2e savings:

Heat pumps offer limited CO_2e savings based on current grid carbon intensity. As the grid decarbonises and in particular during periods of excess renewable electricity generation, heat pumps can offer substantial savings when managed as part of a smart energy supply network.

Anaerobic digestion (AD)

Description:

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” using sewage waste. Other 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 it 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 consisting of a wet liquor and a drier compost type product, both of which will need disposing of.

AD schemes are typically only commercially viable at around 1MW electric upwards, and this would require circa 30 – 50ktonnes of suitable organic waste per annum. A 1MWe system would typically produce less than 1MW usable heat, with a large fraction of heat generated being used in the process.

Resource/ fuel availability:

The University owns a limited amount of potential feedstock for an AD plant, a large fraction of which is farm slurry that has a low calorific value. Some organic waste will be generated on site, but this will be limited given

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

[22] Combined cycle gas turbine

the building uses. Most feedstock will have to be externally sourced.

Potential advantages:

- relatively clean technology with little impact on air pollution
- whilst there are only a few AD installations in the UK, it is relatively mature and simple technology that has a high uptake in other European countries

Potential risks and disadvantages:

- has a large footprint associated with fuel storage and processes, which may impact development capacity on site
- requires a significant volume of waste as feedstock, with associated concerns around vehicle movements to and from site
- generates significant volumes of digestate (both solids and liquids), which would necessitate identifying a suitable disposal route locally, potentially as a fertiliser
- potential for odours from waste handling

Conclusions:

Large scale AD is not currently considered as a viable solution for the site due to the limited feedstock available locally, the large footprint needed for plant and fuel store, and concerns over transport movements.

Potential energy and CO_2e savings:

Not applicable

Appendix 2b: Stand-alone and building-level technologies

The section appraises the applicability of both stand-alone and building-level low and zero carbon technologies for West Cambridge.

Large scale wind turbines

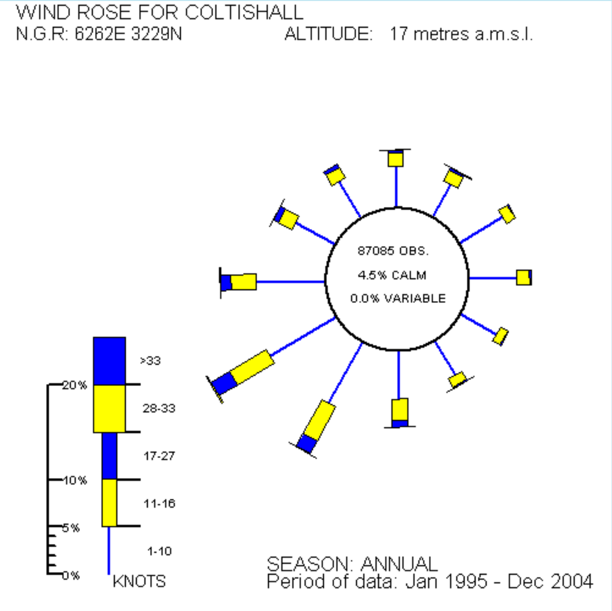
Description:

At the national level, wind power is seen as one of the most economically attractive and mature renewable technologies. Siting of the turbines is critical to optimise performance and hence these are best located in high wind areas with no nearby obstructions that may impede the wind flow and cause turbulence. Minimum average annual wind speeds of around 6 m/s are required for economic operation. Alongside wind speed, consideration also needs to be given to wind direction.

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 significant 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 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.

Wind turbines are available in various sizes. A typical modern 2MW turbine will have a blade diameter of around 80m and hub height of around 60 – 80m. Recent advances are seeing ever larger (5MW plus) turbines being available.

Resource/ fuel availability:



The average annual local wind speed is estimated at around 6m/s at a height of 45m, based on data from the NOABL wind speed database[23]. This is at the lower limit for typical commercial scale wind farms. This estimate is based on data for a 1km square, and the wind speed at the 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.

The wind rose for Coltishall in East Anglia indicates a pre-dominantly south westerly wind direction.

Figure 10. Wind rose from Coltishall in East Anglia (Source: Met Office)

Potential advantages:

- most established and proven renewable technology globally with a number of technology suppliers and specialist developers
- potential to develop large scale wind as an Allowable Solution at an alternative site/ university owned land

Potential risks and disadvantages:

- requirement for large buffer zones around buildings, which may impact development capacity on site
- visual impact may be a concern, although this is a subjective matter
- history of strong local opposition to large scale wind schemes in South Cambridgeshire and Cambridge City

Conclusions:

Large scale wind turbines are not considered suitable due to the requirements for buffer zones and potential visual impact.

Large scale wind turbines can potentially be used as an Allowable Solution, subject to further clarity on eligibility criteria and availability of a suitable site.

Potential energy and CO_2e savings:

Not applicable

Small scale wind turbines

Description:

Small scale wind turbines are designed for operation 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 either tower mounted or building 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.

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

Resource/ fuel availability:

Refer section on ‘large scale wind’ above

Potential advantages:

- can serve as a visible demonstration of renewable energy and encourage other installations in the areas

Potential risks and disadvantages:

- highly susceptible to local wind conditions due to their low height, especially in built up areas where neighbouring buildings can cause turbulence, resulting in a poor output (i.e. load factor of 7-8% compared to 25-30% for large scale turbines); therefore only locations which are open with a strong wind resource are suitable; building mounted turbines are particularly susceptible to turbulence, and require even more careful design
- requirement for buffer zones around buildings for reasons of noise and flicker are a constraint (albeit the requirements are smaller than those required for large scale wind turbines
- vibration issues with building mounted turbines may be a concern for some of the sensitive site uses
- potential visual impact associated with delivering significant CO_2e reductions on site; assuming an optimistic 10% load factor, a single 15kW turbine would produce 13 MWh/yr providing a saving of around 6.5 tCO_2e/yr, and reduce the overall site CO_2e emissions by a mere 0.01%
- not as cost-effective as large scale wind turbines

Conclusions:

There could be opportunities for incorporating small scale wind turbines on some parts of the site, though benefits in terms of energy generation and CO_2e reduction are likely to be small even with a large number of turbines. In addition, the performance is likely to be poor due to the urban nature of the site. The technology is therefore not considered suitable for the site.

The suitability should be reviewed when designing future phases of development, should technological innovations result in products being available that are more suited to the urban environment.

Potential energy and CO_2e savings:

Not applicable

Photovoltaic panels

Description:

Solar photovoltaic (PV) arrays generate electricity from the incoming sunlight. The PV arrays are typically located on roofs and consist of a number of separate panels linked together. Around 8 -10 m^2 of roof space is required per kW of power. 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 or green roofs. As a rule of thumb, the active PV area can be around 50% of total roof area for a typical building, although for optimised buildings, this could be much higher.

PV systems operate best when located on a roof within 30 degrees of due south at around 30- 40 degrees inclination. The systems will work with a small drop in output for other orientations within circa 30- 40 degrees of south, and other inclination angles.

There are a number of commercially available products for use 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.

Resource/ fuel availability:

The UK Solar resource is relatively uniform across the country with marginally higher levels in the south. The resource map (Figure 11) shows that solar irradiation in Cambridge 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.

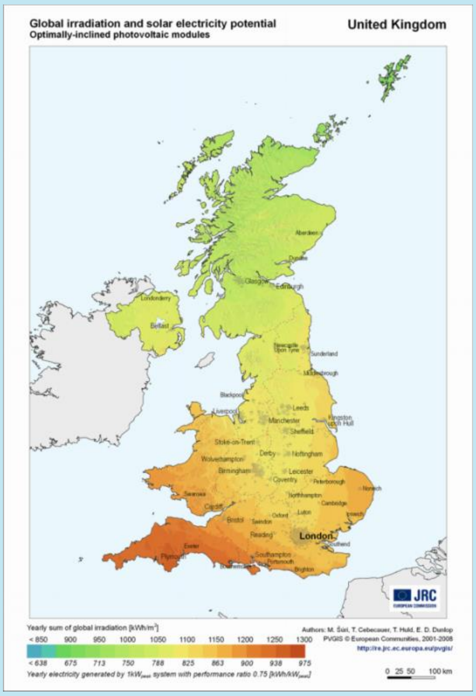

Figure 11. Solar Resource Cambridge (Source: Photovoltaic Geographical Information System (PVGIS)

Potential advantages:

- very mature and reliable technology
- flexible technology that is compatible with most building types; output not dependent on building energy demands
- low ongoing costs with no fuel requirements and minimal maintenance, with pitched roof systems being generally self-cleaning
- modular technology that aligns well with development phasing
- minimal visual impact when roof mounted
- stand-alone PV systems for applications with low power demands (for example, bus shelters and parking meters) can sometimes be cost effective by removing the need for electricity cabling and connections

Potential risks and disadvantages:

- high upfront capital investment; technology currently attracts FITs (feed-in-tariffs) per kWh of electricity generated that reduce overall lifecycle costs, although these are not guaranteed going forward; capital costs have been dropping in recent years and this trend is expected to continue
- potential in urban areas limited by available roof areas, and suitably oriented building facades
- ideally requires optimum orientation, which would need to addressed in design guidelines for individual buildings

Conclusions:

PV technology has very few limitations and could be installed on the roofs of most buildings. The maturity of the technology means this is a relatively low risk solution. Competing uses, such as green roofs and plant space, will limit the amount of roof area available for PV panels.

Potential energy and CO_2e savings:

Roof / building mounted: The masterplan when fully complete will have a roof area of approximately 180,000m^2 excluding existing commercial buildings on site. If 50% of this roof area is available for PV panels, this would provide around 5,500 MWh per annum., which is around 6% of the total predicted electricity demand of the site when fully built out. The installed capacity is projected to save an around 2,850 tonnes per year calculated based on current carbon intensity of electricity in line Part L 2013. This equates to a 5% CO_2e saving when compared to the total site baseline after energy efficiency.

Standalone applications: The masterplan makes allowance for 17,500m^2 of multi-storey car parking area on site. PV panels with an output of 150 W/m^2 and generating 850kWh/kWp per year would have a total output of 550 MWh per year, assuming the panels cover 50% of the available area. This is around 0.6% of the predicted annual electricity demand and 0.5% of the total site baseline CO_2e emissions. Additional ground level car parking may also be able to accommodate PV on canopies.

Solar thermal systems

Description:

The system consists of solar collectors, usually located on the roof, and a storage tank to store the thermal energy. Systems are typically sized to provide a proportion of the hot water demand in buildings.

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 (such systems often have a collector on each east and west facing section of the roof).

Resource/ fuel availability:

Please refer to section on ‘Photovoltaic panels’ above

Potential advantages:

- mature and reliable technology
- low ongoing costs with no fuel requirements and minimal maintenance
- modular technology that aligns well with development phasing
- minimal visual impact when roof mounted
- technology currently attracts payments under the Renewable Heat Incentive (RHI) per kWh of energy generated for system sizes up to 200kW[24]; tariffs levels and availability are not guaranteed in the medium to long term

Potential risks and disadvantages:

- ideally requires optimum orientation, which would need to addressed in design guidelines for individual buildings
- make small contribution to CO_2e emissions reduction in buildings with low hot water demand, e.g. office, academic and research buildings
- potential also limited by available roof areas, and suitably oriented building facades
- not compatible with CHP and other district heating technologies as solar thermal panels meet summer thermal demand
- relatively expensive in terms of delivered energy and CO_2e reduction, although the renewable heat incentive improves the economics

Conclusions:

Solar thermal systems could be suitable for all buildings with a hot water demand. The maturity of the technology means this is a relatively low risk solution. However, the system is not recommended due to its incompatibility with district heating technologies.

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[24] Set at 10.28 p/kWh for installations accredited after 1st April 2016

The technology could be considered on a case-by-case basis for buildings with a sufficient hot water demand where they are not connected to a heat network.

Potential energy and CO_2e **savings:**

Not applicable

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Building level gas-fired CHP

Description:

Smaller scale CHP systems are designed for single building applications. 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_2e 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.

Fuel Cell CHP systems have a much higher electrical efficiency (typically around 35%) resulting in a much lower heat to power ratio and higher CO_2e savings, albeit at a much higher cost than gas engines.

Potential advantages:

- avoids upfront investment relating to DH network

Potential risks and disadvantages:

- single building applications do not provide diversity of baseload, resulting in much smaller systems relative to total heat demand
- higher costs for small CHP systems per kW than for larger systems
- lower electrical efficiency (or higher heat to power ratios) compared to larger CHP systems
- high on-going operation and maintenance costs compared to a single communal system

Conclusions:

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 limited CO_2e reductions. Greater efficiencies are likely to be available for larger scale systems linked to multiple buildings.

Potential energy and CO_2e savings:

Not applicable

Building level heat pumps

Description:

Please refer section on ‘heat pumps connected to DH network’ above.

Potential advantages:

- relatively mature technology
- can provide both heating in winter and cooling in the summer months; this will also improve efficiencies for GSHPs
- can cater to simultaneous heating and cooling demand in different areas/ building uses while offering efficiency gains
- where the CO_2e intensity of the grid is sufficiently low, can provide large CO_2e reductions compared with fossil based systems
- can be an efficient way of providing heat where there is potential to capture waste heat (e.g. from specific building uses such as data centres, or waste heat from chillers)

- technology currently attracts payments under the Renewable Heat Incentive (RHI) per kWh of energy generated for systems with a CoP greater than 2.9; tariffs levels and availability are not guaranteed in the medium to long term

Potential risks and disadvantages:

- heating systems would need to be designed to operate at lower temperatures to allow efficient operation of heat pumps
- ASHPs offer little or no CO_2e savings compared to gas-fired boilers with current gird carbon intensity; field trials (in domestic installations) have indicated CoPs are generally lower than planned or claimed by manufacturers, often resulting is even higher CO_2e emissions and energy costs than gas boilers
- GSHPs offer relatively higher CoPs than ASHPs, but have higher upfront costs
- horizontal loop GSHPs have limited application given the density of heat loads at West Cambridge
- borehole based GSHPs offer relatively higher CoPs than ASHPs, but have higher upfront costs; geotechnical studies and drilling costs mean that larger systems are generally more economic
- as heat pumps are most efficient when the difference in temperature between source and demand is minimal, domestic hot water will either reduce the overall CoP, or will require additional top-up heating

Conclusions:

Heat pumps offer limited CO_2e savings based on current grid carbon intensity. As the carbon grid decarbonises and in particular during periods of excess renewable electricity generation, heat pumps can offer substantial savings when managed as part of a smart energy supply network.

CO_2e savings are greatest for buildings that have sufficient space for a ground source array and have a balanced heating and cooling demand around the year. Building scale heat pumps could also make use of extracted air as a heat source, thereby improving their efficiency, in particular for lab buildings that would be designed with a high air change rate. Specific applications could make use of other heat sources, such as the lake at the southern end of the site, just west of the Sports Centre.

Potential energy and CO_2e savings:

The lake, approximately 3m deep with a surface area of around 4500m^2, would allow a WSHP system of around 500kW to be installed[25]. This can translate to an annual heat output of around 4000MWh if continually operated, or 1500MWh if only operated 8hrs a day. This translates into projected CO_2e savings ranging between 100 – 250 tonnes per annum[26] calculated using carbon intensity figure for grid electricityin line with Part L 2013.

The system could be designed to meet the baseload for the new sports centre and swimming pool on West Cambridge, which is predicted to use around 2100MWh annually for heat. The WSHP system is unlikely to able to meet the peak loads at the periods the centre is in heavy use, and so alternative heating systems would additionally be needed for top-up during peak periods.

Building level biomass boilers

Description:

Please refer section on ‘biomass boilers connected to DH network’ above.

Resource/ fuel availability:

Please refer section on ‘biomass boilers connected to DH network’ above.

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[25] Calculations based on rules of thumb in *CIBSE Technical Memorandum 51 (2013)* for sizing a system for a given lake size, this gives 9kW per m^2 surface area of the lake, providing the lake is 2.5 – 3m deep

[26] Assumes a heat pump with a coefficient of performance of 3, and that the savings occur through displacing heat otherwise generated through natural gas fired boilers.

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