Cambridge City Centre District Heating: Final report

For LCDI

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Executive Summary

Introduction

This report examines the technical and financial viability of district heating (DH) in the centre of Cambridge. The report contains a large amount of technical information and the results of analysis, providing a valuable insight into the viability of a scheme, and recommendations on further work. This non-technical summary aims to summarise this information allowing a wider audience to gain an understanding of this study, and the significant benefits that district heating could bring to Cambridge.

This work has been funded by the Low Carbon Development Initiative (LCDI) which has been created by Renewables East to help provide early stage analysis to de-risk low carbon schemes in the East of England. The project has been largely driven by the City Council and a number of other stakeholders have been consulted including the University of Cambridge and the Anglia Ruskin University (ARU).

What is district heating and how can it benefit Cambridge?

District heating is a system of insulated pipes which distribute hot water from a centralised boiler or heat generation plant, to a number of different buildings to provide space heating and hot water. Schemes can range in size from simply linking two buildings together, to spanning entire cities. In some continental countries the use of DH is widespread – in Denmark around 60% of the countries heat load (and coincidentally 60% of homes) are connected to heat networks, including a scheme across the whole of Copenhagen. This means they do not have individual boilers, but take heat generated from large central systems via the DH network.

There has been a recent surge of interest in District Heating (DH) in the UK promoted by a range of economic and environmental drivers, in particular the need to reduce CO_2 emissions and energy consumption. Many towns and cities have been conducting viability studies to identify where DH schemes can be developed.

The large energy and CO_2 savings from which Cambridge can benefit with a DH network do not arise from the network itself, but from the ability to take heat from a system known as Combined Heat and Power (CHP). CHP systems are similar to mini power stations in that they generate electricity, but by being connected to a heat network, most of the heat which is usually wasted in a power station can be collected and used for heating. This means the overall efficiency of CHP systems is much higher than the traditional arrangement of heat from gas boilers and electricity from large power stations, resulting in energy savings, and therefore cost savings and CO_2 reductions.

The DH network infrastructure can be expensive, and therefore it is important to assess the viability of a scheme to ensure that the operation savings from reduced energy can be used to pay back the capital investment of the DH network and CHP plant. In general, schemes are most viable in areas where there is a high heat demand, such as city centres, and the viability often improves for larger schemes where there are economies of scale and the CHP systems become more efficient.

This report examines a number of options for district heating networks in Cambridge powered by gas fired CHP systems. This work follows on from a study be E.On which identified gas fired CHP as the most appropriate technology for the first stage of DH development, allowing newer and even lower carbon technologies to be retrofitted in the future once they become technically and commercially viable.

Drivers and incentives

There are a large range of drivers and incentives for the development of CHP and DH, based around the need to reduce CO_2 emissions to mitigate climate change, and reduce energy consumption and expenditure. The UK has a legally binding target of reducing CO_2 emissions by 80% from 1990 levels by 2050 drives many other policies, all based around reducing CO_2 emissions. A simple way of summarising the effect of the various policies by stating that emitting CO_2 will become more expensive, either through energy prices, CO_2 taxes, or regulation, and therefore towns and cities should be investing in scheme which can economically reduce CO_2 emissions. For most large organisations the Carbon Reduction Commitment (CRC) means that carbon emissions are taxed providing a direct fiscal incentive to reduce emissions.

Building Regulations governing the conservation of fuel and power are now based around setting CO_2 limits and whilst these have up to know been aimed at new buildings, leading to zero carbon homes by 2016 and non-domestic buildings by 2019, they may in future also target existing buildings. This means that new buildings will need to significantly reduce emissions, supporting the connection to DH networks, but so too will existing, and connection to a DH network may be one of the more cost effective ways of achieving this.

Planning policy is currently in a state of flux with the imminent adoption of the National Planning Policy Framework. However planning policy over the last few years has increasingly concentrated on sustainable development and enabled local authorities to set targets for reducing CO_2 emissions. Many councils including Cambridge have used this to develop policy around encouraging heat networks and CHP.

At present, there is a lack of specific fiscal support for DH and CHP other than the general carbon costs. However it is expected that over time, the Government may examine ways in which DH in general can be supported and the LCDI and Cambridge City Council should monitor changes to the support mechanisms which may become available.

District heating network options for Cambridge

This study commenced by collecting the energy demands of many buildings and sites in areas identified as potentially suitable for DH network development. The main sites of interest were around two general areas: the first around Parkside Pool, opposite Parkers Piece, and ARU, and; the second to the west including the Downing Site, old Addenbrookes site, New Museums Site, and a number of other Council, University of Cambridge, College, and private buildings. The aim of collecting this data is to identify potential customers who have a heat demand which can be met by the DH scheme (typically large heat demands) leading to the design of network options.

This report examines in detail three network layout options.

- **Base Case.** A single scheme closely resembling the one examined by E.On connecting the Parkside Pool to ARU and a few other smaller sites. The energy centre housing the CHP is located at the Kelsey Kerridge / Queen Anne Terrace car park area.
- **Option 1.** A single scheme comprising the eastern area (as per the Base Case) and the higher density western area comprising the New Museums Site, Downing Site, Old Addenbrookes Site, and a number of other Council, University of Cambridge, College, and private buildings in the vicinity. The energy centre is located at the Kelsey Kerridge / Queen Anne Terrace car park area.
- **Option 2.** A single DH scheme covering the same area as Option 1, but with two energy centres, one located at the car park, and the other located somewhere within the New Museums Site/ Downing Site.

These three options are illustrated in the following three figures. The network designs show where hard dig (primarily roads) and soft dig (grass verges and parks) routes are selected. Soft dig routes are lower cost than hard dig and so chosen where possible.

Capabilities on project:
Building Engineering

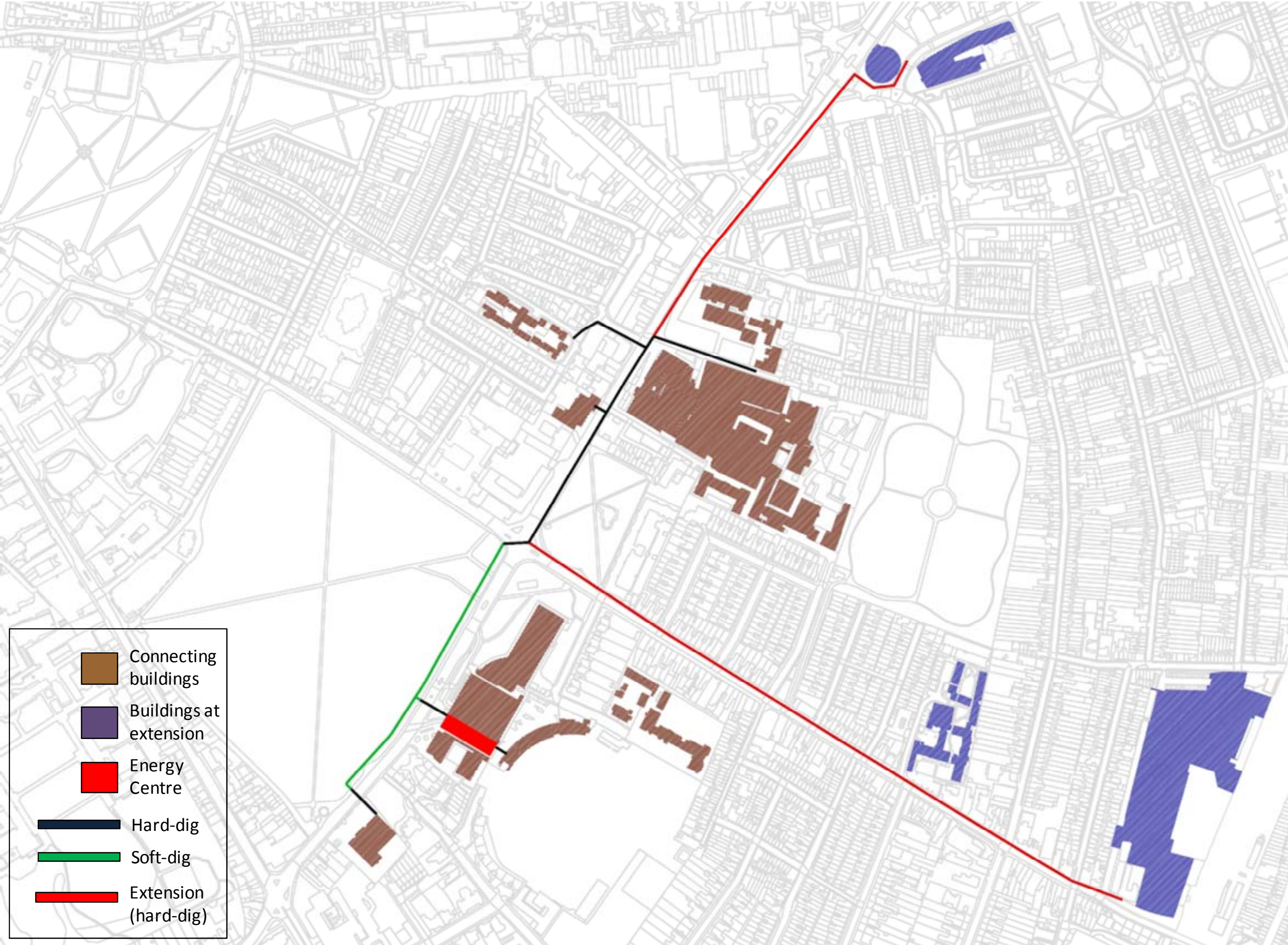

Figure 1: Base case network layout.

Figure 2: Option 1 network layout.

Capabilities on project:
Building Engineering

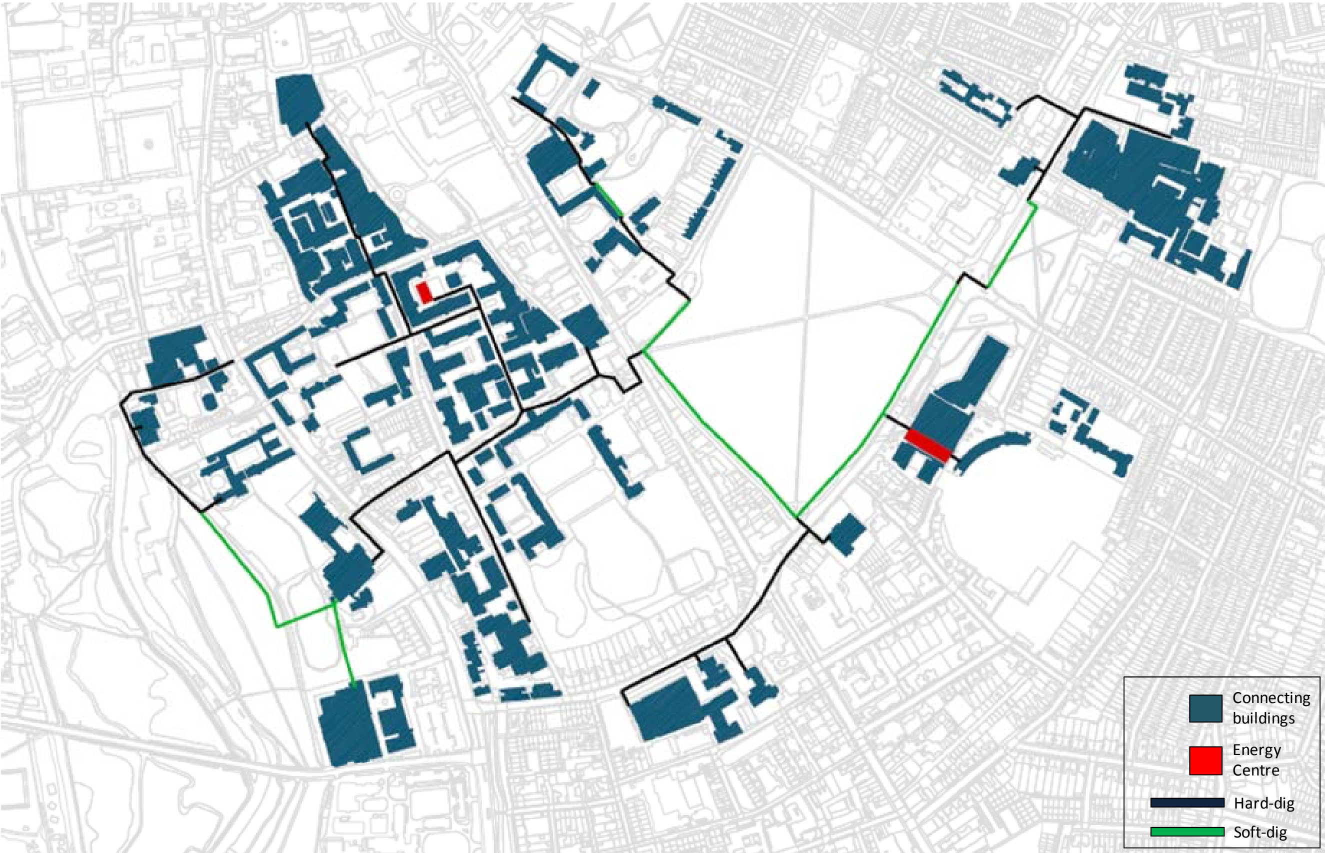

Figure 3: Option 2 network layout.

Economic and environmental analysis

A 30 year lifecycle costing methodology is used to assess the economic performance of each scheme taking into account capital and ongoing costs including the impact of incentives. The model allows for the examination of sensitivities to key parameters such as electricity revenue value (the price which electricity from the CHP system is sold for) and capital funding. A discount methodology is used to determine the Net Present Value (NPV) of each scheme and provide an Internal Rate of Return (IRR). The IRR describes how economic the scheme is and typically the public sector would require rates of around 6% to invest in a scheme whilst the private sector would require over 10%.

The cost and CO_2 effectiveness of schemes is calculated against a counterfactual case of gas boilers at each customer's site. This allows a like for like comparison of the schemes, and a basis for determining the price of heat for customers.

Table 1 shows the results of the economic modelling for the three baseline schemes. The capital costs range from circa £5 million for the Base Case to circa £22 million - £23 million for the larger two options. However the increased scale of the schemes increases the economics, providing IRRs of up to 7% which could be attractive for public sector investment.

Table 1: Economic performance of the baseline schemes

Scheme		**Base Case**	**Option 1**	**Option 2**
Capital cost	£ million	£5.1	£22.2	£23.4
IRR	%	1.4%	6.2%	7.0%

Alongside the baseline analysis, a number of sensitivities have been examined. The most important of these is the price which can be obtained for selling electricity. One method of maximising the value is by selling directly to customers using a “private wire” arrangement, essentially a direct cable connection which is not part of the electricity grid. The analysis demonstrates that this can be cost effective so that the increased electricity sales payback the cost of the connection. Without private wire, a means needs to be found to sell at a retail price to customers over the electricity grid. This usually requires an electricity supply license, and so the scheme needs to either be license exempt (generally restricting the type and number of customers), fully licensed (which is not viable for small generators) or make use of another licensed supplier. This issue could have an impact on the governance structure selected for the scheme.

One of the primary drivers for the scheme is the reduction of CO_2 emissions, and the costs associated with CO_2 emissions. The modelling examines the economics based on the current price of circa £12 per tonne of CO_2 for the CRC, but also with an increased cost of £50 per tonne providing additional incentive under potential future increases.

Conclusions

This report has assessed the technical and economic feasibility of a number of District Heating (DH) scheme options in the centre of Cambridge. It demonstrates that there are potential schemes which can deliver a 60% CO_2 reduction for heating for a number of customers, whilst providing an economic return in the region of 6% to 7%. The success of the scheme will rely on a strong governance structure being formed, and it is likely that a special purpose vehicle combining both public sector (the City Council and potentially University of Cambridge) and private sector / commercial organisations will be best suited.

DH Network options

The initial concept for a DH scheme in central Cambridge was based around the Parkside swimming pool and linking to Anglia Ruskin University (ARU). This allows City Council land at the pool to be used to house the energy centre, providing low carbon heat to the pool, and exporting heat and possibly electricity to the ARU campus. However this report also looks at options which extend to the west of the original scheme, connecting to the large University of Cambridge sites including New Museums, the Downing Site, the Old Addenbrookes site, and a number of other individual buildings. The high heat demands of these sites and relatively dense nature means that the overall heat density on the DH network is higher which should improve the viability.

The economic analysis off the schemes demonstrates that the larger schemes (Options 1 and 2) incorporating the large University site both have similar IRRs of around 6% - 7%, with a capital cost of circa £22 million to £23 million. This could be attractive for public sector investment, and with some additional funding, potentially private sector investment. However the base case scheme centred around the pool and ARU is much less economic with an IRR of around 1% (a capital cost of circa £5 million) which is unlikely to attract investment without significant additional funding. This suggests that any further assessment of DH options in the centre of Cambridge should consider the large scale scheme options, and will need close collaboration with the University of Cambridge in particular to ensure that the proposals are compatible with its current sites and demands for heat. In particular further work is needed to assess the technical viability and costs of providing distribution networks within some of the complex university sites.

Electricity sales

Achieving a good value for the CHP electricity output is central to improving the economics of the schemes. There will be a miss-match in the output profile from the CHP engines and the demand from customers, but due to the scale of demand from customers connected to the heat network, between 90% (base case) and 100% (Options 1 and 2) of the CHP electricity could be used to meet their demand.

Private wire is one method by which electricity can be sold for the maximum revenue value and this study demonstrates that a private wire connection to ARU from an energy centre located in the Parkside Pool area is viable, providing the greatest IRRs. The cost effectiveness of a private wire is determined by the length (and thus cost) of connection and the amount of electricity sold over the connection. Therefore if private wire was to be used on other parts of the scheme, such as at the New Museums site, where the ratio of electricity sales to infrastructure cost was higher, the economics would improve further. But in situations where the ratio may reduce, for example with an energy centre located further away from ARU, then the economics will need re-calculating.

Where a private wire arrangement is not possible, it will be important to maximise the revenue through sales over the electricity grid. The effective cost penalty of this as modelled in this report is the payment of distribution charges. However an arrangement needs to be sought as to how this can be achieved. This could be though either negotiating a power purchase agreement with a supplier which reflects negotiations with local electricity customers (in particular the University of Cambridge, associated colleges, and the Council), or by having a partner in the scheme who is a licensed electricity supplier (assuming that this scheme is not license exempt). Another option is the use of a license-lite arrangement although there are no current examples of this in operation.

When electricity is sold for bulk supply to the electricity grid, there is a significant reduction in the revenue obtained and none of the schemes are economic. It is therefore vital that electricity can be sold to customers, either directly, or via the grid, for the success of the scheme.

Energy centre location

Establishing a suitable location for an energy centre will be key to furthering the technical development of the scheme.

The initial concept of an energy centre located on the roof of the Queen Anne Terrace car park is attractive, making use of Council assets which are currently not optimal (the roof cannot be used in some periods due to ice). The location is close to the ARU, providing potential for a private wire connection, and can provide electricity directly to the Council owned swimming pool. The use of the car park may be possible but it is likely that structural modifications will be required for the car park to take the increased loading from the CHP engines. There would also be no scope for further expansion on this site. The costs of these modifications have not been calculated but could be significant.

Other locations around the Parkside pool are available, but have restrictions. The current temporary boiler location is extremely limited for space, and using the basement / ground floor of the car park is unfavourable due to height restrictions and would result in a loss in revenue to the Council.

In the Option 2 scheme, a second energy centre is included located within the New Museums / Downing Site area. This reduces the amount of plant required at the car park site, and importantly provides good access to the privately owned University of Cambridge electricity networks on these two sites for electricity sales. Further work is required to identify a suitable location – both of these sites are relatively dense – and other considerations such as planning and the cost of building also need to be examined.

Taking a long term strategic view of a DH scheme in Cambridge, it may be desirable to have a larger energy centre site away from the City centre, and the Council Depot along Mill Road adjacent to the railway may be one possibility. This offers advantages of adequate land availability (in Council ownership) with potentially fewer planning restrictions. However the pipework along Mill Road incurs an additional £1.9 million reducing the IRRs by circa 0.9%. Further analysis is required on the cost benefits of developing an energy centre at this site, and the longer term economic benefits to the DH scheme for future expansion.

Carbon savings

One of the prime drivers for the creation of a DH scheme in Cambridge is the potential CO_2 reduction which can be achieved. Overall CO_2 reductions are achieved by the cogeneration of heat and electricity resulting in high efficiencies. Compared with a counterfactual of gas boilers, customers connected to the DH network will typically reduce CO_2 emissions from heating by circa 60% (assuming 2014 grid electricity intensity) for their heating. This brings not only environmental benefits, but also economic benefits through the reduction on current and future carbon taxes. At a current price of £12 per tonnes CO_2, the CRC is an important, if not primary driver for the scheme. However a general view is that carbon taxes will rise, and if a higher cost of £50 per tonne is included (which is closer to the Government projections for non-traded carbon prices), then the IRRs increase by around 3% to circa 9% - 10% which may attract further investment in the scheme alongside attracting more customers.

Governance

There are a large number of governance options open to the scheme each of which has merits and disadvantages. The most important factor when deciding on governance is to determine the key drivers for the scheme, and keep these central to the operation of the scheme. The governance structure also needs to consider the types of customer who may be connected to the scheme, and how the scheme will operate economically in terms of the purchase and sales of energy, and the need to access finance and make an acceptable rate of return.

The discussion in this report suggests that some form of special purpose vehicle comprising the City Council, private sector expertise, and potentially the University of Cambridge, could be the most suitable governance model:

- The public sector involvement will be important both from a financing perspective, enabling low cost finance to be used to develop a scheme which is not deemed commercially attractive, but also importantly to provide the Council with a strategic hold over the future development and direction of the scheme. The involvement of the Council would also lend a degree of credibility to the scheme, particularly in light of the lack of regulation over heat, and this will be increasingly important if the scheme expands to include domestic connections in the future.
- Private sector expertise will be important in the operation of the scheme, and can bring with it benefits such as licensing for electricity sales. Whilst the scheme may not be commercially attractive without additional funding, the operation of a scheme in Cambridge connected with the University could have a high kudos.
- The University of Cambridge, as potentially the largest customer, could see involvement in the governance structure as a way of ensuring the scheme performs to its benefit and is strategically aligned with future University plans.

One option for a SPV could be to develop a membership based model, providing all customers with a degree of ownership of the scheme. This again provides additional security in a market where there is no regulation.

Recommendations

A DH scheme can clearly offer benefits to Cambridge though reduced CO_2 emissions from gas CHP, developing infrastructure which provides flexibility for future plant upgrades, and potentially providing lower cost energy to a wide range of customers. Through this work we understand that there is a strong support within the council, but also generally a good level of interest from the potential customers. To take the scheme further, there are a number of recommendations:

1. To engage further with supply companies. This report can be used for market testing with supply companies and investors. Discussions with these will be important to establish the level of interest in the scheme, the type of involvement they may desire, and to gain feedback on the scheme options. Whilst outline ideas for a governance structure have been given, discussions with suppliers will allow these to be worked up further to a stage where some form of organisation can be formed.

2. Engagement with customers. The signing up of customers for heat and potentially electricity sales is vital for the economics of the scheme, and to reduce risks for investors. The size of some customers (in particular the University of Cambridge) provides benefits in terms of loads, but also a risk if they pull out. Therefore it will be important to commence discussion on both how contractual arrangements may be formed and the levels of tariff which may be attractive, but also to examine further the technical issues around connection, in particular the development of networks on the individual sites.
3. Sales of electricity. Achieving a good revenue value for electricity is key to the economic success of the scheme. Further technical analysis will help establish the potential for private wire, in particular on the University of Cambridge sites if an energy centre was to be located there. However the licensing implications needs to be examined in more detail, both through discussions with potential suppliers, and further examination of the electricity loads and output in relation to licensing exemption. At present little is known about the license lite proposals and further examination of these is required.
4. Energy centre sites. A number of site options have been outlined in this report but further examination is required, especially for energy centres located within the University of Cambridge sites. This further work needs to consider the availability of land and current ownership, planning constraints, the costs (which may be higher for City centre locations), and infrastructure requirements.
5. Financing. It will be important to establish a source of financing to feed into further work on governance structures and design refinement (the level of funding available may have an impact on the size of the first phase of the scheme). Work should be conducted to examine funding sources from within the Council and public sector, the potential customers (who may wish to invest) and from commercial funding sources. A financial model is required to determine the cost implications of the different governance structures and procurement methods.
6. Policy. National policy and regulation is constantly changing in the area of sustainability and low carbon energy. It will therefore be important to constantly update the assumptions used in this report with the latest knowledge around current and future policy. In particular, it is believed the Government will be examining ways of incentivising heat networks and CHP.

1 Introduction

Background

There has been a recent surge of interest in District Heating (DH) in the UK promoted by a range of economic and environmental drivers, in particular the need to reduce CO_2 emissions. Many towns and cities have been conducting heat mapping to identify areas of high heat density and suitable loads, which may support the development of district heating schemes. A report for Cambridge City Council demonstrated that there were a number of areas in the city centre where the heat loads may be sufficient for the development of an economically viable DH scheme which could contribute towards reducing the City's CO_2 emissions[1].

The significant investment required for DH schemes alongside the often low rates of return mean that attracting commercial interest at the early stages of project development can be challenging. A number of feasibility studies may need to be conducted to demonstrate the viability of the scheme before commercial partners become interested. The Low Carbon Development Initiative (LCDI) has been set up by Renewables East with European funding to help in the development of low carbon energy schemes in the East of England, specifically through the de-risking of projects during the early feasibility stages.

In late 2010 / early 2011, the LCDI procured a feasibility study examining a first phase DH scheme in Cambridge City (hereafter referred to as the E.On study)[2]. The initial concept for this scheme was based around linking the City Council owned Parkside Swimming Pool at the Gonville Road / Mill Road junction, to the Anglia Ruskin University (ARU) Campus on East Road. The potential advantages in this scheme are that there is a significant base heat load at the ARU site and the council ownership of the pool can help de-risk the development of a scheme. The E.On study included a number of other sites in the analysis which are in the vicinity, some existing, and some potential development areas. The study demonstrated that the viability of a DH scheme is not only heavily dependent on the costs of the actual DH network and energy centre, but also on the ability to connect loads, and one of the largest potential loads in the scheme (the Grafton Shopping Centre) was subsequently found not to be viable for connection, due to a lack of centralised heating plant and separate heating systems in each retail unit.

Following the E.On study, it became clear that a DH scheme will need to investigate in more detail the viability of individual loads that could be connected, but also identify additional loads, potentially in new areas, which could also become part of a wider area scheme.

Outline of this study

The LCDI contracted AECOM in August 2011 to conduct a further assessment of DH options for Cambridge City centre, building upon the knowledge gained in the E.On study. This study covers the following aspects in assessing the viability of a scheme:

The identification of additional heat loads which could connect to a scheme, including an outline assessment of the viability of connection.

A review of the existing sites identified in the E.On study.

The identification of network layout options and energy centre locations, based on the distribution of heat loads.

An economic assessment of each of the options, including analysis of sensitivities.

A review of potential governance structures which can be used through the procurement and operation of a scheme.

Recommendations on the approach needed to develop a DH scheme for Cambridge.

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[1] Decarbonising Cambridge. Element Energy. 2010.
[2] District Heating Feasibility Study for Cambridge City. E.On for LCDI. 2011.

The outputs from this work will provide an outline design for a DH scheme, and economic analysis which can be used for discussions with potential stakeholders, suppliers and operators to gauge interest.

2 Drivers and incentives

Introduction

There is now a comprehensive range of legislation and policy at various governmental levels which supports the development and implementation of low carbon and renewable energy investments. However policy and regulation in this area is constantly changing and it is important that the drivers and incentives are constantly reviewed throughout a project to ensure they are gaining optimum benefit from these.

The movement in this area can both be positive for schemes but also present problems. On the positive side, many changes support further the need for low carbon energy schemes, and whilst there are fluctuations in levels of support, the overall trend is positive, and must surely continue to be so in light of the international recognition of climate change and the need to reduce CO_2 emissions. However the fluctuations in policy, such as recent Government announcements around Feed in Tariffs, means that there can be a lack of confidence to invest when business models are finely tuned to make use of current incentive offers.

This section provides an overview of international and national drivers and incentives which may help to support a DH scheme in Cambridge.

International policy

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

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

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

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

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

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

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

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

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

National Climate Change and Energy Legislation and Policy

Electricity Market Reform White Paper

There has been widespread agreement that the current UK electricity market needs to be modified to secure a diverse range of electricity supply sources into the future and encourage low carbon generation. The Government published 'Planning our electric future: a White Paper for secure, affordable and low-carbon electricity' in summer 2011 which sets out proposals aimed at creating a secure diverse supply of electricity sources including low carbon systems whilst attracting investment and reducing the impact on energy bills. Key proposals in the paper include emissions performance standards placing a cap on emissions intensities from power generators, introduction of a carbon price floor to support lower carbon generation, and contractual changes over the purchase of electricity. The paper states that the current Climate Change Levy (CCL) which provides a strong financial incentive for CHP (and therefore district heating) will be removed and replaced with the carbon price floor. At present the exact benefit this will provide to CHP is uncertain and so this study assumes the level of incentive will be similar to the CCL exemption for CHP.

Carbon Budgets (2011)

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

Annual Energy Statement (2010)

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

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

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

Comprehensive Spending Review (2010)

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

- Review of Feed in Tariffs (FITs). The CSR announced that the overall level of FITs will be reviewed, with the expectation that the tariffs set for some technologies may be reduced. FIT levels for large scale PV (over 50kW) were heavily cut in August 2011, and in October2011 the government announced that all POV tariffs will be heavily reduced from December 2011.
- Commitment to the Renewable Heat Incentive (RHI). The government had planned to introduce the RHI scheme for non-domestic installations in Autum 2011 followed by the domestic scheme in 2012 following further review. However an EU challenge over the tariff levels is currently delaying the schemes introduction.
- Review of the Carbon Reduction Commitment (CRC). The CSR announces that CRC funds will not be recycled, and that the CRC will therefore operate more as a tax than a market incentive scheme. This means that the costs for all participants are likely to be higher overall.

Household Energy Management Strategy (2010)

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

UK Low Carbon Transition Plan (2009)

The previous Government launched the UK Low Carbon Transition Plan on 15th July 2009. The Plan includes the Renewable Energy Strategy[3] (white paper) and Low Carbon Industrial Strategy. The UK Low Carbon Transition Plan is a Government white paper that sets out policies required to ensure that the UK meets its binding commitment (set legally under the Climate Change Act by the Committee on Climate Change) to reduce carbon emissions by 34% by 2020. The principal policies set out in the document include:

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

UK Renewable Energy Strategy (July 2009)

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

- A rigorous assessment of the local potential for renewable energy;
- Disaggregating local authority specific targets from the regional level;

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

- Ensuring sufficient allocation of sites or areas to secure the achievement of the target;
- Greater clarity on the available land resource;
- Identifying renewable energy ‘growth points’; and
- It also proposes establishing a renewables advisory body.

The Renewable Energy Strategy confirms that a Renewable Heat Incentive will be implemented from April 2011. Tariffs will be payable to energy users generating their own renewable heat.

Consultation on Renewable Electricity Financial Incentives 2009

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

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

Tariff levels have been set for FITs and the scheme started operation in April 2010. However whilst there is commitment to FITs from the Government, the levels have been reduced, in particular for PV installations (see “Comprehensive Spending Review”). The RHI scheme is waiting to be introduced but under challenge from the EU over some of the tariff levels being too high.

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

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

The Climate Change Act (2008)

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

National Planning Legislation and Policy

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

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

- Consider how the spatial strategy will support any regional targets on climate change (paragraph 12);
- Consider the potential to build more efficient energy supply and increasing contributions from renewable and low carbon energy sources into new and existing development (paragraph 13);

- Provide a framework for sub-regional and local planning to focus substantial new development on locations where energy can be gained from decentralised energy supply systems, or where there is clear potential for this to be realised (paragraph 13); and
- Ensure opportunities for renewable and low carbon sources of energy supply and supporting infrastructure, including decentralised energy supply systems, are maximised (paragraph 13).

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

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

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

Following the publication of the draft National Planning Policy Framework (NPPF) in July 2011, it is unlikely that the revised Planning Policy Statement will be adopted.

The Planning and Energy Act (2008)

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

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

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

- PPS3 (housing) sets out policies on increasing housing supply and density.
- PPS11 (Regional Spatial Strategies).
- PPS12 (Local Spatial Planning)
- PPS22 (Renewable Energy)

Planning Act (2008)

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

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

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

The Localism Bill

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

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

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

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

The Draft National Planning Policy Framework (July 2011)

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

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

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

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

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

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

Regional Planning Policy

It should be noted that with the change of Government in May 2010, regional powers are in the process of being abolished which will probably result in the removal of regional level policy relating to planning and development.

East of England Regional Assembly – The Regional Spatial Strategy

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

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

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

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

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

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

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

Capabilities on project:
Building Engineering

Building Regulations and the Code for Sustainable Homes

Building Regulations Part L – Conservation of Fuel and Power

As seen in the previous section, there many policies relating to energy and CO_2 emissions in the built environment, which are helping to drive the development of DH networks. Many of these aspirations and policies manifest themselves in the form of regulations, in particular the Building Regulations Part L - Conservation of Fuel and Power. The Eastern Extension in St Neots will be subject to future versions of the building regulations and the development of DH on this site, including the potential connection to an existing St Neots DH scheme, will be one method of helping to achieve the standards.

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

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

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

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

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

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

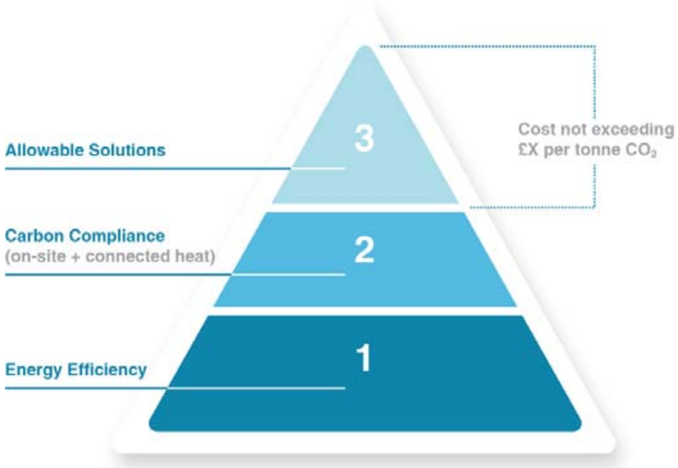


Figure 4. The proposed energy hierarchy set out in the Government's consultation on the Definition of Zero Carbon Homes.

The government then announced in July 2009 that the Zero Carbon Definition will follow the methodology outlined in the 2008 consultation with the Carbon Compliance element set at 70% of regulated emissions (the DER). The Carbon Compliance (expressed as a % of the regulated load emissions) sets a minimum fraction of emissions which must be reduced by on-site measures, such as energy efficient building design and low and zero carbon technologies. Policy development in the non-domestic sector is some time behind the domestic sector, but a similar system is proposed, with a carbon compliance level set at 54% in the aggregate[4], as outlined in the Consultation "Zero Carbon for new Non-Domestic Buildings" (November 2009)

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

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

Above the Carbon Compliance level, the remaining emissions can either be offset using more on-site technologies and efficiency measures, or through investment in an "Allowable Solution". An Allowable Solution is a method by which additional CO_2 reductions can be made either on the site or offsite using other means. Government is yet to make a definitive announcement on Allowable Solutions and there is therefore considerable uncertainly surrounding how they might be structured. The Zero Carbon Hub has published some recommendations for Allowable Solutions[5] which outline the following possibilities:

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

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

'On-site' options

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

'Near-site' options

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

'Off-site' options

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

Allowable Solutions must provide genuine additional CO_2 reductions, and so simple offsetting measures such as the purchase of green electricity are not compliant as this would in turn effectively increase the CO_2 content of the remaining grid electricity. Methods to directly offset the emissions from the development could take a variety of forms, one example being a developer investing in wind farms, and then providing shares of the wind farm company to the house owner (these would be attached to the house and so passed on to subsequent occupiers). A DH scheme such as that proposed in St Neots could be eligible for Allowable solutions provided it meets the investment targets required in the form of cost effectiveness of CO_2 reduction. Cambridgeshire Horizons have recently conducted a study examining the potential for a local Community Energy Fund (CEF) which would act as a forerunner to a national Allowable Solutions scheme, and potentially informing the development of a national scheme. The DH proposals in St Neots have been included in the analysis of the CEF and it is expected that the St Neots project would be able to benefit from this scheme.

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

Part L of the building regulations has mainly focussed on improving the efficiency of new building stock These are documents 1a and 2a). Whilst Parts L1b and L2b are aimed at existing buildings, the main emphasis is on performance of replacement fabric and services, and there is currently little regulation aimed at reducing overall emissions from buildings. However it is widely recognised that the current existing stock will still make up the majority of our building stock by 2050, and therefore should be the main target of further CO_2 reductions (there is not much further to go with new buildings). Therefore it can be anticipated that future building regulation revisions, perhaps in combination with other regulation such as energy performance certificates, will increasing concentrate on improving standards on the existing stock. This could act as a driver to the development of DH, providing large CO_2 reductions for hart to treat buildings and where building refurbishment is significantly less economic.

Code for Sustainable Homes

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

Mandatory requirements exist under the following credits:

- Energy
- Water
- Embodied Impacts of Construction Materials;
- Surface Water Runoff;
- Construction Site Waste Management;
- Household Waste Storage Space and Facilities.

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

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

Figure 5 below illustrates the latest Government published advice on CO_2 reduction targets, with reductions in regulated and un-regulated loads, and the fractions which are required from Carbon Compliance, and possibly Allowable Solutions. It should be noted that in the March 2011 Budget the government announced that the definition of zero carbon no longer includes unregulated emissions (appliances).

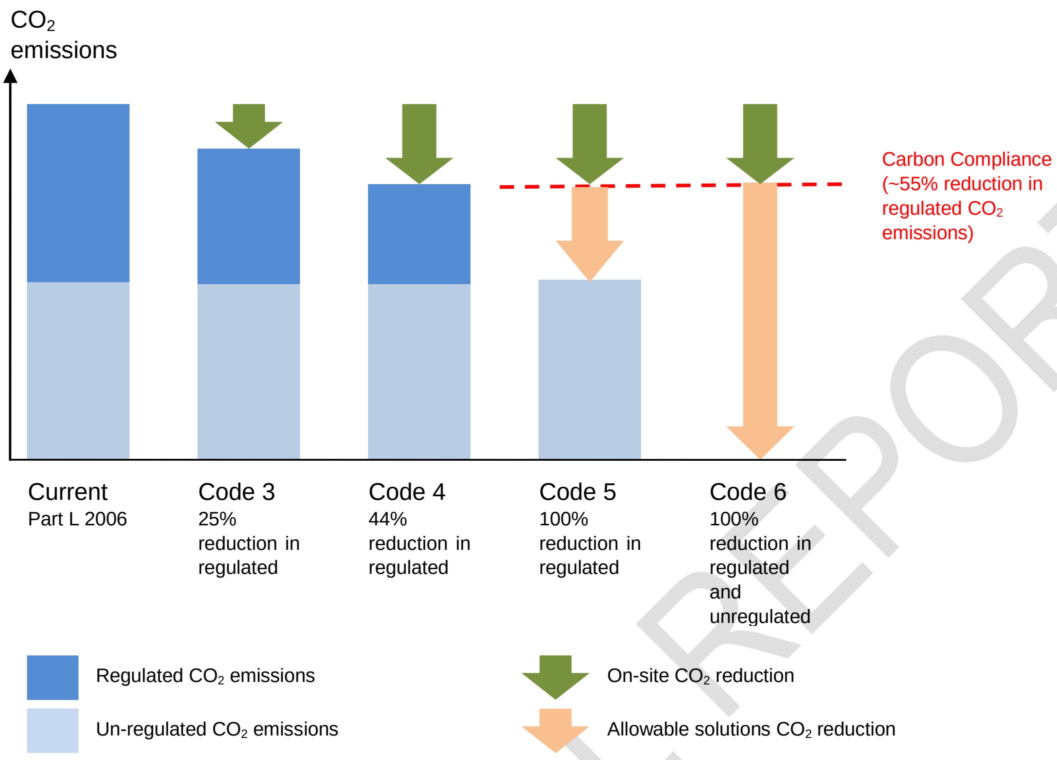


Figure 5. CO_2 emission targets under proposed revisions for Part L of the building regulations (2006), and their relation to the Code for Sustainable Homes. Note that when the Code is aligned with building regulations, the target for Code level 6 will be the same as for Code 5 and allowable solutions will only be required to fund regulated emissions.

Other incentives related to CHP and District Heating

A district heating incentive?

The current support and incentive regime is mainly directed at the generation and supply of energy rather that the distribution of energy. This means that the installation of district heating networks are not directly incentivised, but the heat they supply can be. Renewable heat sources (for example biomass CHP) can attract fiscal incentives such as the Renewable Heat Incentive (RHI) (for the heat output) or Renewable Obligation Certificates (ROCS) for the electricity output which aim to make the schemes more economic. However gas CHP, despite often delivering comparable CO_2 savings, is exempt from the RHI and ROCs and the climate change levy is the only direct fiscal driver. This may appear reasonable because gas fired CHP can be economic in its own right, particularly in standalone applications (at a building scale or on an industrial site). However in the drive to increase the uptake of CHP through district heating schemes, the substantial additional infrastructure cost often renders schemes uneconomic.

The original consultation on the Renewable Heat Incentive (2010) from the UK government outlines future ideas for a district heating incentive. This would:

- Provide an uplift per kWh of heat delivered to help finance the scheme.
- Be available to schemes where the main source of heat is eligible for the RHI (not gas CHP)
- Be applicable to schemes which provide heat to hard to treat properties (inferring that more appropriate technologies and schemes are available to other properties).

Perhaps most importantly, the consultation finished with a call to evidence on District Heating suggesting that the initial ideas may significantly change.

The proposal for a DH uplift is attractive and only a small incentive per kWh would have a large impact on the viability of DH schemes, but the initial RHI Consultation ideas appear very restrictive, in particular in relation to gas fired CHP.

Whilst there has been no information published since this consultation on DH incentives, it is understood that the Government is currently conducting more work into heat, including the second phase of the RHI (which covers the domestic sector and complex technologies and infrastructure) with a view to publishing a consultation on heat in early 2012. This may include an incentive scheme aimed at DH and future work on the Cambridge DH scheme should closely follow any announcements.

The London RE:FIT scheme

There are many potential barriers to the development of low carbon and energy efficiency schemes including risks around potential lifecycle cost savings, and lengthy and costly procurement of services. "RE:FIT", London's building retrofit programme aims to help overcome these barriers by providing a framework of contractors who will provide services and schemes on an energy performance contract basis. This means:

- Customers do not need to go through an OJEU process, but can procure the services from contractors on the framework with a mini tender. The process is OJEU complaint and all the contractors went through the OJEU process to become a framework supplier.
- There is no risk over the performance of schemes. A fixed upfront price is given by the contractor with a contractual level of savings. If these targets are not met, the financial risk lies with the contractor, so the customers business case stands.

The scheme is open to all public bodies in the UK and district heating and CHP suppliers are on the framework.

The RE:FIT scheme could offer a route for the LCDI and Cambridge City Council to invest in a district heating scheme with relatively low risk and procurement costs (and time). However the energy performance contracting arrangement may not fit within the desired governance format (see later in this report) and with the financial risk on the suppliers side, the economic return to the Council and participants may be smaller.

Summary

This section provides a brief overview of the policies and regulation which are acting as drivers for CO_2 reductions, and indirectly, district heating and CHP. It is fair to say that most of the drivers in regulation and planning are aimed at new development, and the Government has not taken the decision to target DH specifically for existing areas. However with increased recognition that existing buildings will be the main target for CO_2 reductions, it is likely that regulations will increasingly target this sector in the future, potentially incentivising DH schemes.

It is clear that policy and regulation in the low carbon arena is rapidly changing with important documents and changes published virtually every year. There have also been recent concerns in light of the global economic conditions that the UK Government will relax its aspirations for reducing CO_2 emissions, and proponents of this point to the reductions in FITs and ROCs. There remains however a high level commitment both politically and economically, supported by Acts, which push for reducing CO_2 emissions. Therefore whilst there may be some fluctuations in support over time, the overall trend will remain.

At present, there is a lack of specific support for DH and CHP other than the general carbon costs in the form of CRC and CCL, although the latter is currently uncertain. The FITs are only available for micro CHP units, and RHI (or ROCs) only available to renewably fuelled CHP. However it is expected that over time, the Government may examine ways in which DH in general can be supported and the LCDI and Cambridge City Council should monitor changes to the support mechanisms which may become available.

Capabilities on project:
Building Engineering

3 Identification of energy demands

Introduction

The original energy demands identified in the E.On study were based around a scheme in the ARU area. However, an initial meeting during this study identified the potential for connecting to areas outside the E.On areas of study, extending to the west of the city across Parkers Piece. The rationale for examining this expansion the scheme to cover this new area was because of the potential for linking to the Mandela House Council building on Regent Street would make the study more compelling and attractive if a number of much larger sites in this vicinity are also available for connection to the scheme.

This section of the report provides an overview to the review of existing identified loads, and also the new loads identified as part of this work.

Distribution of loads

The starting point for this study was to identify all of the main loads, which may be of interest for a DH network including existing sites and potential new developments. The map in Figure 6 shows the buildings considered in the original E.On study (shaded in red) and all additional sites/buildings considered in this study (shaded in blue).

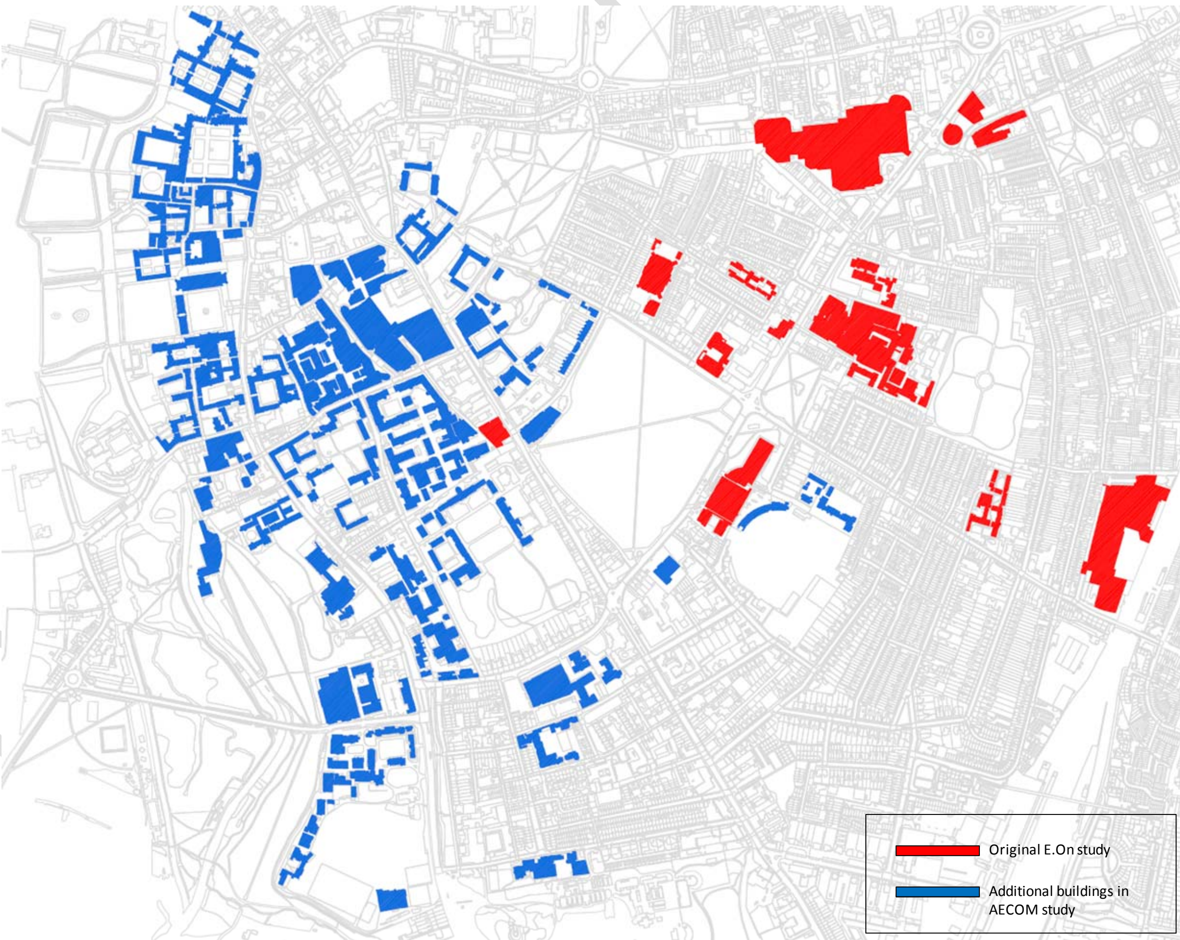


Figure 6: Map showing sites/buildings originally considered in the E.On's study and the additional sites/buildings bought into consideration in this study

The map in Figure 7 shows the location and ownership of the energy demands identified for analysis. Towards the east of the map is the area assessed in the E.On study. Apart from the ARU site and the Kelsey Kerridge Leisure Centre and Parkside Pool complex, the demands are fairly distributed with a number of sites to undergo re-development. ARU is the largest load in the area, and would serve as the anchor load for the scheme.

There is a large cluster of potential demands towards the west of the map, which extend into the central areas of the city. The majority of these sites are in University of Cambridge ownership (the Downing Site, New Museums Site, Old Addenbrookes Site, Fitzwilliam Museum, Cambridge University Press, Engineering and Chemistry Departments) and College ownership (Emmanuel College, Downing College, Pembroke College, Peterhouse College and Christs College). In addition, there are a small number of buildings in Council ownership (Mandela House, the Corn Exchange and the Guildhall).

To the south are a number of schools including the Leys School, the Perse Foundation School, and St Mary's School. These are all just outside of the core area of interest and generally separated by main roads from the rest of the western grouping.

The inclusion of a number of hotels across the city and the Grande Arcade and Lion Yard shopping centres were also suggested for review. However, no further data were obtained and they were excluded from further analysis.

The green outlined areas shown on Figure 7 are possible extensions (Phase 2) to a core network (north side of Trumpington Street along the Kings Parade, the Young Street area and along Mill Road).

Table 2 lists all the sites/buildings considered in this study with assigned unique ID, which corresponds to labels in the map in Figure 8. The table also indicates whether a site/building is included in the analysis.

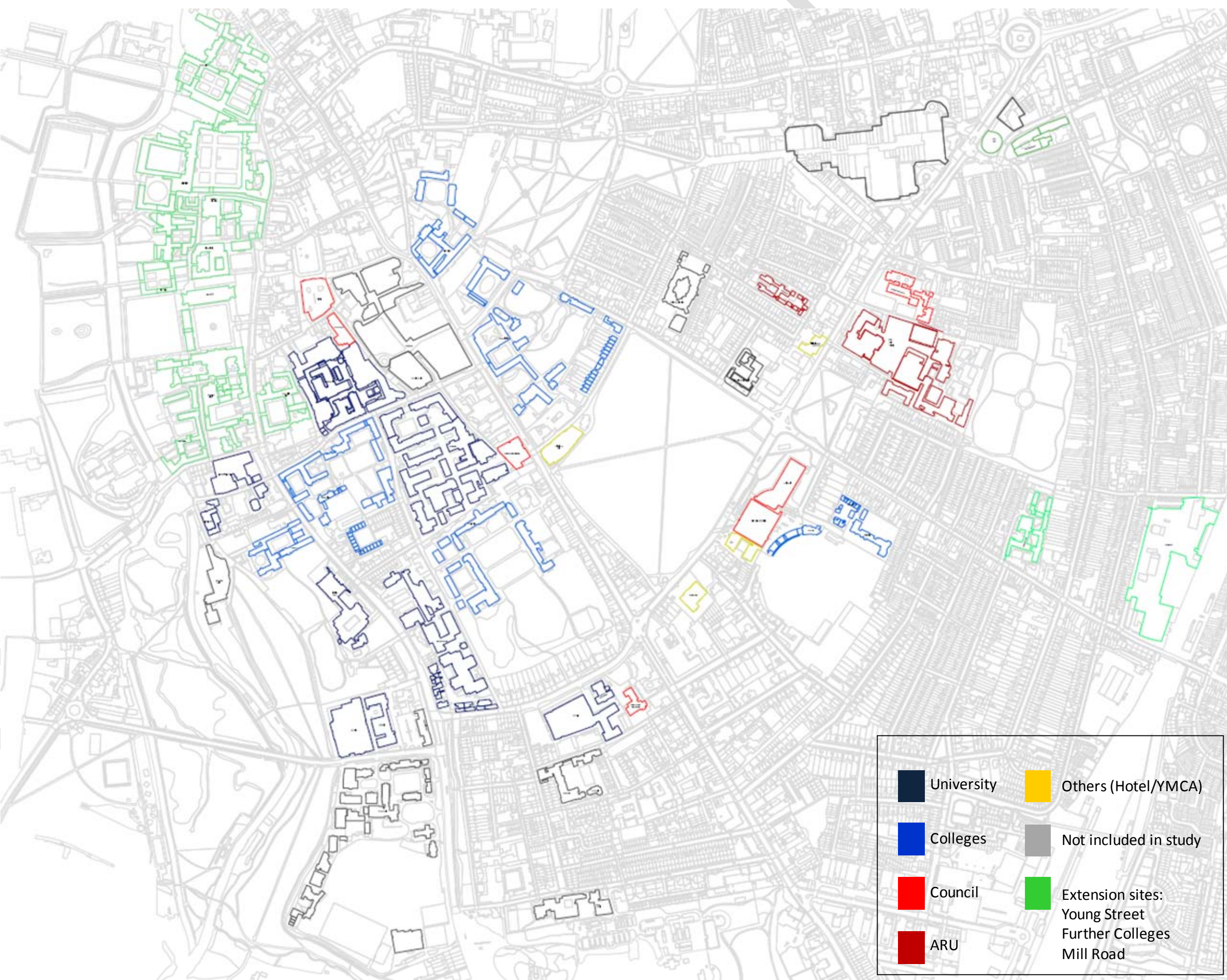


Figure 7 Map showing sites/buildings considered in the study by current ownership and status

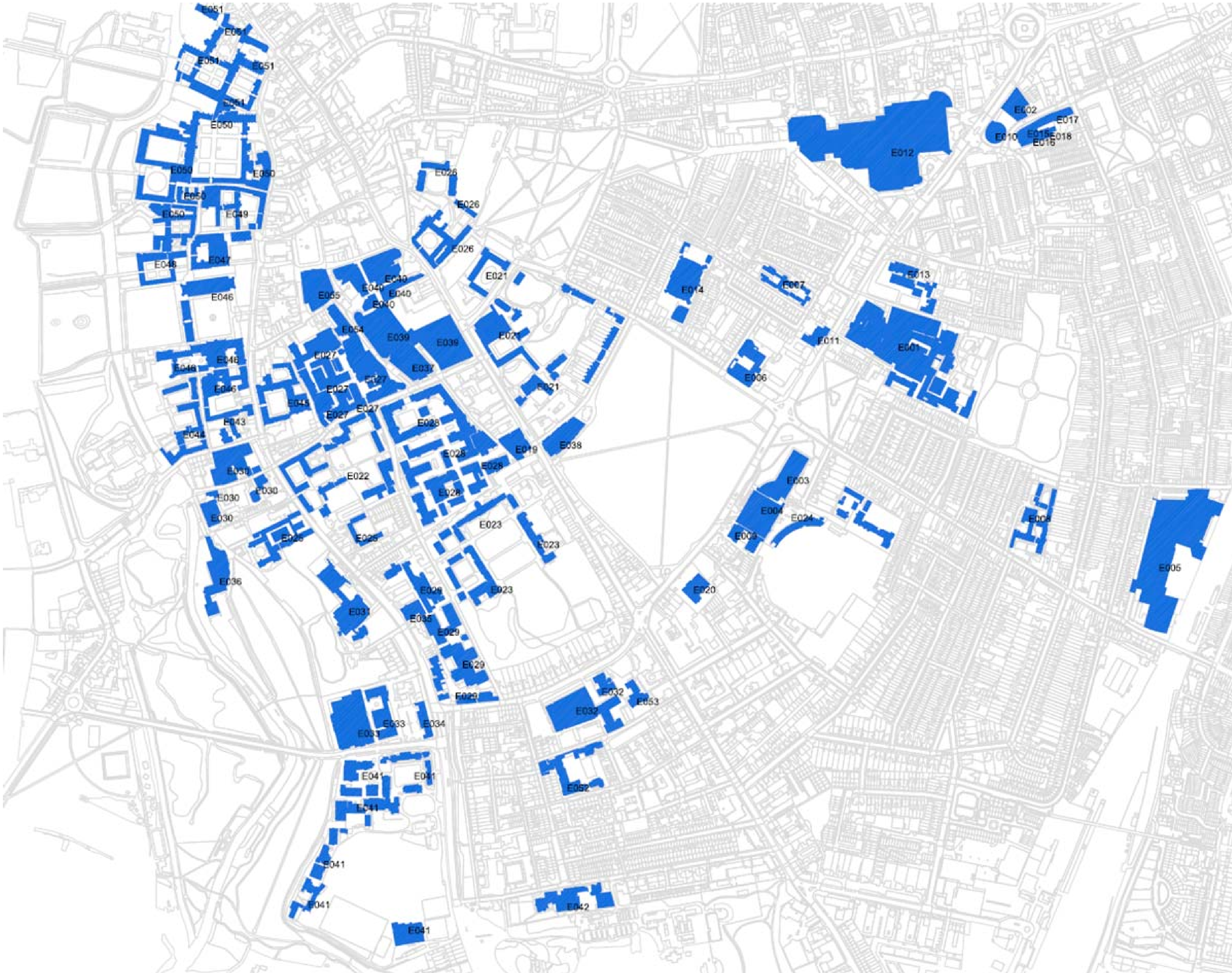


Figure 8: Map showing sites/buildings with their unique ID number, which corresponds to Table 2

Ind	Include	Code	Building Name
1	✓	E001	Anglian-Ruskin University (ARU)
2	✗	E002	Mackays site
3	✓	E003	Parkside Pool (PP)
4	✓	E004	Kelsey Kerridge (KK) sports centre & QAT
5	✓	E005	Mill Road Depot
6	✗	E006	Redevelopment of the police station site
7	✓	E007	Brandon Court
8	✓	E008	Ditchburn Place
9	✓	E009	YMCA
10	✓	E010	Cambridge Crown Court
11	✓	E011	Civil Justice Centre Cambridge County Court
12	✗	E012	Grafton Centre
13	✓	E013	St Matthew's School
14	✗	E014	Parkside Community College
15	✓	E015	Youngs site, ARU Phase 1
16	✓	E016	Youngs site, ARU Phase 2
17	✓	E017	Youngs site, ARU Phase 3
18	✓	E018	Youngs site, ARU Existing Reception
19	✓	E019	Mandela House
20	✓	E020	Gonville Hotel
21	✓	E021	Emmanuel College
22	✓	E022	Pembroke College
23	✓	E023	Downing College
24	✓	E024	Hughes Hall
25	✓	E025	Peterhouse College
26	✓	E026	Christ's College
27	✓	E027	New Museum's site (Uni area code M)
28	✓	E028	Downing site (Uni area code D)
29	✓	E029	Old Addenbrooke's site (Uni area code E)
30	✓	E030	Silver Street/Mill Lane site
31	✓	E031	Fitzwilliam Museum
32	✓	E032	Chemistry, Unilever, ScottPolarInstiture
33	✓	E033	Uni Bdg no 32 - Eng Uni bdg no 4 – Scroope Terrace (
34	✗	E034	Royal Cambridge Hotel
35	✗	E035	Hotel Du Vin, Trumpington Street
36	✗	E036	Hilton Garden House Hotel
37	✗	E037	Crowne Plaza Hotel
38	✓	E038	University Arms Hotel
39	✗	E039	Grand Arcade
40	✗	E040	Lion Yard
41	✗	E041	Leys School
42	✗	E042	St Mary's School
43	✓	E043	St Catherine's College
44	✓	E044	Queens' College
45	✓	E045	Corpus Christi College
46	✓	E046	King's College
47	✓	E047	Old Schools Site
48	✓	E048	Clare College
49	✓	E049	Gonville & Caius College
50	✓	E050	Trinity College
51	✓	E051	St John's College
52	✗	E052	Perse School
53	✓	E053	St Albans School
54	✓	E054	The Corn Exchange
55	✓	E055	The Guildhall

Table 2 Table showing all the sites/buildings considered in the study. The column 'Include' indicates whether a particular site/building was included in the analysis of the scheme.

Energy data availability

Obtaining accurate energy data is vital when assessing the viability of a DH scheme. It is the key parameter to ensure that the assumptions on heat sales are correct as this will drive the electricity generation and heat generation by the CHP system, which will then in turn determine the expenditure on fuels and revenue from sales. Where possible, measured heat demand profiles should be used to allow an assessment of the operation regime for the CHP system, allowing thermal store capacity to be optimised and the run hours for the CHP system to be maximised.

Access to data can often be a problem and ensuring a complete set of information that adequately describes the energy demand of the area scope can be a lengthy process if not impossible. Firstly a suitable contact is needed within each organisation and they need to be interested and willing to cooperate. It is often the case that energy consumption is not well monitored or metered or available in some useful format. This can mean that the profile information is limited (sometimes down to an annual level) and due to metering arrangements, it can be difficult to understand which parts of a site the data corresponds to. This latter issue is a particularly important problem on some of the sites in this study, such as the large University and College sites where one meter may cover many buildings or on some occasions, several meters covering one large building. Issues also arise from lumped metering of process energy use such as for catering and when meter reading is available in ‘units consumed’ and not in ‘kWh’, for example. On occasions, one or two readings for specific months in a full year are missing from the database.

The map in Figure 9 shows the level of data obtained on gas and electricity consumption from each of the sites/buildings. In general, good quality data, show in ‘green’ has been obtained at a monthly level for most of the sites, reflecting the fact that these are predominantly under the ownership of colleges, the University of Cambridge, or ARU, all of whom have staff with responsibility for energy purchase and monitoring of energy use to help limit expenditure. These stakeholders have also expressed a general but genuine interest in subscribing into a decentralised energy scheme within the city, which is in-line with their remit of reducing CO_2 emission to meet their respective environmental targets as well as lowering their energy bills. Most of their buildings are earmarked as potential anchor loads for the scheme and it is therefore vital that they continue to buy into the premise of such a scheme taking place in the near future.

In Figure 9, the ‘red’ sites on the map show where no data has been obtained and estimations made. These are for the YMCA building and the Mill Road Depot re-development. Only annual data was available for the University Arm’s Hotel, the Civil Justice Court and the Crown Court, shown in ‘blue’.

Sites where no data have been obtained despite diligent enquiries and potential future sites if the DH scheme were to be extended (Phase 2 – Colleges along Kings Parade) are shown in ‘grey’ on the map. These are sites/buildings not included further in the analysis. In ‘grey’ are also some of the sites/buildings considered outside of the areas suitable for a Phase 1 DH network development (colleges along Kings Parade), where currently no data was obtained but assumed to be available in future when the study involving Phase 2 becomes relevant.

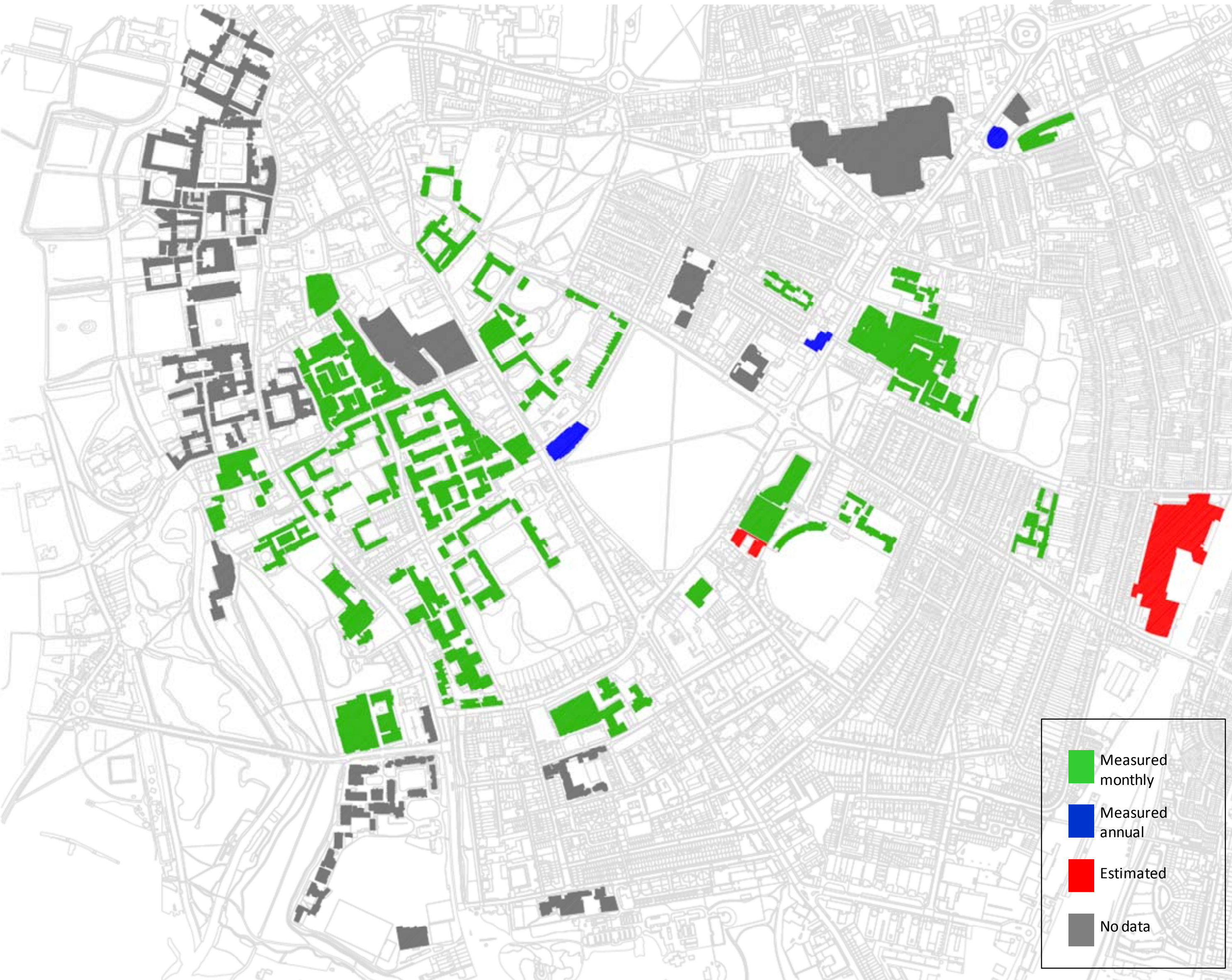


Figure 9: Map showing the quality of energy data received for the study

Energy demand analysis

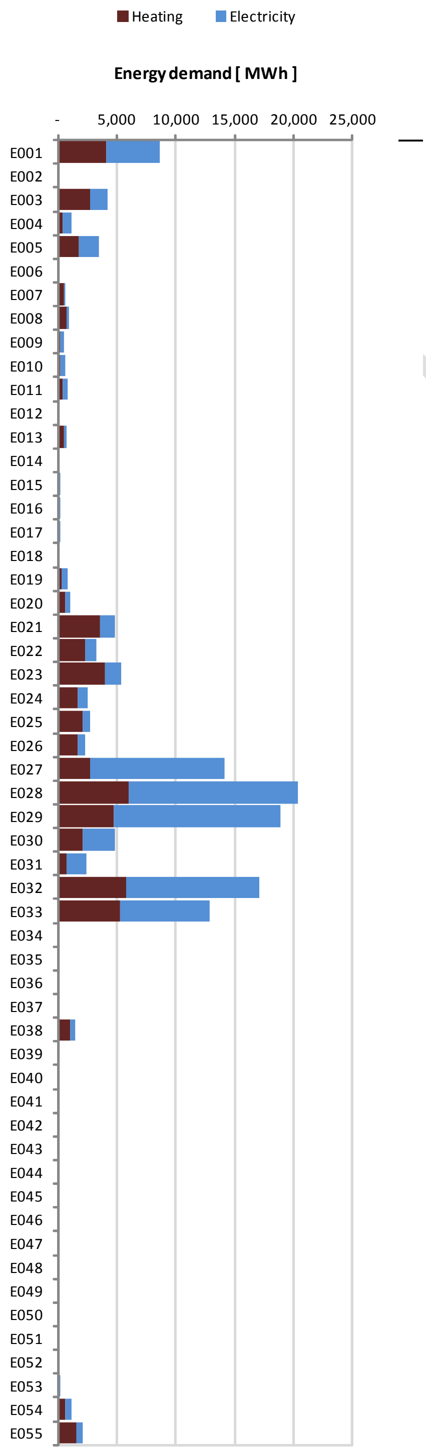
Raw energy data and other relevant information received from the various potential customers for the scheme were processed and rationalised upon receipt to tailor them into useable form for the analysis and to inform on assumptions to be made on site/building energy demands.

Figure 10 and Figure 11 are heat maps capturing, respectively, the site/building annual heating and electricity demands for all the buildings identified for connection to the scheme, which correspond to the list in Table 3.

Table 3: Summary of the site/building estimated floor areas (m²), total heat and electricity demands (MWh). It also indicates the proportion of each site/building heat demand over the total in the analysis.

Capabilities on project:
Building Engineering

Ind	Include	Code	Building Name	TOTAL floor area (estimated) [m²]	ENERGY TOTAL heat [MWh]	ENERGY TOTAL electricity [MWh]	Proportion heat
			TOTAL	440,166.50	53,922	78,771	100%
1	✓	E001	Anglian-Ruskin University (ARU)	44,266	4,127.02	4,549.14	7.7%
2	✗	E002	Mackays site	-	-	-	0.0%
3	✓	E003	Parkside Pool (PP)	3,415	2,743.69	1,456.84	5.1%
4	✓	E004	Kelsey Kerridge (KK) sports centre & QAT	4,400	380.74	779.59	0.7%
5	✓	E005	Mill Road Depot	27,000	1,802.25	1,620.00	0.0%
6	✗	E006	Redevelopment of the police station site	-	-	-	0.0%
7	✓	E007	Brandon Court	2,807	490.08	97.70	0.9%
8	✓	E008	Ditchburn Place	2,420	675.24	274.93	0.0%
9	✓	E009	YMCA	3,739	224.34	229.52	0.4%
10	✓	E010	Cambridge Crown Court	4,031	226.14	362.79	0.0%
11	✓	E011	Civil Justice Centre Cambridge County Court	3,500	420.00	416.50	0.8%
12	✗	E012	Grafton Centre	-	-	-	0.0%
13	✓	E013	St Matthew's School	3,342	500.33	188.51	0.9%
14	✗	E014	Parkside Community College	-	-	-	0.0%
15	✓	E015	Youngs site, ARU Phase 1	2,284	54.19	127.45	0.0%
16	✓	E016	Youngs site, ARU Phase 2	1,323	32.45	74.40	0.0%
17	✓	E017	Youngs site, ARU Phase 3	1,523	38.38	86.20	0.0%
18	✓	E018	Youngs site, ARU Existing Reception	230	5.80	13.02	0.0%
19	✓	E019	Mandela House	3,422	337.04	479.45	0.6%
20	✓	E020	Gonville Hotel	3,792	581.31	456.14	1.1%
21	✓	E021	Emmanuel College	19,753	3,519.94	1,264.99	6.5%
22	✓	E022	Pembroke College	12,962	2,278.65	968.74	4.2%
23	✓	E023	Downing College	22,159	3,948.65	1,419.07	7.3%
24	✓	E024	Hughes Hall	8,943	1,707.47	855.75	3.2%
25	✓	E025	Peterhouse College	11,920	2,124.05	595.74	3.9%
26	✓	E026	Christ's College	9,593	1,709.23	614.34	0.0%
27	✓	E027	New Museum's site (Uni area code M)	56,669	2,682.40	11,444.00	5.0%
28	✓	E028	Downing site (Uni area code D)	61,022	5,955.60	14,474.00	11.0%
29	✓	E029	Old Addenbrooke's site (Uni area code E)	46,628	4,690.00	14,227.00	8.7%
30	✓	E030	Silver Street/Mill Lane site	25,240	2,095.80	2,741.00	3.9%
31	✓	E031	Fitzwilliam Museum	13,856	753.20	1,672.00	1.4%
32	✓	E032	Chemistry, Unilever, ScottPolarInstiture	9,404	5,815.50	11,284.00	10.8%
33	✓	E033	Uni Bdg no 32 - Eng Uni bdg no 4 – Scroope Terrace (	62,046	5,256.00	7,643.00	9.7%
34	✗	E034	Royal Cambridge Hotel	-	-	-	0.0%
35	✗	E035	Hotel Du Vin, Trumpington Street	-	-	-	0.0%
36	✗	E036	Hilton Garden House Hotel	-	-	-	0.0%
37	✗	E037	Crowne Plaza Hotel	-	-	-	0.0%
38	✓	E038	University Arms Hotel	4,182	1,034.97	439.08	1.9%
39	✗	E039	Grand Arcade	-	-	-	0.0%
40	✗	E040	Lion Yard	-	-	-	0.0%
41	✗	E041	Leys School	-	-	-	0.0%
42	✗	E042	St Mary's School	-	-	-	0.0%
43	✓	E043	St Catherine's College	-	-	-	0.0%
44	✓	E044	Queens' College	-	-	-	0.0%
45	✓	E045	Corpus Christi College	-	-	-	0.0%
46	✓	E046	King's College	-	-	-	0.0%
47	✓	E047	Old Schools Site	-	-	-	0.0%
48	✓	E048	Clare College	-	-	-	0.0%
49	✓	E049	Gonville & Caius College	-	-	-	0.0%
50	✓	E050	Trinity College	-	-	-	0.0%
51	✓	E051	St John's College	-	-	-	0.0%
52	✗	E052	Perse School	-	-	-	0.0%
53	✓	E053	St Albans School	1,404	102.08	88.08	0.2%
54	✓	E054	The Corn Exchange	850	611.84	493.27	1.1%
55	✓	E055	The Guildhall	10,447	1,541.13	507.92	2.9%



Capabilities on project:
Building Engineering

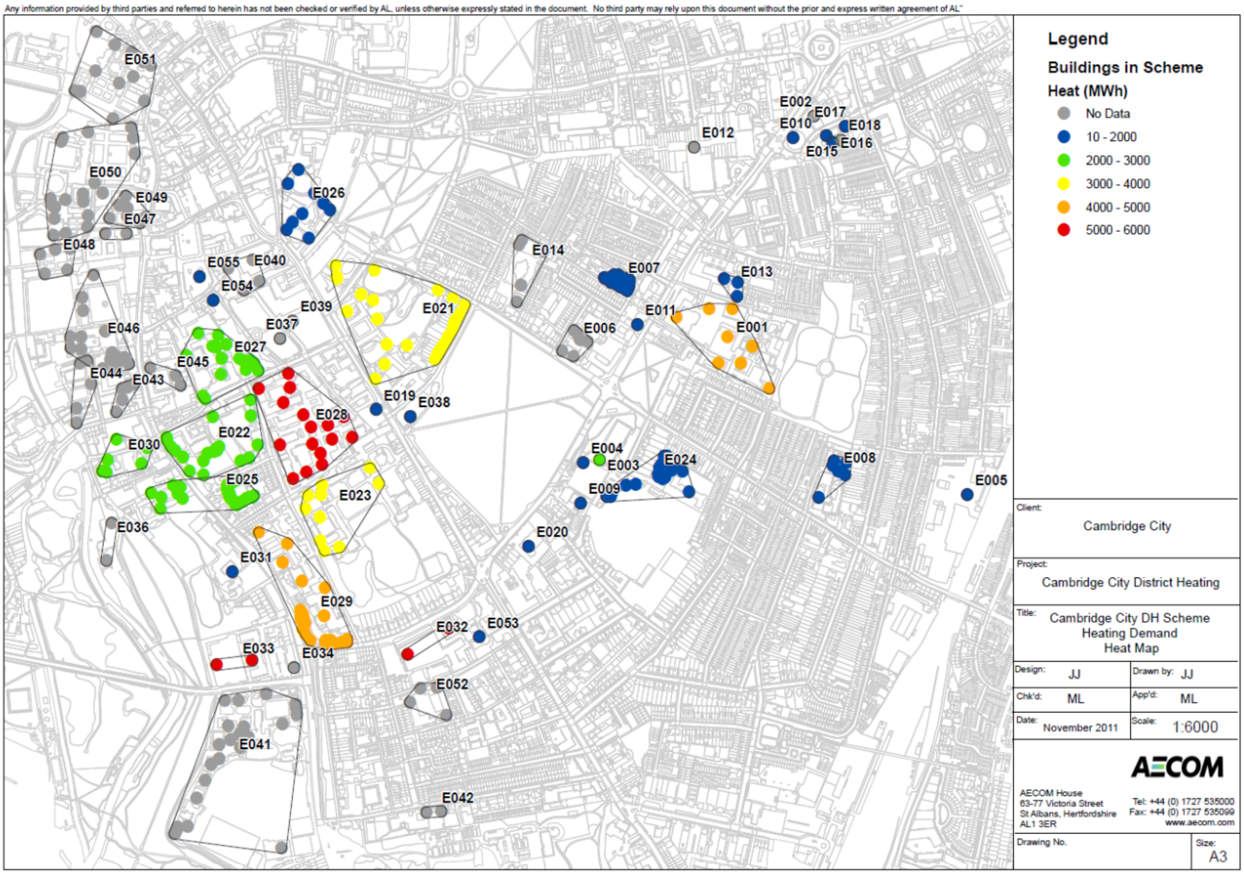


Figure 10: GIS heat map of site/building heat demands

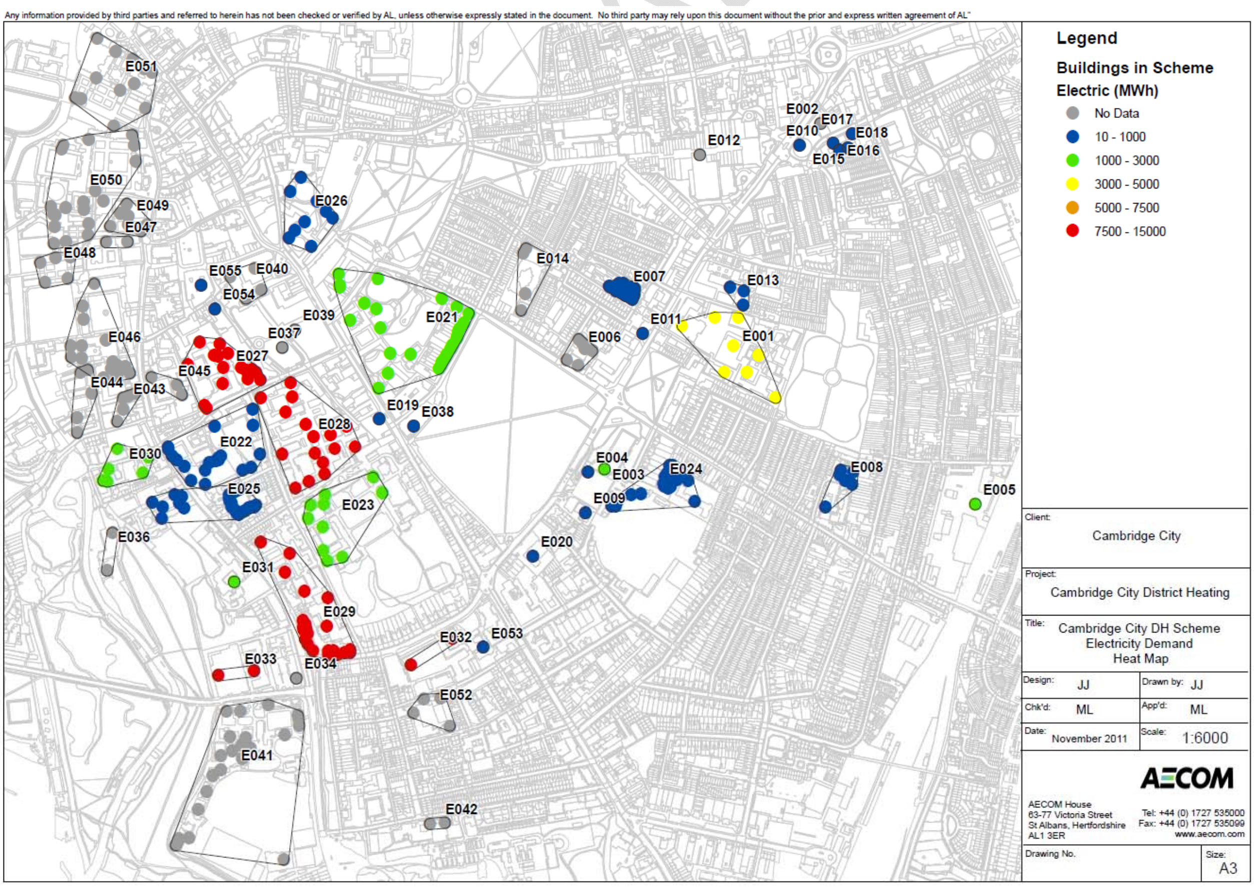


Figure 11: GIS heat map of site/building electricity demands

The heat maps illustrate the energy demand density throughout the cityscape. It can be clearly seen that there is a large energy demand concentration in a few areas, which would act as anchor points for the district energy scheme and certainly a strong indication of a feasible scheme could be underway. Please note that same colour scale within a bounded shape is used for buildings identified under a unique site ID and therefore the energy demand is the total for the whole site. For example, all the buildings in Downing Site have the same colour scale corresponding to their collective energy demand.

Another point to note is that the quoted floor areas for the buildings are indicative or estimates based on information received. In some cases, building floor area was not obtainable and therefore a superficial internal floor area was estimated based on matching building energy demand with corresponding building type energy benchmark figures. This was carried out with reference to building foot print inferred from other sources, such as the Ordinance Survey Map provided by the city council and maps from GoogleMaps to further inform this approach for estimating floor areas.

The ARU campus is an anchor load on the Eastern side of the city, complemented by the Parkside Pool complex. On the Western side of the city, the University sites such as the Downing Site, New Museums Site and the Old Addenbrokes Site, are the major energy consumers followed by the colleges, namely Emmanuel College and Downing College. It is essential that these anchor sites/buildings are connected to the scheme and it is therefore paramount that the scheme continues to command the commitment and interest of the respective organisations are throughout the process of realising the scheme beyond the stage of feasibility study.

In comparison, the colleges have comparable heating demand to the university sites; however, in general, university sites are registering much higher electricity consumption, where the potential for internal sales of electricity generated by the CHP scheme should be considered. This is preferable over sales to the national grid and this benefit will be discussed in detail in Section 4.

There are no data received yet for the colleges located along the Kings Parade at this stage of the study, but this would be required if the study considers Phase 2 of the scheme at a later stage.

Some assumptions were made regarding the ARU Young Street site development based on received information but overall the energy demand is relatively low towards this part of the city for the scheme.

A summary of the information received for all the sites/buildings considered in the study is presented in Appendix 1. Descriptions on the approaches used to process the relevant information into a format usable in the analysis was also included.

4 District Heating Network layout options

Introduction

Due to the nature of DH schemes, there will be more than one option for a potential DH network layout in most cases. In this section, the range of options is discussed qualitatively, which led to the identification of three network layout options for modelling and more detailed assessment. Key factors, which are considered include:

- The size and profile of heating demands
- The locations and the availability of space for energy centres
- The location of anchor demands as well as other demands in relation to the potential energy centre location
- The phasing of the energy demands, in particular whether they are ones already existing or to arise in the future when the development considered is built
- The agglomeration of demands on sites of multiple buildings, and in particular the heat density of these agglomerated areas
- The ease of installing the network taking into account distances and nature of the installation area (this is particularly important in city centre areas where the network is likely to be located along busy roads and along historical corridors around the city)

Discussion of network layout considerations

The original E.On report examined a DH network in the eastern part of the current area of interest. Figure 12 is a mosaic of several map fragments from the E.On report showing the original proposed DH network route for scheme. The feasibility study was based around an energy centre at the Kelsey Kerridge / Parkside Pool complex, with distribution to the sites along East Road, Mill Road, Parkside and Gonville Place. The main energy demand is at the Anglia Ruskin University (ARU) complex with other smaller demand spread around the scheme area. The site located at the far end of the network along Mill Road, which is at the current Council Depot site is yet to be planned and it is uncertain whether and when redevelopment at this site will come forward. The network leading out towards the west of the scheme across Parkers Piece connects to the Mandela House council building.

The rationale for the sites selected in the original E.On feasibility study stemmed from the desire to link the energy intensive Parkside Pool / Kelsey Kerridge sports centre to the ARU campus, and potentially the Grafton Centre. The other smaller sites were subsequently identified as potentially suitable for connection if a network was in the vicinity. However, following the removal of the Grafton Centre from the potential network scheme (due to the incompatible heating systems), and once the relatively small nature or uncertain building of some of the other schemes is taken account of, the overall rationale for a network in this area is significantly reduced.

Capabilities on project:
Building Engineering

Figure 12: The mosaic of map fragments from the E.On report showing the original proposed DH scheme for Cambridge City.

In this study, the area to the west of the original E.On study area has been identified as having potential interest. This arose partially from the concept of linking the original heat network option to the council offices at Mandela House on Regent Street. However, once a connection has been made to Mandela House, it opens up opportunities to connect to a much larger area to the west of Regent Street comprising of University facilities, schools, University Colleges and other council-owned buildings. It is clear from the mapping of demands (heat maps in Figure 10 and Figure 11) that the potential heating demands and heat density of these areas is much higher, therefore potentially more economically viable as a wider scheme, than the original scheme as it is only covers the eastern side of the city.

For Phase 1 of the scheme, which may expand in the future, the aim is to identify low risk or anchor customers, i.e. customers who would be willing to enter into a long-term contract for heat supply. In the area to the west, which includes the Downing Site, New Museums Site, and a number of Colleges, where buildings currently exist. This reduces the risk to the developer. However, in the less dense area to the East, large parts of the network (for example along Mill Road) depend on the connection of one or two smaller sites, and to sites which have not yet been developed, or even planned. This presents a higher level of risk in terms of uptake.

The scale of the areas of interest also needs to be considered when defining network options. Where there are a number of smaller sites, connection using a DH network will allow the use of a larger CHP unit with increased efficiency (and hence CO_2 savings), which also lead to a more economic operation. However, once sites become sufficiently large, they may justify a large enough CHP system in their own right and the benefits of linking to other areas becomes less pronounced – i.e. there are limited benefits from economies of scale to justify the expenditure on a DH network and connection. In addition, the value of electricity generated is much higher where the CHP displaces imported power on a host site than for a larger scheme where the electricity is sold into the electricity market. The ARU campus is one area where this may be true – the campus could justify a sufficiently large CHP unit in its own right and if other suitable heat loads are not located close by, then the rationale for a DH network is reduced.

Finally, the location of the energy centre needs to be carefully considered. The location proposed clearly needs to have adequate space to host the energy centre building and plant, and be positioned to allow connection to the existing electricity and gas utilities. It should also be well positioned in relation to the heat demands allowing the length of heat network to be optimised. It is important that the energy centre site is not used to justify the network – having a convenient site around which a network is built will probably lead to sub-optimal designs compared with finding a site in an optimal network location.

However, in some cases, particularly with mature and fully-developed sites such as that of the City of Cambridge, it is often difficult, if not impossible, to openly propose and gain approval for a location of an Energy Centre derived for an optimal network configuration. A sub-optimal site would normally be brought forward and the scheme would have to be developed from that point on.

Other factors to consider when proposing an energy centre location include planning restrictions, implication of adjacency with existing buildings, implication of ground works at mature, developed sites, air quality issues and even aesthetics.

Energy Centre Proposal

For this study, the client has put forward a potential site for an Energy Centre next to the Parkside Pool, the city council's highest CO_2 emitter in the city. The available space is on the top level of the Queen-Anne Terrace car park. As an alternative option, the client has also suggested an indicative location for a second Energy Centre somewhere within the University of Cambridge precinct. These two proposed Energy Centre locations are discussed in the following sections.

Energy Centre 1 - The Queen-Anne Terrace car park (KK/QAT)

The council-owned KK/QAT car park as an Energy Centre location is reasonably attractive in that it is adjacent to several buildings earmarked to connect to the DH scheme as can be seen in Figure 13. This would imply a significant negation of pipe work to transport heat across distances. The availability of the space, which is approximately 880m², came about due to an under-utilised top level car park, which poses health and safety issues from the hazard of ice formation on the floor surfaces during the winter months. The use of this space would imply no loss of ground spaces, which the city would have to incur for a ground-level Energy Centre. There is also no potential for invasion into any conservation areas.

Therefore, this proposed location fair favourably within the ranks of the planning authority in general. Furthermore, there are no other planning restrictions of real concern here as the planning authority is already aware of and are in favour of the extension to the Kelsey Kerridge leisure centre, next to the proposed location on the top level. Currently, the Kelsey Kerridge building is slightly lopsided towards the left on the front elevation and therefore construction of additional structure to the right hand-side of the building is favourable.

There is a permanent planning permission for the Parkside Pool temporary boilers situated at the back of the building shown in shade of 'dark blue' in Figure 13. This space can be available for use by auxiliary plant for the Energy Centre such as the thermal stores, pump room and pressurisation system. However, the availability of space might be quite limited considering the size of what might have to be located there. With potential shortage of space, counter-measures might have to be considered. For example, the use of another location for the back-up/top-up boilers or even adopting the strategy of remote local boilers by putting existing boilers of connecting buildings into service as part of the DH scheme. There are, however, complex technical and management implications with this arrangement.

Capabilities on project:
Building Engineering

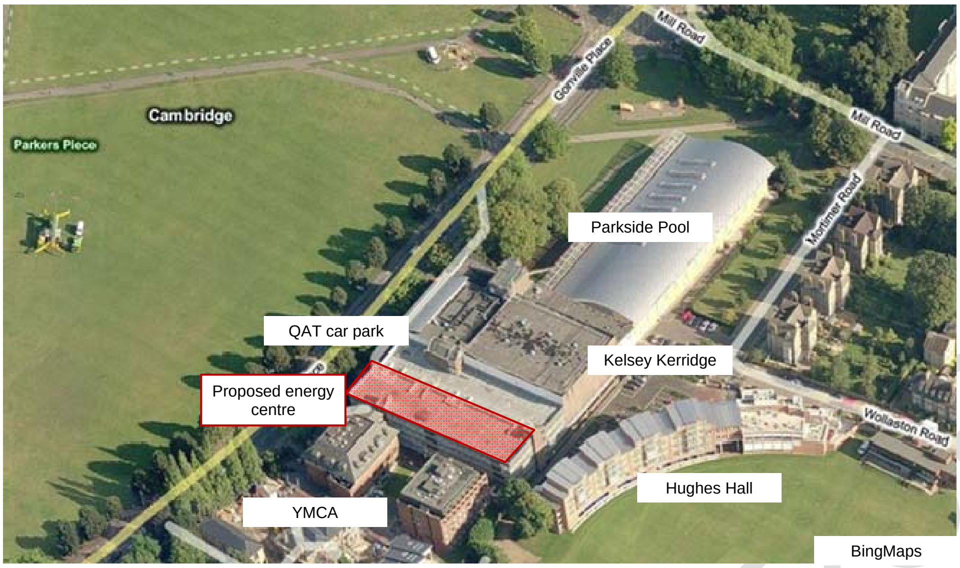


Figure 13: Proposed Energy Centre location at KK/QAT sandwiched between the YMCA to the west, Kelsey Kerridge leisure centre and the Parkside Pool complex to the west and the Hughes Hall on the south elevation. The proposed energy centre location is shaded in ‘red’.

Whilst there is no definite restriction stated specifically for the KK/QAT top level structural extension, there is a general limitation to the overall city skyline related to restrictions of the Conservation Area and the MoD and Marshalls Airport – there are restriction in place in relation to the heights of new buildings for aircraft safety reason. There is no immediate restriction due to access to daylight and view of sky of neighbouring buildings, including the Hughes Hall; however, this is subject to more detailed assessment if plans of an Energy Centre at this location are to go ahead.

Therefore, the general tone from the planning authority is to limit structural extension on the top level of KK/QAT to below 6m, which should take the finished structure to approximately the same height as the left-side of the building, hence potentially achieving the balance the council seeks.

Consideration would also need to be given to flue height and location, again in relation to the Conservation Area and MoD and Marshalls Airport safety restrictions. In conflict with this height restriction, the Clean Air Act requires flue to be over the surrounding buildings by certain height and at a given distance from adjacent buildings, which could potentially lead to flue having to exceed the restriction of the former. This should be investigated further in more detail.

In addition to this, any proposed Energy Centres location within the city will be situated within the council's defined Air Quality Management Area (AQMA). To this end, any development within this area would need to comply with a set guidance and requirements. The height of flue stack determines that dispersion level of pollutant and therefore the local air quality. The nature and mechanism of this dispersion process is complex and therefore A more comprehensive air quality assessment should be carried out to determine the full impact of Energy Centre flue.

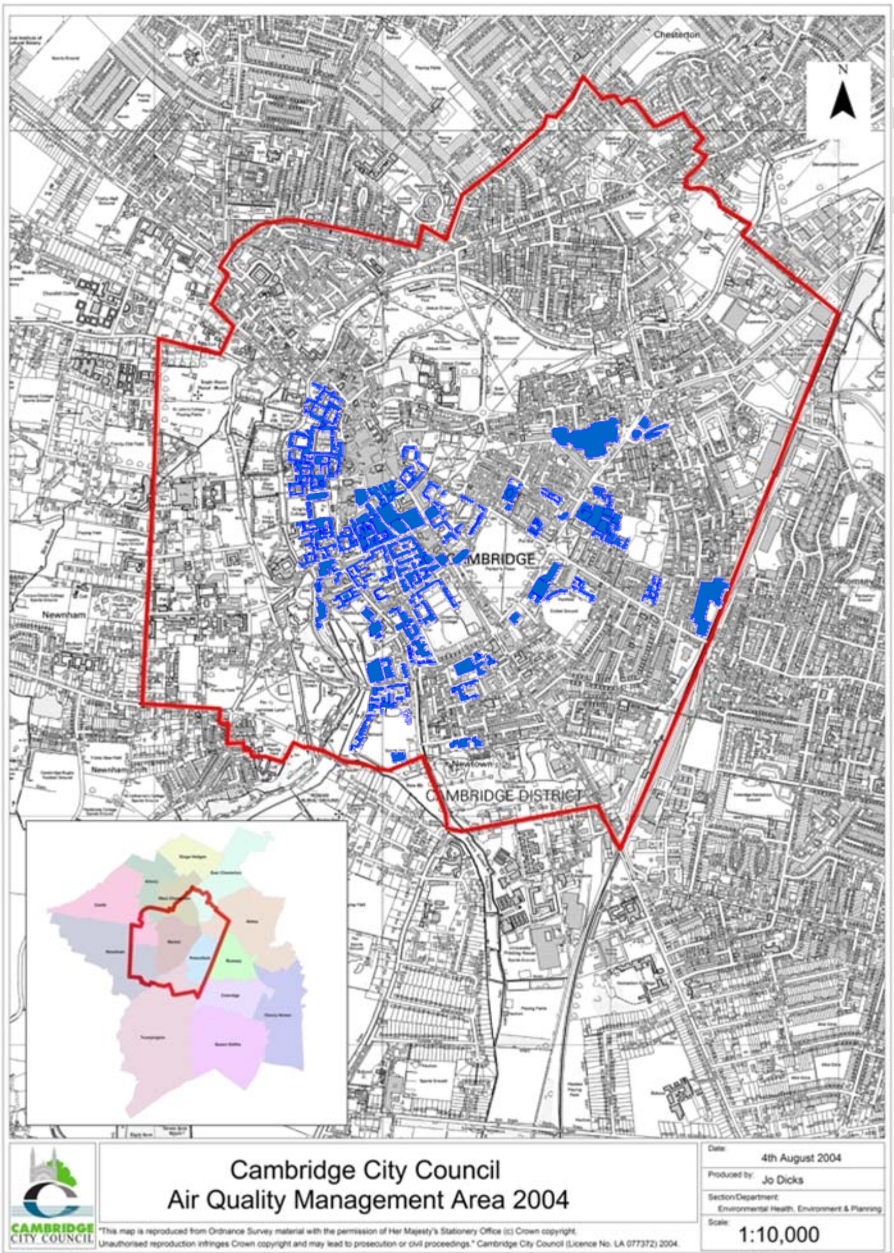


Figure 14: Map showing the Cambridge City Air Quality Management Area.

Capabilities on project:
Building Engineering

Structural appraisal

There has been a general but real concern over the structural implication of placing an Energy Centre on the top level of the KK/QAT car park. This car park structure is, in essence, no different from any typical trenchard car park designed to bear the weight of multiple static and dynamic loading of vehicles. However, it is generally not designed to specifically accommodate loading exerted by that of heavy plant equipment. Typically, the load concentration (kN/m2) of this sort of plant equipment is at least of an order of magnitude larger than that of a commuter vehicle. To this end, there would be a grave concern that the top level of the KK/QAT or any floor of the car park for that matter will not be able to take the structural loading of an Energy Centre.

A high-level structural appraisal of this proposed Energy Centre location has been undertaken by an in-house structural engineer. Based on the limited information available, the car park can be described as to be a split level multi storey concrete frame car park. Each 16m-wide floor is supported on pairs of columns at varying centres of approximately 7.5 and 5m along the deck. Across the deck the columns are set in by some 3m from each edge forming a central 10m span with 3m edge cantilevers. The car park is some 57m long split into three structural sections by double beam/column movement joints. It is not clear how frame stability is achieved.

Figure 15 shows the floor plan of part of the KK/QAT car park top level where the top-half of the plan has been allocated for the Kelsey Kerridge dive gym and changing facility extension, whilst the bottom-half is the allocated Energy Centre space. Figure 16 shows several photos of the proposed space for the Energy Centre and of the KK/QAT car park intermediate floors, to give a perspective of the amount of space made available.

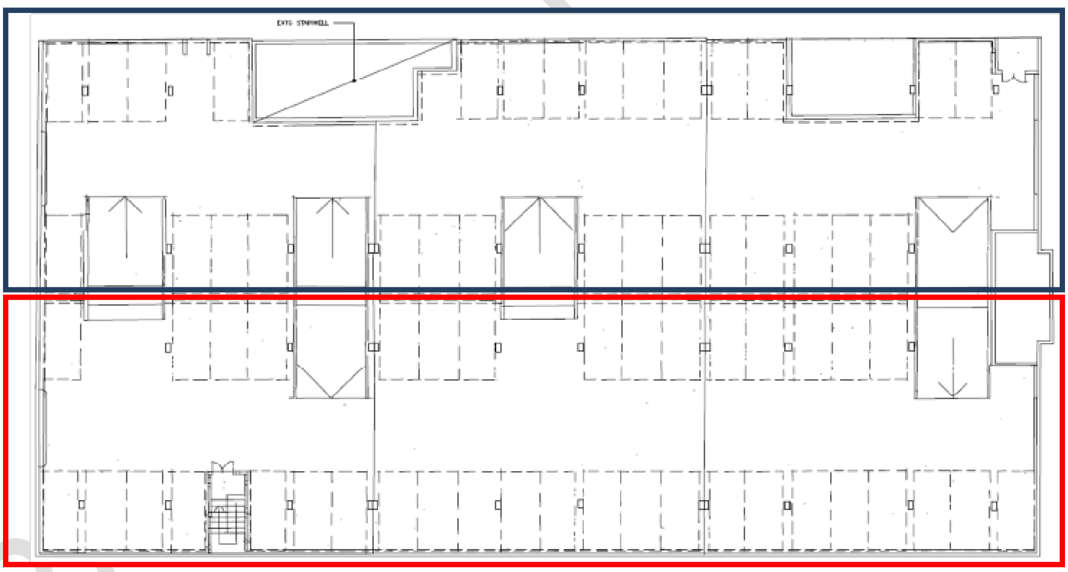


Figure 15: floor plan of the KK/QAT car park top level, marked in red border on the bottom half of the floor plan. The blue box contains the part allocated for the Kelsey Kerridge leisure centre extension

Capabilities on project:
Building Engineering

Figure 16**:** Photos showing the top level of the KK/QAT and a typical intermediate floor

The following comments are based on the above assumptions about the car park construction and the assumption that the decks are designed to carry the car park imposed loading of 2.5kN/m2. On the outset, this is not sufficient load capacity for heavy items of plant to be placed directly on the floor deck. It may, however, be possible to place plant on a grillage of steel beams supported on stub columns located over the main car park columns or on sleeper walls over the beam lines shown in Figure 17.

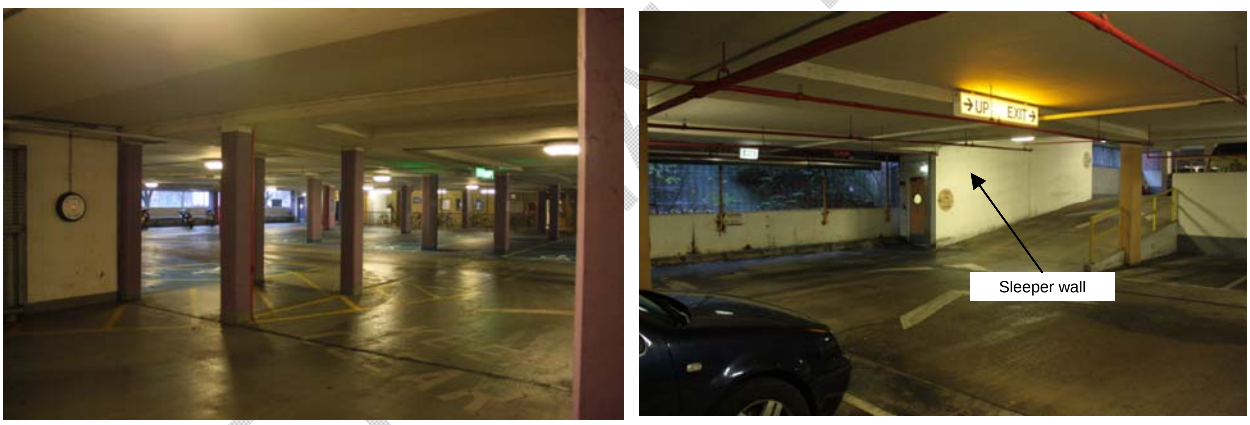


Figure 17: photos showing vertical beams and sleeper walls around the car park levels

It is assumed that other than the plant equipment, the top level floor will only need to support an average imposed load of 1.0kN/m2 made up of access routes with a live load of 1.5kN/m2 and generally non accessible areas with a snow load of 0.6kN/m2. This would allow loads of approximately 75kN and 30kN to be transferred to each of the internal and movement joint split columns respectively from the plant support grillage, without exceeding the assumed existing load capacity of the frame.

With allowance for the weight of the support grillage this would allow a plant weight of 96kN on every bay adjacent to a movement joint and 120kN on bays away from movement joints. Alternatively a weight of 240kN could be placed on a bay away from movement joints if no plant is placed on adjacent bays as shown in Figure 19.

Another arrangement which would allow approximately uniformly distributed weight allowance across the floor plate would be to have the support grillage spanning across all the available vertical columns and sleeper walls. This will transfer a nominal load of 24kN down each support to give an overall weight allowance of 860kN as shown in Figure 19.

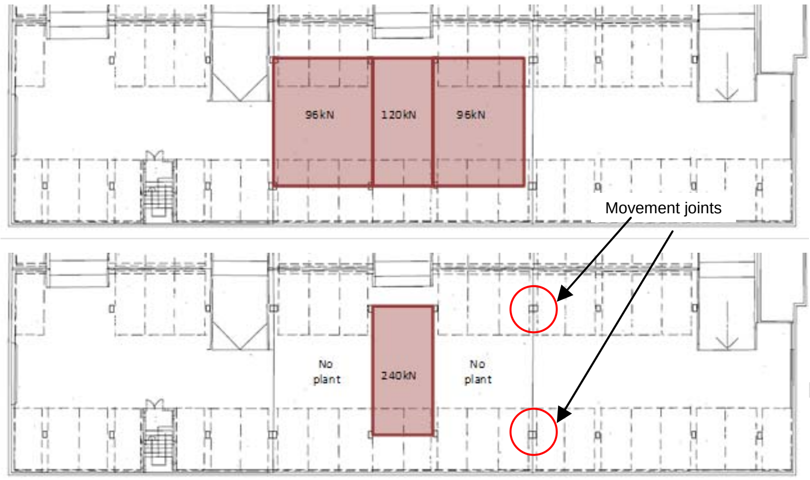


Figure 18: indication of weight limits achievable via different configurations of support grillage

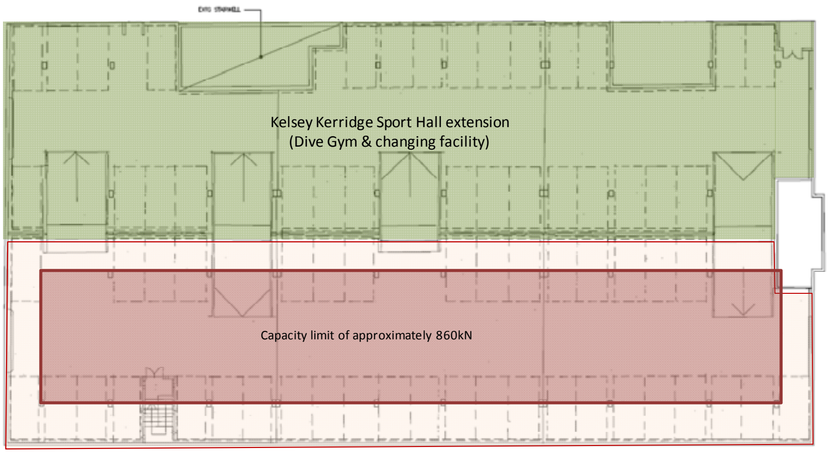


Figure 19: diagram indicates the provision of grillage of steel beams, which increases the weight capacity by transferring the plant load directly onto the vertical supporting columns across the entire floor plate

The existing waterproofing would have to be cut back and then re-dressed around the new stub columns or sleeper walls. It is likely that the top level of grillage may be some 600-800mm above the existing deck which may cause a planning issue of plant visibility. Any screening weight would have to be deducted from the allowable plant weight.

All of the above is based on a slightly educated conjecture and would need more details and a full understanding of the car park to confirm or otherwise the assumptions. It is possible that higher plant loads could be carried if the upper columns within the car park were to be further strengthened. This would then have additional capital investment to weigh out in order to take things forward.

As there were no comprehensive structural survey carried out, which is not within the scope, the study assumed that it is generally feasible to place an Energy Centre on this proposed location; however discussions and proposals put forward throughout the study would make reference to the structural implications of this location.

Alternative location - KK/QAT car park underground level

The structural implication of placing an Energy Centre at KK/QAT top level and the cost of the consequential counter-measures may be adequate to render the proposed location unfeasible. As a result, alternative location will be required. There several proposals made with regards to alternative locations in the vicinity of the eastern side of the city.

One immediate alternative is to move the proposed location from the top-level of the KK/QAT car park to somewhere in the basement. This will negate issues with structural loading, albeit issues with height clearance between floors may now be an issue and will have to be assessed in more detail. Access when locating the plant equipment during construction and installation of the Energy Centre will also then be less of an engineering feat, therefore reducing the cost of construction considerably. The downside is the loss of parking spaces at this level.

The council has expressed concern over the loss of revenue should spaces from the basement of the car park were to be used for an Energy Centre. These spaces are in full use throughout the year unlike the spaces on the top floor. Cost benefit analysis to determine the whether the amount of space required and hence the direct loss of revenue to make way for the Energy Centre can be outweighed by the benefits of the DH scheme in place for the city. It will be a difficult decision for the council to make and it would be essential for the DH scheme the right balance could be brought to the table.

An innovative supplement to this proposal would then be to use the unrecoverable waste heat from the Energy Centre CHP engines to heat the floor of top level car park so that it does not freeze over during winter months, rendering the space usable again. This way, the loss of car parking spaces from the underground levels to the Energy Centre could be recovered from revived spaces on the top-level. The construction of a light-weight roof structure over this top level would help alleviate the problem with ice formation further and also favour the levelling of the lopsidedness of the Kelsey Kerridge building. Further study would be required to consider the feasibility of this approach.

Energy Centre 2 – University of Cambridge

The council has also put forward the potential of a location for a second Energy Centre to serve the city-wide DH scheme somewhere within the University of Cambridge precinct. Considering the fact that the University is the major energy consumer in the western area of the city, the rationale would be to locate an Energy Centre in the vicinity of this large energy demand. The benefit would be two-fold as not only there will potentially be a significant reduction in DH pipe cost related to pipe dimensions over long distance if the supply were to come from KK/QAT, but also the ability to set up infrastructure for direct use of electricity generated by the Energy Centre located here. The associated cost with this setup should also be optimised compared to a case where private wire that has to travel long distances, again from KK/QAT if the intention is to persist with direct use of electricity. The effect on revenue from electricity sales for different setups would be covered in section 4.

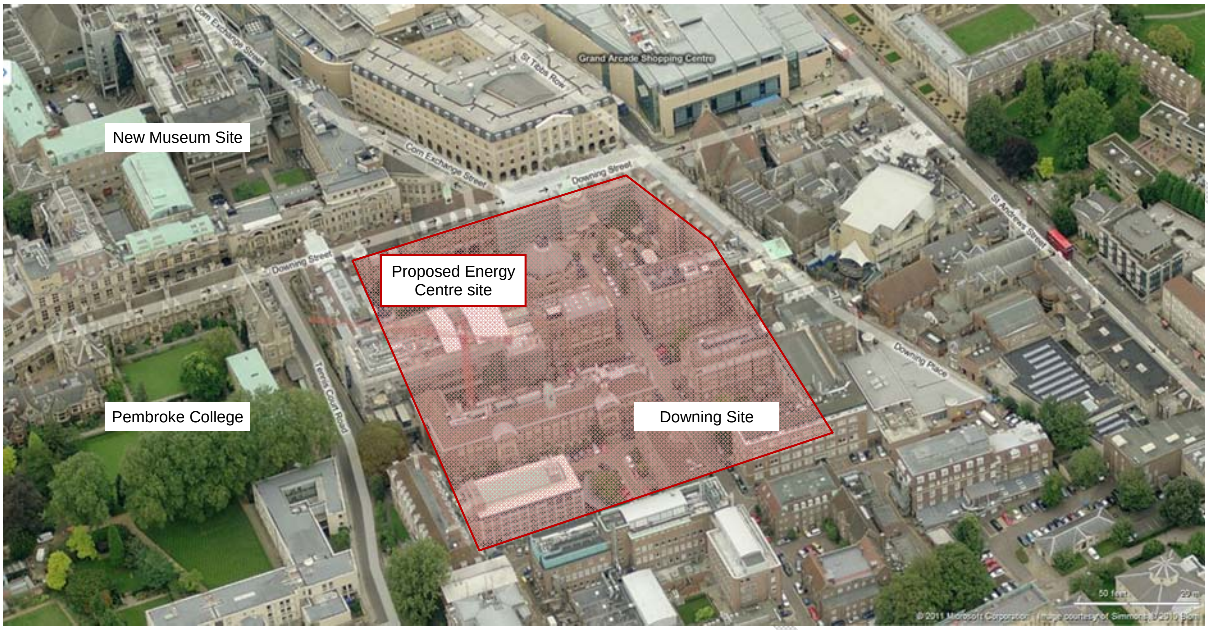
There is also a large incentive for uptake for the University as utilising its land for locating an Energy Centre would automatically command them at least an indirect influence over the operations and the development strategy of the DH scheme. The current notion suggests that the University is open to this idea and would accommodate discussion of any proposal put forward.

Unfortunately, the exact location for an Energy Centre is yet to be determined due to the dense build-up topography in this area. Therefore, whilst difficulty in locating a suitable location will be the primary concern, the constraints of available quantity of space will be another major issue. Pertaining this, the issue of air quality management will be another factor that must be closely looked at.

However, in terms of available of a possible location, there are constantly plans for refurbishment and redevelopment in the pipeline and at the moment, the New Museum Site is undergoing some construction and refurbishment work. It is probably too late to incorporate an Energy Centre at this stage but it is an example that similar opportunities may arise in the coming days.

Capabilities on project:
Building Engineering

For the interest of aiding discussion and analysis in this study, an indicative site was proposed, which is the Downing Site as shown in Figure 20 and specifically the Energy Centre is situated in the area shaded in red. More work would be required to establish the overall suitability of a location within the University precinct.



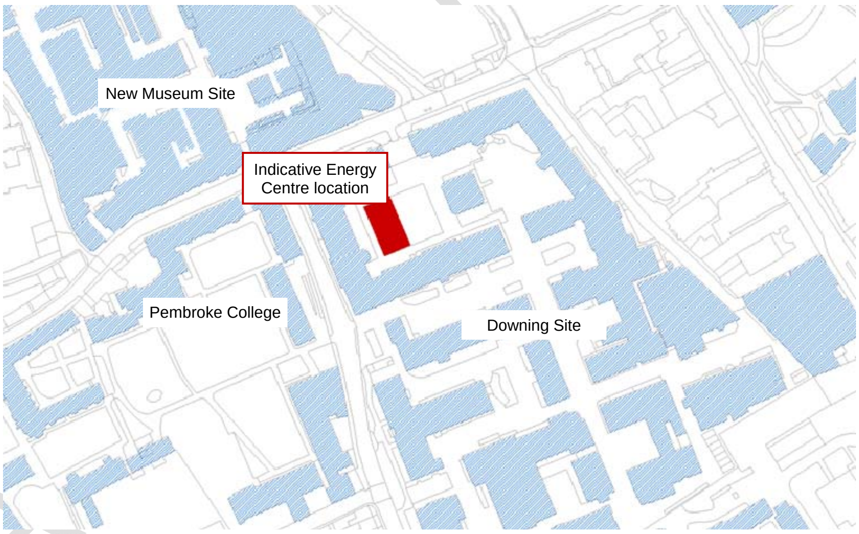


Figure 20: Proposed Energy Centre 2 location within the University of Cambridge precinct. An indicative location was loosely made in the Downing Site with the intention to aid discussion and the study.

Other Energy Centre locations considered

Mill Road Depot

The redevelopment of the Mill Road Depot, which is council-owned, opens up the opportunity to consider the possibility of incorporating an Energy Centre to serve not only the new development but as the source of energy generation for this DH scheme. As the redevelopment of this predominantly brown field site and generally open space (see Figure 21), and that currently plans are unknown and timeline unclear, there should be plenty of room to manoeuvre in a proposal for an Energy Centre to be incorporated.

The added benefit of this site is that it is situated at the boundary of the Air Quality Management Area, implying the potential of slightly relaxed planning requirements with relation to air quality. This favours locating an Energy Centre here where it is perceived that the impact of its flue pollutant dispersion will be minimal on the city centre. It also opens up the added opportunity to consider the use of alternative fuel, e.g. biomass at the Energy Centre at a later stage.

The downside of this location would be the additional distance the DH network would have to cover to deliver energy to the demands. This is approximately 800m mainly along Mill Road and the excavation work on route will mainly be hard-dig, although some portion may be soft-dig if a route on fringes of the University of Cambridge Cricket Ground parallel to Wollaston Road is possible. This would undoubtedly represent additional cost of the overall scheme, which would be balanced by a reduction in Energy Centre construction cost at this location and the absence of complexity associated with Energy Centre at the KK/QAT car park.

Figure 21: The location of the Mill Road depot earmarked for redevelopment where there could be an opportunity to propose an Energy Centre.

Energy centre on Parkers Piece

There was a proposal that the potential of Parkers Piece as an Energy Centre location should be investigated. However, a number of issues were immediately highlighted by the council, the most important being that Parkers Piece is protected public open space, mostly for its recreational and amenity value, which any loss of that would be met with considerable objections. Changes to the original look of Parkers Piece would make a negative impact on it as an historic feature of the city and subsequently on the conservation area as a whole. The council has express that there would not be much support for this proposal internally within the council and most probably similar sentiment would transpire from the local community, and it would be seen as a last resort should no other suitable location can be found.

Network options

Analysis of the energy demands and from an internal AECOM workshop comprising DH experts led to the development of three network options for Cambridge City, listed below along with a Base Case, defined for the purpose for comparison:

- **Base Case.** A single scheme closely resembling the one examined by E.On, but includes several additional small buildings, whilst excluding several of the original buildings considered. The energy centre is located at the Kelsey Kerridge / Queen Anne Terrace (KK/QAT) car park area.
- **Option 1.** A single scheme comprising the eastern area (as examined by E.On) and the higher density western area. The energy centre is located at the Kelsey Kerridge / Queen Anne Terrace car park area.
- **Option 2.** A single DH scheme covering the same area as Option 1, but with two energy centres, one located at KK/QAT car park, and the other located somewhere within the New Museums Site/ Downing Site. Removal of a section of the DH network could effectively split the scheme into two hydraulically separate networks (this sub-option is not presently considered as there will be advantages in terms of flexibility and security of supply in linking the two areas together).
- **Option 3.** A single DH scheme based in the western area supplied from an energy centre at the New Museums/Downing site, with two separate CHP systems on the KK/QAT car park and ARU sites in the eastern area.

These network options are discussed in more detail below.

Base Case

Based closely on the E.On's original DH scheme, the Base Case was derived primarily as a compactor against which subsequent options are benchmarked. Several originally considered buildings were dropped whilst several others in the vicinity were added to form the Base Case. In summary, these are:

- **Excluded buildings from original study**
  - Grafton Centre
  - MacKay Site
  - Redevelopment of Police Station
  - Parkside Community College
- **Added buildings**
  - Gonville Hotel
  - Hughes Hall

Figure 22 shows the proposed DH network for the Base Case with potential extension to the Young Street area and to the far end of Mill Road where the redevelopment of the Mill Road Depot is situated. The analysis carried out only covers the core area of the Base Case scheme, i.e. not including buildings at the extensions. Table 4 lists all the buildings in the study, indicating ones included in the analysis of this option.

Capabilities on project:
Building Engineering

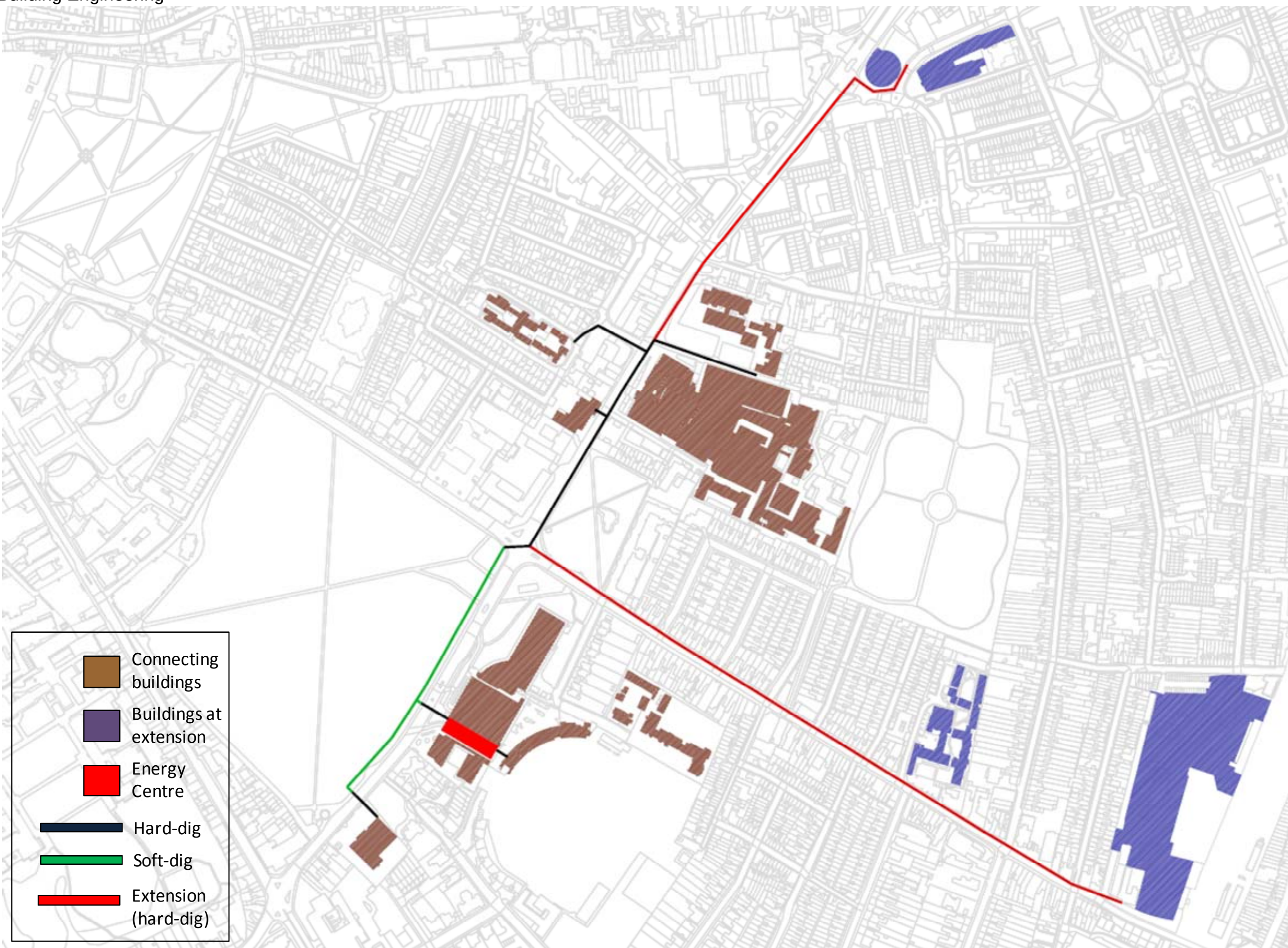


Figure 22: Map showing the Base Case DH network with possible extension to the far eastern side to the Young Street area and towards the far end of Mill Road

Ind	Include	Code	Building Name	TOTAL floor area (estimated) [m²]	ENERGY TOTAL heat [MWh]	ENERGY TOTAL electricity [MWh]	In Option
			TOTAL	78,204.05	11,175	9,030	
1		E001	Anglian-Ruskin University (ARU)	44,266	4,127.02	4,549.14	
2		E002	Mackays site	-	-	-	
3		E003	Parkside Pool (PP)	3,415	2,743.69	1,456.84	
4		E004	Kelsey Kerridge (KK) sports centre & QAT	4,400	380.74	779.59	
5		E005	Mill Road Depot	27,000	1,802.25	1,620.00	
6		E006	Redevelopment of the police station site	-	-	-	
7		E007	Brandon Court	2,807	490.08	97.70	
8		E008	Ditchburn Place	2,420	675.24	274.93	
9		E009	YMCA	3,739	224.34	229.52	
10		E010	Cambridge Crown Court	4,031	226.14	362.79	
11		E011	Civil Justice Centre Cambridge County Court	3,500	420.00	416.50	
12		E012	Grafton Centre	-	-	-	
13		E013	St Matthew's School	3,342	500.33	188.51	
14		E014	Parkside Community College	-	-	-	
15		E015	Youngs site, ARU Phase 1	2,284	54.19	127.45	
16		E016	Youngs site, ARU Phase 2	1,323	32.45	74.40	
17		E017	Youngs site, ARU Phase 3	1,523	38.38	86.20	
18		E018	Youngs site, ARU Existing Reception	230	5.80	13.02	
19		E019	Mandela House	3,422	337.04	479.45	
20		E020	Gonville Hotel	3,792	581.31	456.14	
21		E021	Emmanuel College	19,753	3,519.94	1,264.99	
22		E022	Pembroke College	12,962	2,278.65	968.74	
23		E023	Downing College	22,159	3,948.65	1,419.07	
24		E024	Hughes Hall	8,943	1,707.47	855.75	
25		E025	Peterhouse College	11,920	2,124.05	595.74	
26		E026	Christ's College	9,593	1,709.23	614.34	
27		E027	New Museum's site (Uni area code M)	56,669	2,682.40	11,444.00	
28		E028	Downing site (Uni area code D)	61,022	5,955.60	14,474.00	
29		E029	Old Addenbrooke's site (Uni area code E)	46,628	4,690.00	14,227.00	
30		E030	Silver Street/Mill Lane site	25,240	2,095.80	2,741.00	
31		E031	Fitzwilliam Museum	13,856	753.20	1,672.00	
32		E032	Chemistry, Unilever, ScottPolarInstiture	9,404	5,815.50	11,284.00	
33		E033	Uni Bdg no 32 - Eng Uni bdg no 4 – Scroope Terrace (	62,046	5,256.00	7,643.00	
34		E034	Royal Cambridge Hotel	-	-	-	
35		E035	Hotel Du Vin, Trumpington Street	-	-	-	
36		E036	Hilton Garden House Hotel	-	-	-	
37		E037	Crowne Plaza Hotel	-	-	-	
38		E038	University Arms Hotel	4,182	1,034.97	439.08	
39		E039	Grand Arcade	-	-	-	
40		E040	Lion Yard	-	-	-	
41		E041	Leys School	-	-	-	
42		E042	St Mary's School	-	-	-	
43		E043	St Catherine's College	-	-	-	
44		E044	Queens' College	-	-	-	
45		E045	Corpus Christi College	-	-	-	
46		E046	King's College	-	-	-	
47		E047	Old Schools Site	-	-	-	
48		E048	Clare College	-	-	-	
49		E049	Gonville & Caius College	-	-	-	
50		E050	Trinity College	-	-	-	
51		E051	St John's College	-	-	-	
52		E052	Perse School	-	-	-	
53		E053	St Albans School	1,404	102.08	88.08	
54		E054	The Corn Exchange	850	611.84	493.27	
55		E055	The Guildhall	10,447	1,541.13	507.92	

Table 4 List of buildings, where connected sites/buildings in Base Case are indicated

Option 1

The Option 1 scheme is illustrated in Figure 23 showing the location of the buildings, which could be connected, the DH network route (including areas of hard dig and soft dig) and the energy centre location (shown in red). The following points should be noted:

- At the very eastern end, the only loads considered for connection are the ARU campus, the neighbouring St Matthews Primary school, Brandon Court (residences owned by the Council) and the Civil Justice Centre. These are all located in close proximity and the network length to connect them is relatively small.
- The loads previously identified along Mill Road are either considered too small (Ditchburn Place, residences owned by the Council) or uncertain (the Mill Road Council Depot) to justify the construction of a network in the first phase. In addition, Mill Road is a busy road and the construction of a network would cause significant disruption, hence requiring complex traffic and diversion management if further pursued.
- The Courts have relatively small heat demands and the servicing is understood to be via a PFI arrangement, whilst the future of the Mackays site is uncertain, but again it is likely have a relatively small heat load (due to its use for new build residences), hence limiting the extent of the heat network to the St Matthews Primary school.
- The network extends south-west from the energy centre to the Gonville Hotel and Chemistry department. Part of this route (a soft dig along the side of Parkers Piece) is required to reach the western area. The remainder of the leg is to reach the Chemistry department along Lensfield Road and this route is similar in length to the alternative route of reaching the Chemistry department from the Western area, but this limits the additional capacity on other parts of the network that would be required for this alternative route.
- The network around Parkers Piece is shown as soft dig and assumed to be installed away from the roads within the grassed area. The selection of route alongside roads is to limit the network length – a diagonal connection across Parkers Piece would require additional pipes to reach some of the loads on the south-west along Lensfield Road.
- Within the western area, the network is assumed to pass within the Downing Site and the New Museums Site where possible, to limit disruption to through roads. In particular, this proposed route would keep to a single crossing point over Downing Street because the installation of a network along this route would be extremely disruptive to traffic.
- The furthest extent of the network in the North is the Guildhall. This is adjacent to the New Museums site, provides a public sector load (and the associated lower risk).

It can be seen from the Option 1 layout in Figure 23 that there are two distinct network neighbourhoods central in the west (Downing Site and New Museums) and the east (ARU campus). The proposed Energy Centre at KK/QAT is located between these areas on the Council's own property and therefore the pipes to connect the energy centre to the two areas are relatively long (albeit there are areas of soft dig reducing the cost). This spatial distribution perhaps indicates that the energy centre is in a sub optimal location although the benefit of the heat loads at the site (Kelsey Kerridge leisure centre and the Parkside Pool) will help to improve the overall viability of the scheme in this option.

Capabilities on project:
Building Engineering

Figure 23: Map showing the Option 1 DH network covering city wide connecting the eastern and western part of the city with proposed Energy Centre at KK/QAT

Ind	Include	Code	Building Name	TOTAL floor area (estimated) [m²]	ENERGY TOTAL heat [MWh]	ENERGY TOTAL electricity [MWh]	In Option
			TOTAL	440,166.50	53,922	78,771	
1	✓	E001	Anglian-Ruskin University (ARU)	44,266	4,127.02	4,549.14	✓
2	✗	E002	Mackays site	-	-	-	✗
3	✓	E003	Parkside Pool (PP)	3,415	2,743.69	1,456.84	✓
4	✓	E004	Kelsey Kerridge (KK) sports centre & QAT	4,400	380.74	779.59	✓
5	✓	E005	Mill Road Depot	27,000	1,802.25	1,620.00	✗
6	✗	E006	Redevelopment of the police station site	-	-	-	✗
7	✓	E007	Brandon Court	2,807	490.08	97.70	✓
8	✓	E008	Ditchburn Place	2,420	675.24	274.93	✗
9	✓	E009	YMCA	3,739	224.34	229.52	✓
10	✓	E010	Cambridge Crown Court	4,031	226.14	362.79	✗
11	✓	E011	Civil Justice Centre Cambridge County Court	3,500	420.00	416.50	✓
12	✗	E012	Grafton Centre	-	-	-	✗
13	✓	E013	St Matthew's School	3,342	500.33	188.51	✓
14	✗	E014	Parkside Community College	-	-	-	✗
15	✓	E015	Youngs site, ARU Phase 1	2,284	54.19	127.45	✗
16	✓	E016	Youngs site, ARU Phase 2	1,323	32.45	74.40	✗
17	✓	E017	Youngs site, ARU Phase 3	1,523	38.38	86.20	✗
18	✓	E018	Youngs site, ARU Existing Reception	230	5.80	13.02	✗
19	✓	E019	Mandela House	3,422	337.04	479.45	✓
20	✓	E020	Gonville Hotel	3,792	581.31	456.14	✓
21	✓	E021	Emmanuel College	19,753	3,519.94	1,264.99	✓
22	✓	E022	Pembroke College	12,962	2,278.65	968.74	✓
23	✓	E023	Downing College	22,159	3,948.65	1,419.07	✓
24	✓	E024	Hughes Hall	8,943	1,707.47	855.75	✓
25	✓	E025	Peterhouse College	11,920	2,124.05	595.74	✓
26	✓	E026	Christ's College	9,593	1,709.23	614.34	✗
27	✓	E027	New Museum's site (Uni area code M)	56,669	2,682.40	11,444.00	✓
28	✓	E028	Downing site (Uni area code D)	61,022	5,955.60	14,474.00	✓
29	✓	E029	Old Addenbrooke's site (Uni area code E)	46,628	4,690.00	14,227.00	✓
30	✓	E030	Silver Street/Mill Lane site	25,240	2,095.80	2,741.00	✓
31	✓	E031	Fitzwilliam Museum	13,856	753.20	1,672.00	✓
32	✓	E032	Chemistry, Unilever, ScottPolarInstiture	9,404	5,815.50	11,284.00	✓
33	✓	E033	Uni Bdg no 32 - Eng Uni bdg no 4 – Scroope Terrace (	62,046	5,256.00	7,643.00	✓
34	✗	E034	Royal Cambridge Hotel	-	-	-	✗
35	✗	E035	Hotel Du Vin, Trumpington Street	-	-	-	✗
36	✗	E036	Hilton Garden House Hotel	-	-	-	✗
37	✗	E037	Crowne Plaza Hotel	-	-	-	✗
38	✓	E038	University Arms Hotel	4,182	1,034.97	439.08	✓
39	✗	E039	Grand Arcade	-	-	-	✗
40	✗	E040	Lion Yard	-	-	-	✗
41	✗	E041	Leys School	-	-	-	✗
42	✗	E042	St Mary's School	-	-	-	✗
43	✓	E043	St Catherine's College	-	-	-	✗
44	✓	E044	Queens' College	-	-	-	✗
45	✓	E045	Corpus Christi College	-	-	-	✗
46	✓	E046	King's College	-	-	-	✗
47	✓	E047	Old Schools Site	-	-	-	✗
48	✓	E048	Clare College	-	-	-	✗
49	✓	E049	Gonville & Caius College	-	-	-	✗
50	✓	E050	Trinity College	-	-	-	✗
51	✓	E051	St John's College	-	-	-	✗
52	✗	E052	Perse School	-	-	-	✗
53	✓	E053	St Albans School	1,404	102.08	88.08	✓
54	✓	E054	The Corn Exchange	850	611.84	493.27	✓
55	✓	E055	The Guildhall	10,447	1,541.13	507.92	✓

Table 5 List of buildings, where connected sites/buildings in Option 1 are indicated

Option 2

The Option 2 scheme is identical to the Option 1 scheme in terms of the heat loads connected and the layout of the network. However, due to the clear distinction between the eastern and western areas, two energy centres are proposed. The Kelsey Kerridge leisure centre / Queen Anne Car park is retained as location for an Energy Centre, primarily to serve the ARU and neighbouring sites, and the network which extends down to the Chemistry department.

The second Energy Centre is assumed to be located somewhere within the Downing Site providing heat to the western part of the network. An indicative location is shown in Figure 24, although the exact location of this second Energy Centre is unlikely to have a large impact on the design of the DH network in this area. Further work will be required to ascertain the suitability of sites in terms of availability, access, services, and planning considerations. However, it is assumed that a suitable site could be found somewhere within the western network region.

One argument that arises is that if pipe connecting the western and eastern parts of the scheme along the south-west side of Parkers Piece is removed, it would allow essentially two schemes to operate separately with a small saving in capital costs. However, the inclusion of the connection would allow for resilience and the soft dig and location of the pipe means that the additional cost for this section could be relatively low. As a result this link has been retained in the costs and economic analysis.

With the availability of two Energy Centre in this option, it is assumed that the total CHP capacity for this scheme to be split equally. There are other sets of argument that support this approach, which relates to space constraints in one hand and structural implication in the other as discussed earlier.

Capabilities on project:
Building Engineering

Figure 24: Map showing the Option 2 DH network covering city wide connecting the eastern and western part of the city with proposed Energy Centre at KK/QAT and at the vicinity of Downing Site where marked location is indicative and to aid discussion

Ind	Include	Code	Building Name	TOTAL floor area (estimated) [m²]	ENERGY TOTAL heat [MWh]	ENERGY TOTAL electricity [MWh]	In Option
			TOTAL	440,166.50	53,922	78,771	
1		E001	Anglian-Ruskin University (ARU)	44,266	4,127.02	4,549.14	
2		E002	Mackays site	-	-	-	
3		E003	Parkside Pool (PP)	3,415	2,743.69	1,456.84	
4		E004	Kelsey Kerridge (KK) sports centre & QAT	4,400	380.74	779.59	
5		E005	Mill Road Depot	27,000	1,802.25	1,620.00	
6		E006	Redevelopment of the police station site	-	-	-	
7		E007	Brandon Court	2,807	490.08	97.70	
8		E008	Ditchburn Place	2,420	675.24	274.93	
9		E009	YMCA	3,739	224.34	229.52	
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11		E011	Civil Justice Centre Cambridge County Court	3,500	420.00	416.50	
12		E012	Grafton Centre	-	-	-	
13		E013	St Matthew's School	3,342	500.33	188.51	
14		E014	Parkside Community College	-	-	-	
15		E015	Youngs site, ARU Phase 1	2,284	54.19	127.45	
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18		E018	Youngs site, ARU Existing Reception	230	5.80	13.02	
19		E019	Mandela House	3,422	337.04	479.45	
20		E020	Gonville Hotel	3,792	581.31	456.14	
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25		E025	Peterhouse College	11,920	2,124.05	595.74	
26		E026	Christ's College	9,593	1,709.23	614.34	
27		E027	New Museum's site (Uni area code M)	56,669	2,682.40	11,444.00	
28		E028	Downing site (Uni area code D)	61,022	5,955.60	14,474.00	
29		E029	Old Addenbrooke's site (Uni area code E)	46,628	4,690.00	14,227.00	
30		E030	Silver Street/Mill Lane site	25,240	2,095.80	2,741.00	
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33		E033	Uni Bdg no 32 - Eng Uni bdg no 4 – Scroope Terrace (	62,046	5,256.00	7,643.00	
34		E034	Royal Cambridge Hotel	-	-	-	
35		E035	Hotel Du Vin, Trumpington Street	-	-	-	
36		E036	Hilton Garden House Hotel	-	-	-	
37		E037	Crowne Plaza Hotel	-	-	-	
38		E038	University Arms Hotel	4,182	1,034.97	439.08	
39		E039	Grand Arcade	-	-	-	
40		E040	Lion Yard	-	-	-	
41		E041	Leys School	-	-	-	
42		E042	St Mary's School	-	-	-	
43		E043	St Catherine's College	-	-	-	
44		E044	Queens' College	-	-	-	
45		E045	Corpus Christi College	-	-	-	
46		E046	King's College	-	-	-	
47		E047	Old Schools Site	-	-	-	
48		E048	Clare College	-	-	-	
49		E049	Gonville & Caius College	-	-	-	
50		E050	Trinity College	-	-	-	
51		E051	St John's College	-	-	-	
52		E052	Perse School	-	-	-	
53		E053	St Albans School	1,404	102.08	88.08	
54		E054	The Corn Exchange	850	611.84	493.27	
55		E055	The Guildhall	10,447	1,541.13	507.92	

Table 6 List of buildings, where connected sites/buildings in Option 2 are indicated

Option 3

Options 1 and 2 are both effectively extensions of the original feasibility work, with the concept of a heat network connected to ARU and neighbouring areas, and an Energy Centre at the Kelsey Kerridge leisure centre / Queen Anne car park. The following points can be observed from the maps of these two options and the associated load data:

- ARU represents the largest load in the eastern area and could support a CHP scheme on its own site. This could extend to neighbouring sites.
- The original location for the energy centre at Kelsey Kerridge leisure centre / Queen Ann car park is relatively isolated with respect to the eastern and western load areas.
- The heat load at the Chemistry Department and Neighbouring buildings could be connected to the western part of the scheme with a similar length (or possible a slightly reduced length) DH connection.

The above points suggest that the focus of a heat network should be in the western area, with standalone schemes in the eastern area, based around ARU. The Chemistry department and neighbouring loads could be connected directly to the western area from along Tennis Court Road. The development of CHP at the Kelsey Kerridge leisure centre and Parkside Pool, potentially linking to the Gonville Hotel will be subject to the viability of a site based scheme. The map in Figure 25 illustrates this third option with the DH scheme Energy Centre located in the University site.

It was highlighted that it would not be reasonable for the standalone CHP schemes at Kelsey Kerridge or ARU to subsidise this western scheme. Furthermore, this would detract from the original concept of a city-wide scheme, which has always been the strong intention of the client. To exclude the Parkside Pool complex from the city-wide scheme would be politically unacceptable to the client. Also, in the interim report, it was shown that this option has not projected a good return in investment as originally anticipated. Therefore, no further analysis has been carried out and reported in this report.

Capabilities on project:
Building Engineering

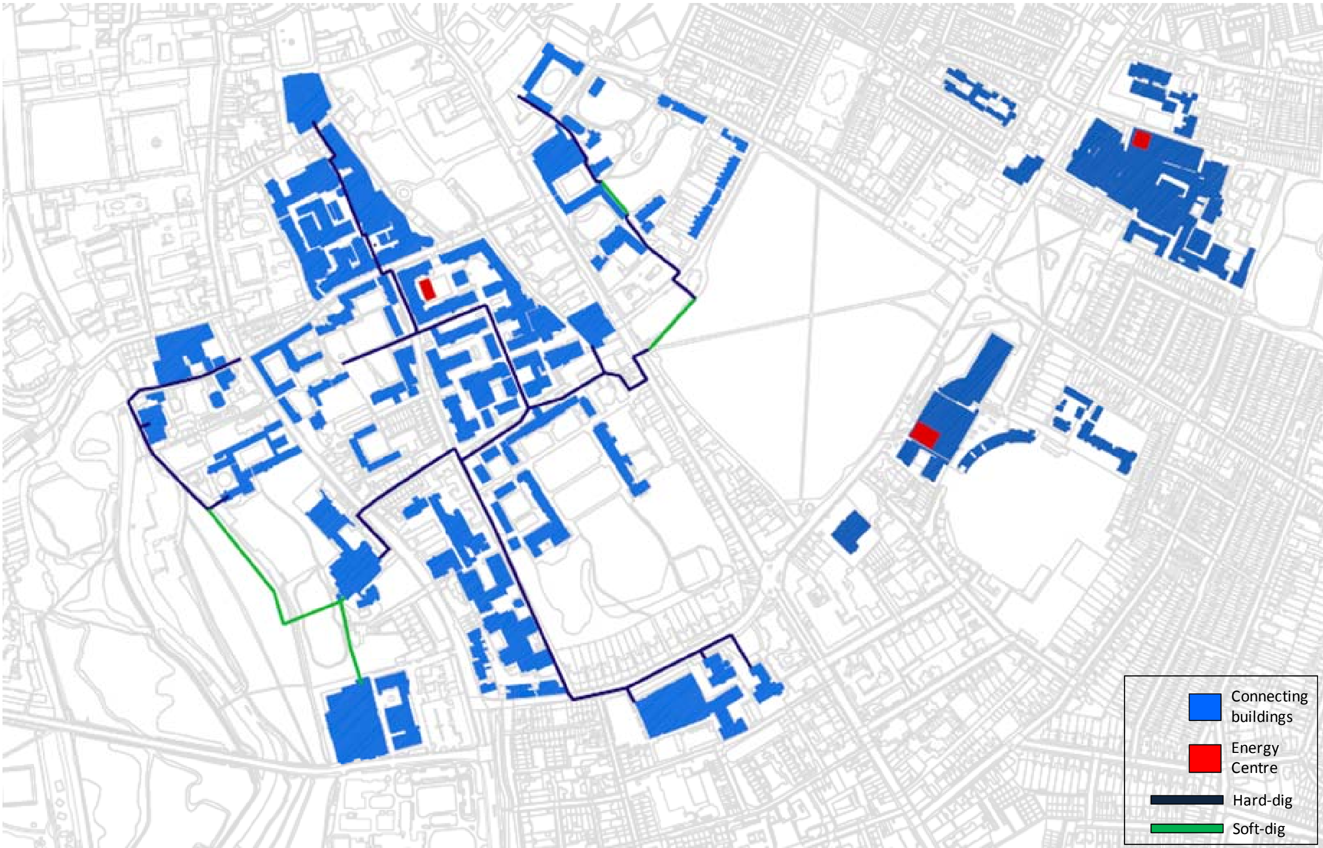

Figure 25: Map showing the Option 3 DH network covering city wide covering only the western part of the city with proposed Energy Centre in the vicinity of Downing Site. There are possibly separate schemes for the Parkside Pool area and the ARU

Ind	Include	Code	Building Name	TOTAL floor area (estimated) [m²]	ENERGY TOTAL heat [MWh]	ENERGY TOTAL electricity [MWh]	In Option
			TOTAL	351,154.93	36,829	58,369	
1	✓	E001	Anglian-Ruskin University (ARU)	44,266	4,127.02	4,549.14	✗
2	✗	E002	Mackays site	-	-	-	✗
3	✓	E003	Parkside Pool (PP)	3,415	2,743.69	1,456.84	✗
4	✓	E004	Kelsey Kerridge (KK) sports centre & QAT	4,400	380.74	779.59	✗
5	✓	E005	Mill Road Depot	27,000	1,802.25	1,620.00	✗
6	✗	E006	Redevelopment of the police station site	-	-	-	✗
7	✓	E007	Brandon Court	2,807	490.08	97.70	✗
8	✓	E008	Ditchburn Place	2,420	675.24	274.93	✗
9	✓	E009	YMCA	3,739	224.34	229.52	✗
10	✓	E010	Cambridge Crown Court	4,031	226.14	362.79	✗
11	✓	E011	Civil Justice Centre Cambridge County Court	3,500	420.00	416.50	✗
12	✗	E012	Grafton Centre	-	-	-	✗
13	✓	E013	St Matthew's School	3,342	500.33	188.51	✗
14	✗	E014	Parkside Community College	-	-	-	✗
15	✓	E015	Youngs site, ARU Phase 1	2,284	54.19	127.45	✗
16	✓	E016	Youngs site, ARU Phase 2	1,323	32.45	74.40	✗
17	✓	E017	Youngs site, ARU Phase 3	1,523	38.38	86.20	✗
18	✓	E018	Youngs site, ARU Existing Reception	230	5.80	13.02	✗
19	✓	E019	Mandela House	3,422	337.04	479.45	✓
20	✓	E020	Gonville Hotel	3,792	581.31	456.14	✗
21	✓	E021	Emmanuel College	19,753	3,519.94	1,264.99	✓
22	✓	E022	Pembroke College	12,962	2,278.65	968.74	✓
23	✓	E023	Downing College	22,159	3,948.65	1,419.07	✓
24	✓	E024	Hughes Hall	8,943	1,707.47	855.75	✗
25	✓	E025	Peterhouse College	11,920	2,124.05	595.74	✓
26	✓	E026	Christ's College	9,593	1,709.23	614.34	✗
27	✓	E027	New Museum's site (Uni area code M)	56,669	2,682.40	11,444.00	✓
28	✓	E028	Downing site (Uni area code D)	61,022	5,955.60	14,474.00	✓
29	✓	E029	Old Addenbrooke's site (Uni area code E)	46,628	4,690.00	14,227.00	✓
30	✓	E030	Silver Street/Mill Lane site	25,240	2,095.80	2,741.00	✓
31	✓	E031	Fitzwilliam Museum	13,856	753.20	1,672.00	✓
32	✓	E032	Chemistry, Unilever, ScottPolarInstiture	9,404	5,815.50	11,284.00	✗
33	✓	E033	Uni Bdg no 32 - Eng Uni bdg no 4 – Scroope Terrace (	62,046	5,256.00	7,643.00	✓
34	✗	E034	Royal Cambridge Hotel	-	-	-	✗
35	✗	E035	Hotel Du Vin, Trumpington Street	-	-	-	✗
36	✗	E036	Hilton Garden House Hotel	-	-	-	✗
37	✗	E037	Crowne Plaza Hotel	-	-	-	✗
38	✓	E038	University Arms Hotel	4,182	1,034.97	439.08	✓
39	✗	E039	Grand Arcade	-	-	-	✗
40	✗	E040	Lion Yard	-	-	-	✗
41	✗	E041	Leys School	-	-	-	✗
42	✗	E042	St Mary's School	-	-	-	✗
43	✓	E043	St Catherine's College	-	-	-	✗
44	✓	E044	Queens' College	-	-	-	✗
45	✓	E045	Corpus Christi College	-	-	-	✗
46	✓	E046	King's College	-	-	-	✗
47	✓	E047	Old Schools Site	-	-	-	✗
48	✓	E048	Clare College	-	-	-	✗
49	✓	E049	Gonville & Caius College	-	-	-	✗
50	✓	E050	Trinity College	-	-	-	✗
51	✓	E051	St John's College	-	-	-	✗
52	✗	E052	Perse School	-	-	-	✗
53	✓	E053	St Albans School	1,404	102.08	88.08	✗
54	✓	E054	The Corn Exchange	850	611.84	493.27	✓
55	✓	E055	The Guildhall	10,447	1,541.13	507.92	✓

Table 7 List of buildings, where connected sites/buildings in Option 3 are indicated

Highlights of the proposed DH routes

It is essential at this point in the report to highlight on several areas of the proposed DH routes for discussion and to emphasise for attention. Considerable amount of thought and analysis have gone into the planning and proposal of the DH routes, taking into account a range of parameters and factors. These are aimed at:

- optimising/minimising DH pipe trench and length
- minimising disruption to main traffic and access trunks around the city
- minimising excavation cost by utilising soft ground as much as possible
- optimising on DH pipe length by using routes of network supplying a particular sites to also serve as a through way to subsequent sites
- using low traffic access routes around the city where possible

The DH route connecting the east and west side of the city to derive a city wide scheme to some extend has been perceived to be costly, however, the use of soft-grounds on Parkers Piece would significantly reduce the overall excavation cost in this section of the network (Figure 26). There is an added advantage of not disrupting any high traffic trunks, hence doing away with traffic management costs and other indirect costs associated with such disruptions. As long as the excavation activity is sympathetic to restoring the ground condition to pre-excavation state as well as being sensitive to the requirements of the covenant in place for Parkers Piece, the proposed route would be all the more favourable.

Figure 26: Bird's eye-view from BingMaps showing Parkers Piece with indicative DH pipe route on soft-ground (partial network shown) along Regent Terrace and Gonville Place

In addition to this, as shown in Figure 27, the use of soft-ground along the back of Fitzwilliam Museum to deliver energy to the Engineering Department site and northwards to the Old Press site would also be a favourable proposition for the scheme. This is also an example in this scheme where the proposed route take the heat pipes supplying energy to a building (Fitzwilliam Museum) through the plantroom area of the building to connect to other sites/buildings. Ultimately, the feasibility of this proposal will need to be evaluated in more detail.

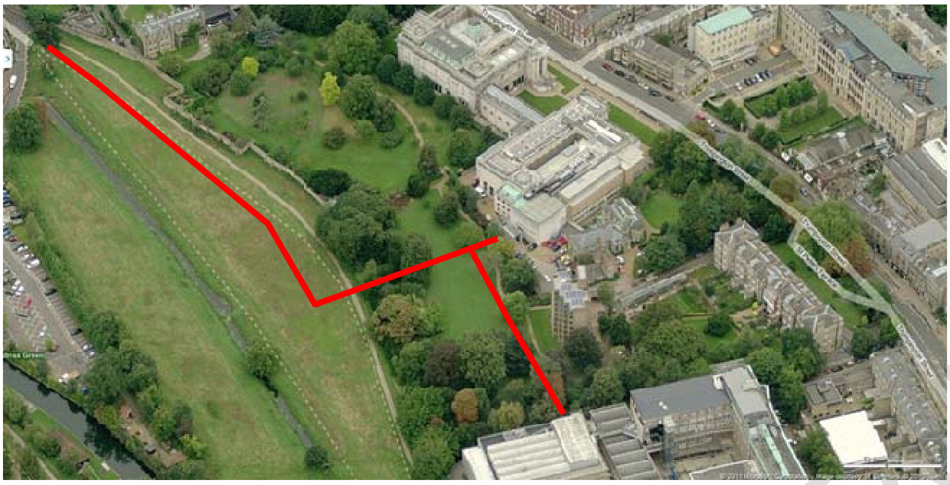

Figure 27: Bird's eye-view from BingMaps showing the soft-ground at the back of Fitzwilliam Museum with indicative DH pipe route (partial network shown) leading northwards to the Old Press site and down to the Engineering Department site.

It is proposed that the New Museum site is used also as a through way for the DH pipes to reach the council's Corn Exchange and the Guildhall buildings as shown in Figure 28. This would allow the same excavated ground to lay secondary pipes connecting to the buildings in this site to be used to also lay pipes that stretches across the site to the Corn Exchange instead of using the busy Corn Exchange Street, which would be extremely disruptive.

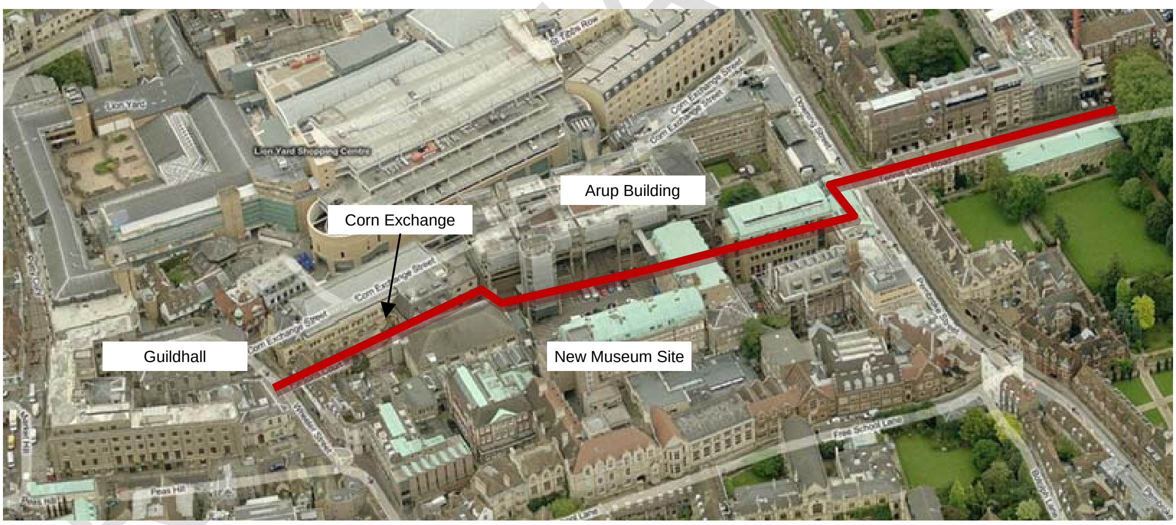

Figure 28: Bird's eye-view from BingMaps showing the proposed DH route across the New Museums site to deliver heat to the Corn Exchange and the Guildhall, with indicative route (partial) marked in red.

Another similar example of this is shown in Figure 29 where the proposed DH route cuts through the Downing site to deliver energy along Tennis Court Road and up to the New Museums Site, whilst also supply heat to the Downing Site buildings.

Whilst this may appear to be a favourable approach avoiding the use of busy main roads as much as possible, more detailed evaluation will be required with regards to excavation within existing building sites. This is because extensive excavation around existing building grounds may run into complex and difficult predicaments due to other services already in the grounds or even, in some cases, the presence of hazardous asbestos material from old installations. All this may lead to route diversion or risk unforeseen uplift in network costs and project delays.

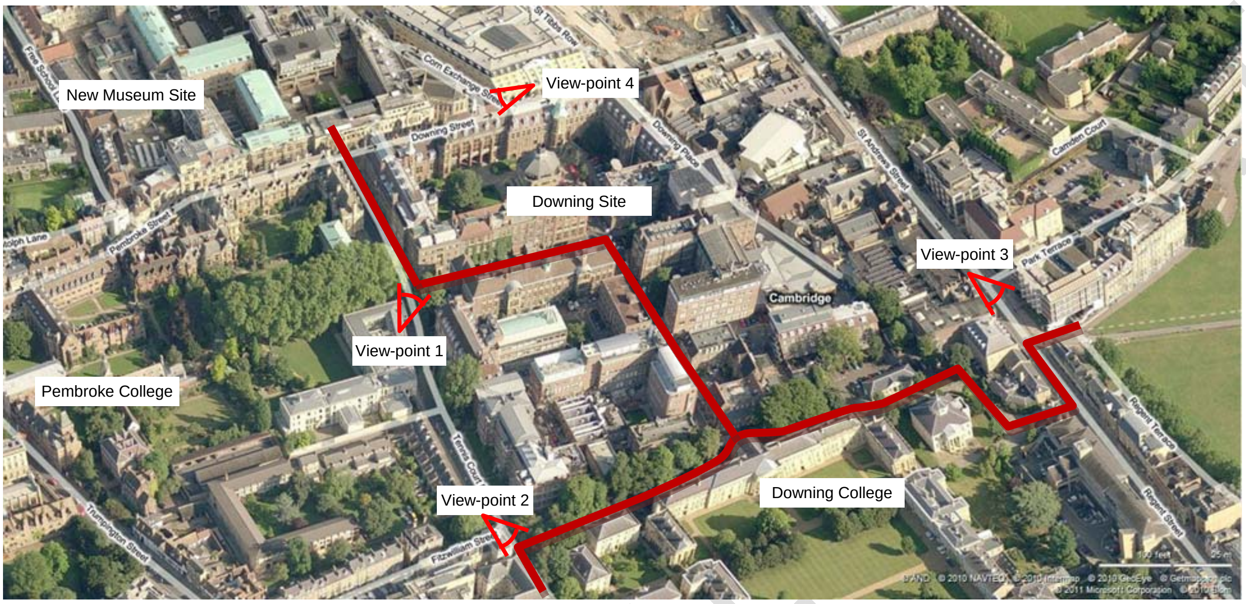

Figure 29: Bird's eye-view from BingMaps showing the use of the Downing Site grounds as through way for the DH route to deliver energy to other sites/buildings thereafter.

The map in Figure 29 is marked with points around the city where the proposed DH route would have to cross roads. During the formulation of the DH routes, consider care has gone into minimising the crossing of roads, therefore the ones that remain in the route are unavoidable and are necessary to connect to sites/buildings for the scheme to be possible.

Figure 30 shows the view from Google StreetView that corresponds to markings in Figure 29 to highlight the type of roads the DH route would be crossing. Most of these roads are busy main traffic trunks, hence good traffic management and planning would be required.

Capabilities on project:
Building Engineering

View-point 1: junction out of Downing Site onto Tennis Court Road opposite Pembroke College heading north towards the New Museum Site and

View-point 2: junction out of Downing College onto Tennis Court Road next to the Old Addenbrokes Site and Fitzwilliam Street

View-point 3: DH route crossing Regent Street, a busy traffic trunk in the city

View-point 4: proposed DH route would have to cross the Downing Street, another busy traffic trunk, to get to the New Museums Site, the Corn Exchange and the Guildhall

Figure 30: Street elevations from Google StreetView of roads around the city where the proposed DH route would have to cross.

Perhaps one of the most disruptive road crossings by the proposed DH route is that required around the Gonville Road-East Road and Mill Road-Parkside intersection shown in Figure 31. This is required to deliver energy to the sites/buildings along East Road and potentially up to the Young Street area. Again, a good traffic management and well-planned construction programme will be required to minimise the impact on traffic flow at this intersection as it is anticipated the work around this area will take considerable time to complete. Figure 32 shows snapshots of the intersection at street level highlighting issues of heavy traffic during peak hours.

Capabilities on project:
Building Engineering

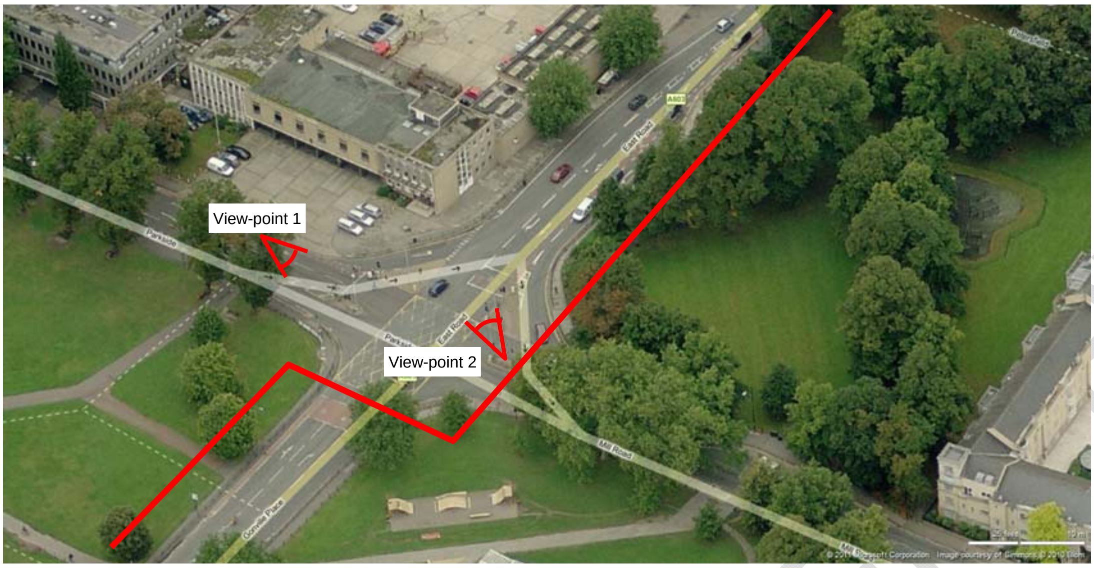

Figure 31: Bird’s eye-view from BingMaps showing the Gonville Road-East Road and Mill Road-Parkside intersection where the proposed DH route would have to cross.

View-point 1: view of Gonville Road-East Road and Mill Road-Parkside intersection from Parkside

View-point 2: view of Gonville Road-East Road and Mill Road-Parkside intersection from Mill Road

Figure 32: Street elevations from Google StreetView of Gonville Road-East Road and Mill Road-Parkside intersection

CHP scheme sizing

This section summarises the sizing of the CHP engines for the different options considered in this study. In general, several criteria were taken into account in the process and these are:

- the extent of heat demand diversity, how this vary throughout a typical day and how the demand changes on a monthly through a typical year
- structural implications
- the number of Energy Centres
- percentage of site heat demand to be met by CHP

To address the items above the following corresponding approaches were adopted:

- considering the site heat demand is fairly diverse, multiple engines were used to provide the flexibility and ability for modulation of CHP capacity to ensure optimum operation and maximise heat demand met by CHP rather than conventional boilers
- potential structural issues at KK/QAT has led to the use of multiple engines of smaller capacity in the effort to distribute overall engine weight and minimise load concentration
- equal number of engine units and capacity were assumed for when the total CHP capacity is split between two Energy Centres
- the CHP plant operation in each scheme was assume to meet 70% of the total site heat energy demand, with the remainder to be met by top-up boilers

Base Case

For the Base Case, the total site heat demand is approximately 11,175MWh. For this the proposed Energy Centre capacity is 2MWth CHP, comprising of 1 unit of 1.6MWth and 1 unit of 0.4MWth CHP engines. This CHP scheme generated approximately 8,000MWh of heat, whilst the remainder are met by top-up boilers.

The site electricity demand is estimated at approximately 9MWh where this can be offset by up to approximately 77% of the 7.3MWh generated by the CHP engines depending on the load matching over the year. Figure 33 shows the annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines.

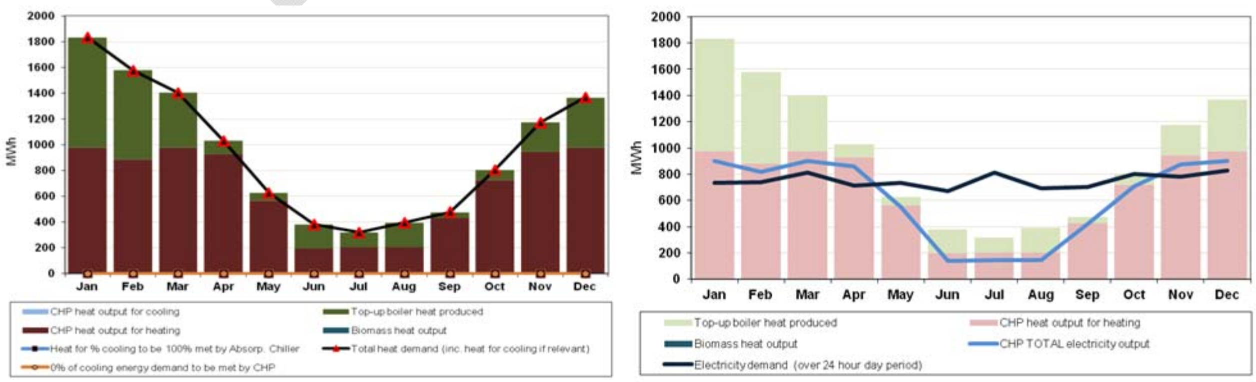

Figure 33: Base Case annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines

Option 1

In Option 1, the total site heat demand is approximately 53,921MWh. For this the proposed Energy Centre capacity is 10.3MWth CHP, comprising of 4 units of 2.2MWth and 1 unit of 1.4MWth CHP engines. This CHP scheme generated approximately 38,621MWh of heat, whilst the remainder are met by top-up boilers.

The site electricity demand is estimated at approximately 78,771MWh where this can be offset by up to an average of 77% of the 34,579MWh generated by the CHP engine sdepending on the load matching over the year. Figure 34 shows the annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines.

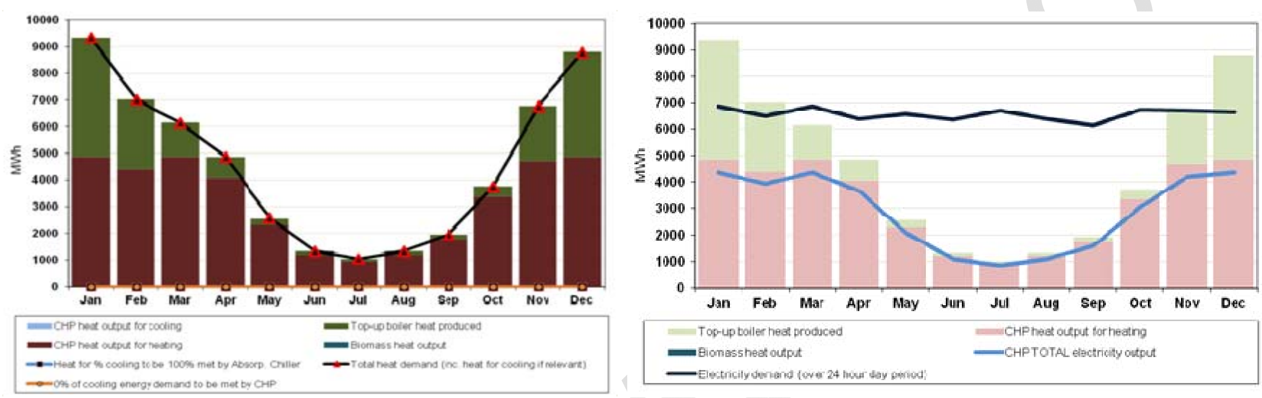

Figure 34: Option 1 annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines

Option 2

Similar to Option 1, Option 2 the total site heat demand is approximately 53,921MWh. As there are two Energy Centres proposed in this option, the total CHP capacity of10.3MWth CHP is split equally, comprising of 2 units of 1.6MWth and 2 units of 0.9MWth CHP engines in each Energy Centre. This CHP scheme generated approximately 38,723MWh of heat, whilst the remainder are met by top-up boilers.

The site electricity demand is as Option 1 at approximately 78,771MWh, a portion of which can by up to an 77% of the 36,556MWh generated by the CHP engines depending on the load matching over the year. Figure 35 shows the annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines.

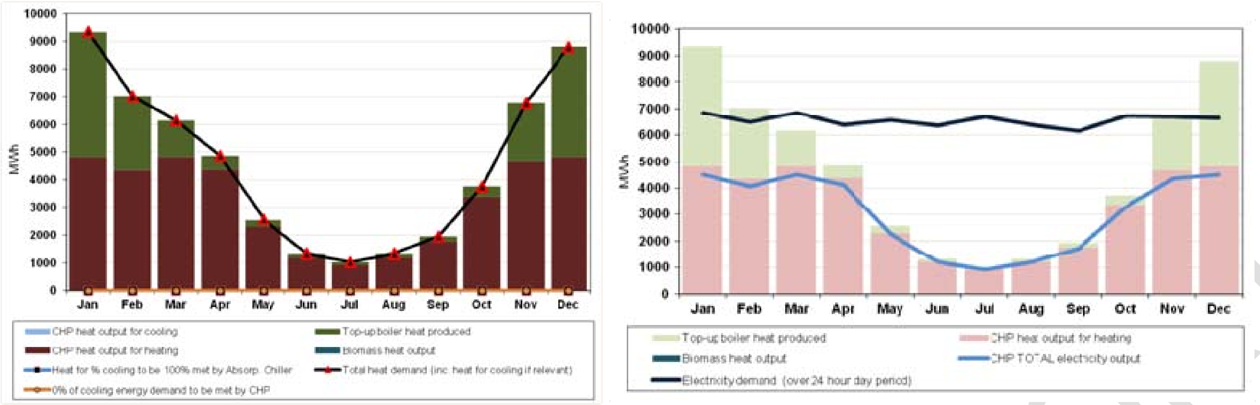

Figure 35: Option 2 annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines

Option 2 sensitivity testing

For sensitivity analysis, which feeds into the economic analysis, two levels of CHP operations were looked at further and are summarised below:

- For 60% site heat demand to be met by CHP plant
- Heat generated by CHP: 33,034MWh
- Electricity generated by CHP: 27,137MWh

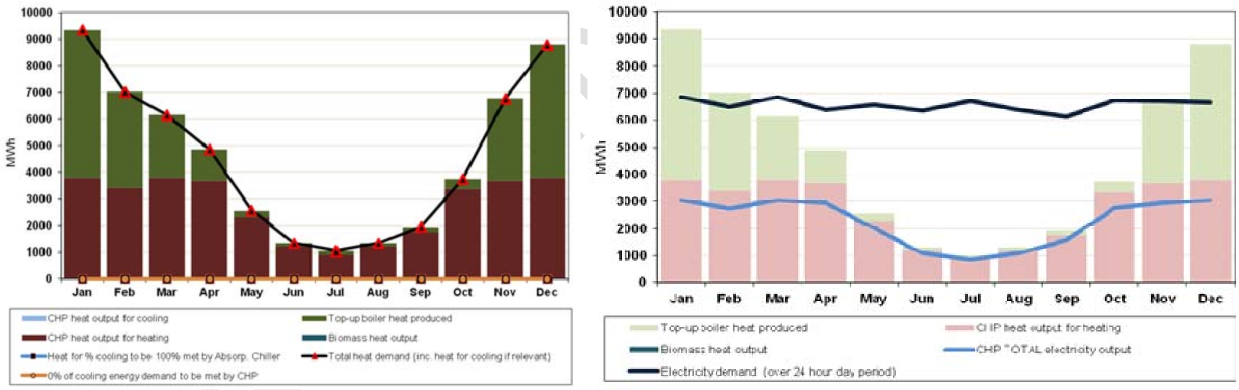

Figure 36: Option 2-low CHP heat annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines

- For 80% site heat demand to be met by CHP plant
- Heat generated by CHP: 44,463MWh
- Electricity generated by CHP: 43,537MWh

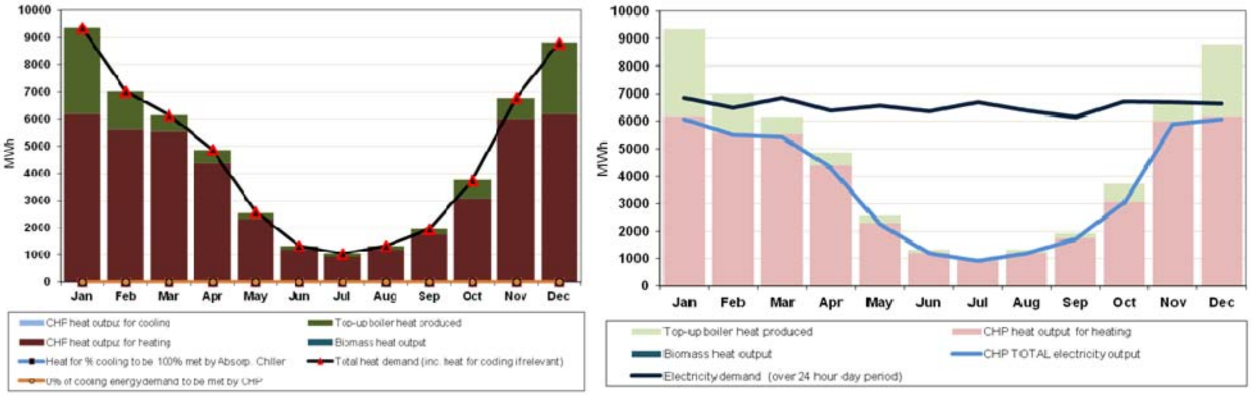

Figure 37: Option 2-high CHP heat annual profile of heat demand, CHP engine and top-up boiler heat generation and the corresponding site electricity demand and that generated by the CHP engines

Indicative Energy Centre plant layout

This section briefly describes the plant room configurations that may be required for a typical CHP Energy Centre. Please note that any proposal here should be treated as only for guidance and functions as a high level feasibility information. The plant room layouts are described using block diagrams to indicate the different plant equipment required in the Energy Centre, which is essence could be used as guidance on the amount of plant room space required. Two sets of drawings are presented here, the first for the one Energy Centre option and second for the two Energy Centres option.

Option 1 – one energy centre at KK/QAT

Figure 38 shows the indicative plant room layout for the KK/QAT Energy Centre option. It can be seen there are issues with insufficient space available to accommodate a 10MWe CHP capacity Energy Centre. 5 units of approximately 2MWe engines were used with the intention of distributing the weight of engines and other plants across the available space. This is with the assumption that the load density (static and dynamic) of each engine can be safely accommodated by the building structure. Some plants are being placed on the ground level as a matter of requirement and this is shown to encroach into part of the Hughes Hall parking space at the back of KK/QAT. The thermal store, pump station and pressurisation system are located where the pool temporary boilers are currently situated. It has to be pointed out that there is no space available for back-up/top-up boilers in this location and additional space elsewhere would be needed. This is not shown in the drawings.

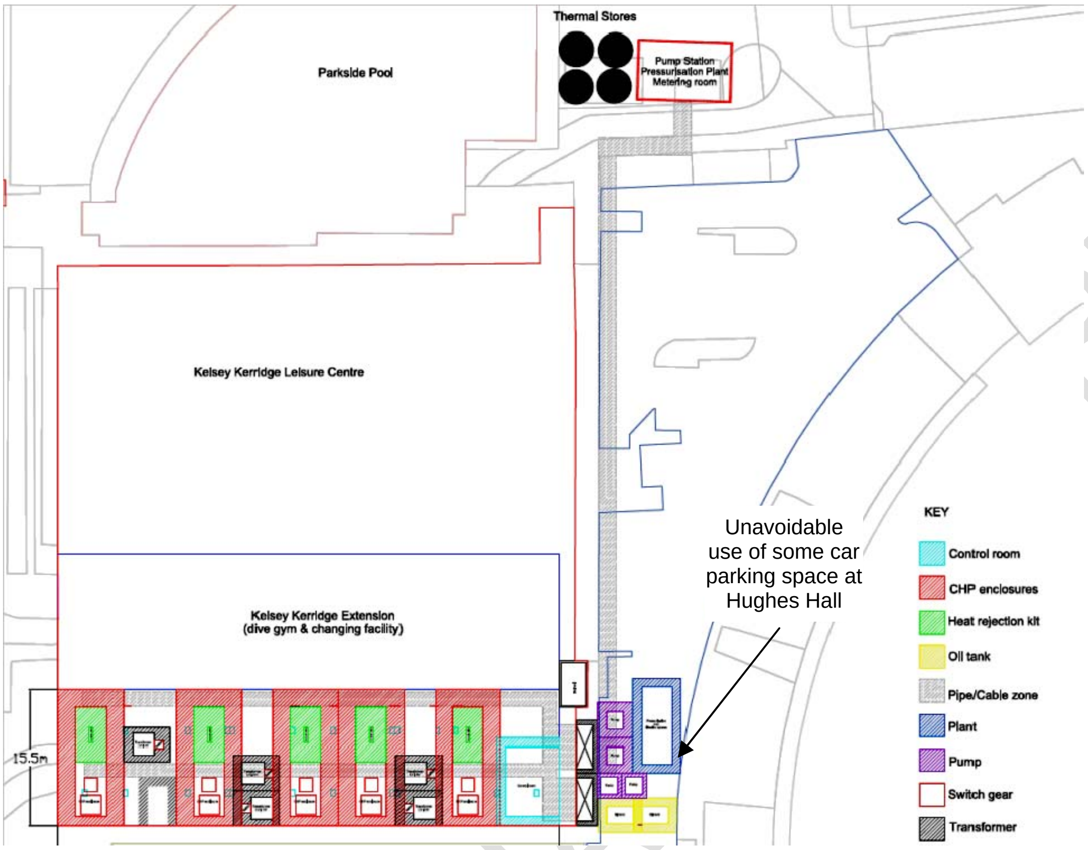

Figure 38: High-level drawing of indicative plant room layout for the Energy Centre proposed at the KK/QAT car park site for one Energy Centre approach. Coloured hatchings are clearance area required for the respective plant equipment symbolised in the legend.

Option 2 – one energy centre at KK/QAT and one energy centre at indicative location in Downing Site

Figure 39 shows the indicative plant room layouts for the KK/QAT and that for the Downing Site. The total of 10MWe CHP capacity is split equally between these two Energy Centres and there are 4 engines in each centre to generate the required demand.

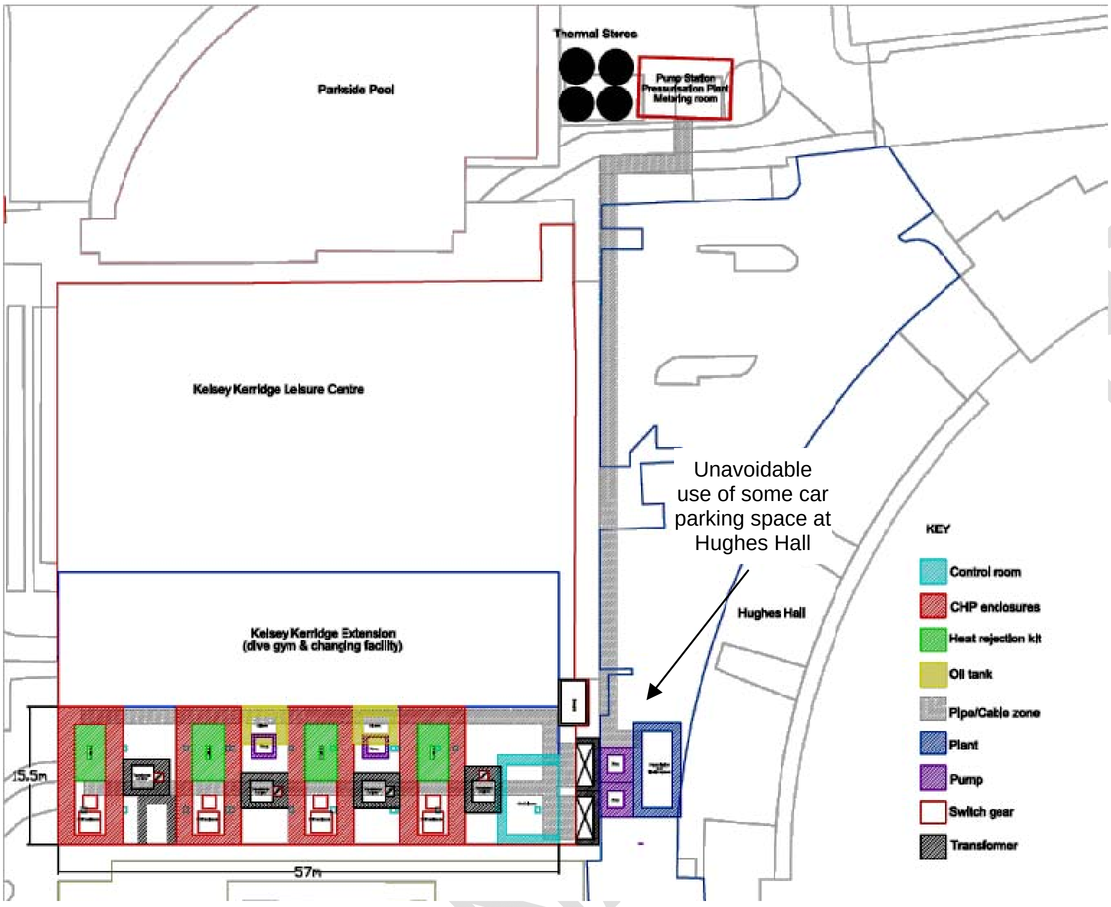

Figure 39: High-level drawing of indicative plant room layout for the Energy Centres proposed at the KK/QAT car park site and the Downing Site for two Energy Centres approach. Coloured hatchings are clearance area required for respective plant equipment.

It can be seen that even with reduced capacity, the space at KK/QAT is not adequate to accommodate all the plants and would still require the use of part of the Hughes Hall parking space. Also, there remains the issue of no available space for the back-up/top-up boilers.

At the Downing Site, space constraint at the site meant that the Energy Centre will have to be multi-storey as suggested in Figure 40. The ground floor would have to be double-height to allow for adequate ventilation and space for ductwork. Additional floors are needed to accommodate other plants including the back-up/top-up boilers, which are sized for 40MWth.

With the constraints and issues highlighted for both cases, it rationale would be to seriously consider the Mill Road depot option. Although it has its own share of issues and unknowns, there are no immediate issues with structural loading and space constraints at this site.

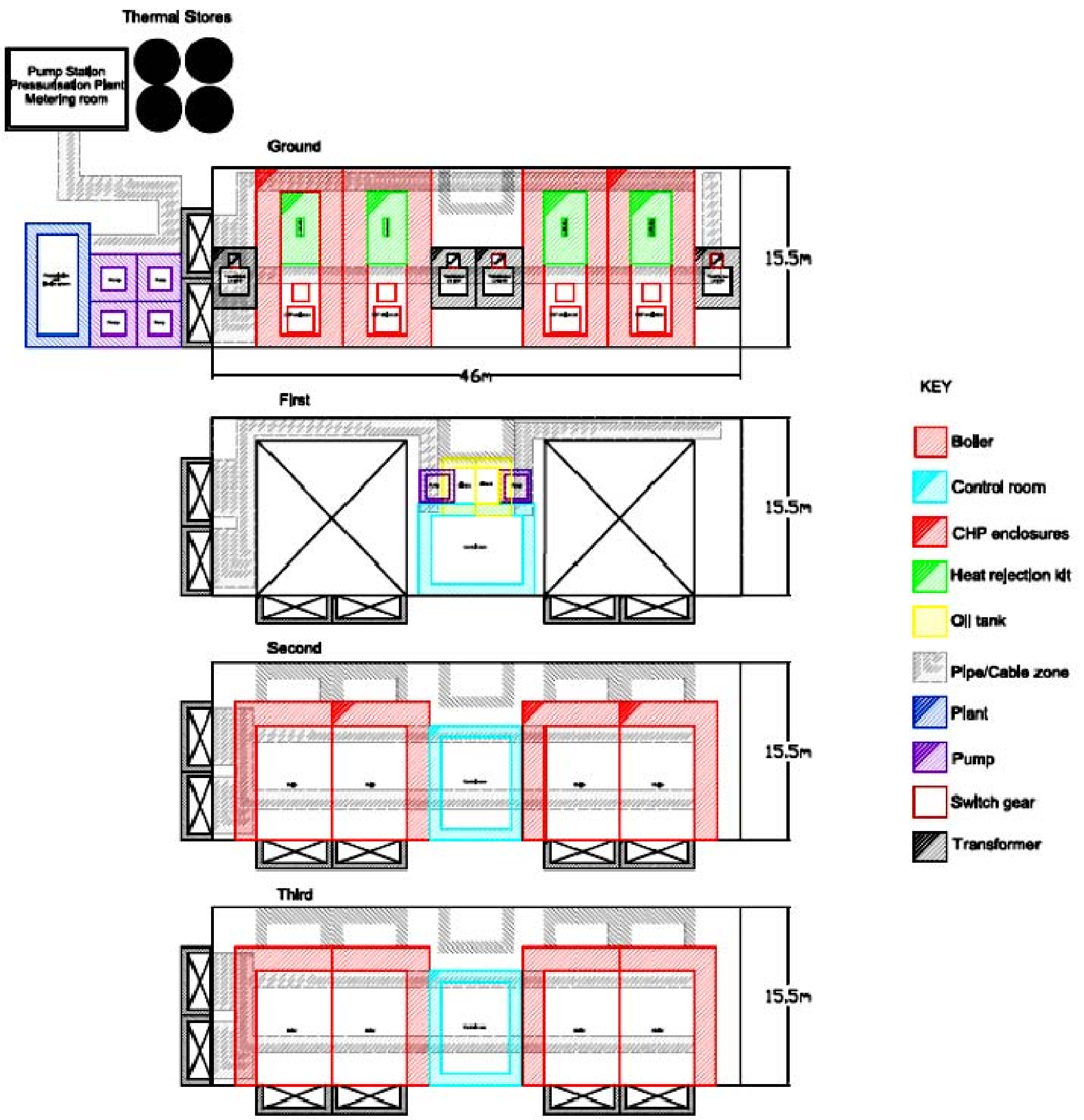

Figure 40: High-level drawing of indicative plant room layout for the Energy Centres proposed at the KK/QAT car park site and the Downing Site for two Energy Centres approach. Coloured hatchings are clearance area required for respective plant equipment.

Private wire

The development of a private wire/private electricity network infrastructure would allow DH scheme customers to be supplied with both the electricity from the grid and from that generated directly by the Energy Centre. In essence, the private electricity network will be operated in the same way as any regulated network, so the standard of supply does not differ.

The intention of a private wire is to facilitate the direct sales of locally generated electricity, shown to be financially preferable by customers over the purchase of electricity from the grid, due to the advantage of the competitive prices of site generated electricity. This is an infrastructure currently not present and would require development and construction.

There has been a proposal for a private wire connecting the ARU campus to the Energy Centre at KK/QAT. There is also another proposal of a private wire network from the Downing Site Energy Centre to the buildings in Downing Site and the New Museums Site. With regards to the alternative Energy Centre at Mill Road Depot, there will immediately be an implication of high cost to realise any form of private wire from this generation source.

For the interest of discussion, the following describes the infrastructure required for delivering power to the ARU campus from KK/QAT, as shown in Figure 41 where the expected distance to cover by the private wire is approximately 400m from the Energy Centre, running alongside the excavation route for the DH heat pipes where possible, thereafter taking its own route through Donkey Common to the ARU campus sub-station location shade in blue.

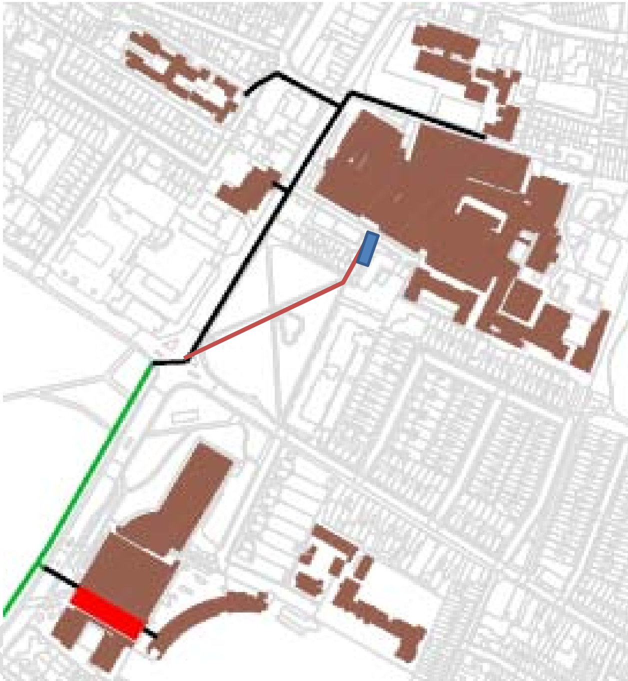

Figure 41: map showing the proposed route for the private wire from KK/QAT Energy Centre to the ARU campus sub-station. The private wire cable can be placed alongside the excavation route for the DH heat pipes and thereafter taking its own route through Donkey Common to the sub-station location indicated in blue.

The electrical output in amps derived from the CHP plant will be significant (circa 15,000 amps) and the connected load sub-stations are generally remote. It is uneconomical to transfer this load at low voltage (400 Volts) over these distances due to the volt drop limitations of low voltage networks. It would therefore be necessary to distribute at HV to the distribution points (except the most local) with transformers providing the low voltage supplies after the sub-station being supplied to buildings at the site. Assuming the local Grid voltage is 11,000 Volts it would make sense to align with this voltage. This would also allow supply synchronisation suiting paralleling and export to grid criteria.

There are a number of ways of achieving this and there are advantages and disadvantages to both options and these would need detailed consideration and associated costing from both capital and maintenance perspectives. The general schematic of the electrical system is shown in Figure 42 where two configurations could be considered.

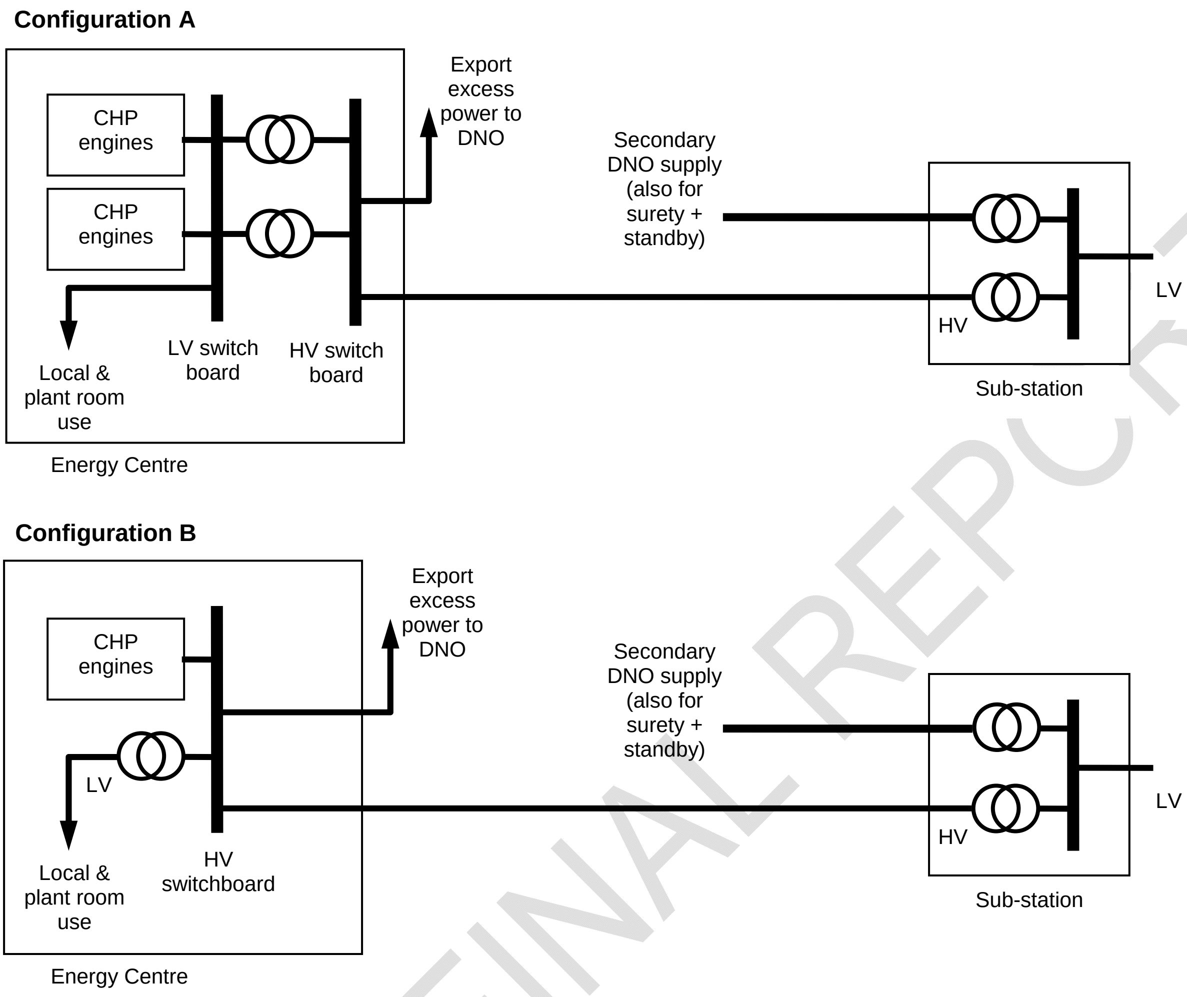

Figure 42: schematic diagrams illustrating possible private wire configurations where, Configuration A is for a LV alternator CHP engine setup and Configuration B with HV alternator CHP engine setup.

Configuration A:

LV CHP alternators generate at 400 Volts and via transformers step-up to 11,000 Volts for connection directly to a 11,000 Volt network. Thereafter, the HV private wire transmits electricity to the sub-station where a transformer will step-down to site-specific voltage requirement before connecting to a LV switchboard, which is also connected to supply from the grid. At the Energy Centre, LV electricity is also supplied for local and plant room use where required. Facility to export electricity to the grid can be connected to the HV switchboard.

Configuration B:

HV CHP alternators generate the required voltage for connection directly to a 11,000 Volt Network. At the Energy Centre, HV power can be step-down to LV via a transformer for local and plant room use if required. Facility to export power to the DNO can also connect to the HV switchboard.

A number of key issues will need to be considered, which also include space availability and planning, the operation and protection strategies to safe-guard assets against faults, safety inter-locking, earthing and metering for import and export of electricity. The 11,000 Volt network arrangement itself would also need more detailed consideration but would likely be based on a parallel radial or open ring main arrangement. This would depend on consideration of Operating and Management strategies and associated protection studies. Early decisions on operating modes would also need to be considered (Island Mode for example) followed by close liaison with the local Regional Electrical Co for compliance with G59 Guidance.

5 Economic and Environmental Analysis of Options

Introduction

This section provides a summary of the economic and environmental analysis of the DH network options described in the previous section. The economic analysis is based on a 30 year discounted cashflow and includes the following:

- Capital expenditure of DH network, CHP and boiler plant, energy centre and utilities connections.
- Replacement costs of CHP plant after 15 years.
- Energy costs.
- Electricity sales revenue
- On-going costs for administration, network and CHP operation
- Development costs at 5% of the capital cost.

Economic outputs are presented for a baseline case and then a number of sensitivities examined:

- The revenue from exported electricity.
- The sizing and the operation of the CHP systems
- Capital adjustments (representing capital changes or grant funding)
- The value of CO_2 emissions savings.

Assumptions and methodology

A monthly model is used to simulate the performance of the network and CHP system over a year making use of the energy load information collected from potential customers and simulated monthly loads (based on degree day distributions) where necessary.

A 30 year lifecycle costing methodology is used to assess the economic performance of each scheme taking into account capital and ongoing costs including the impact of incentives. The model allows for the examination of sensitivities to key parameters such as electricity revenue value and capital funding. A discount methodology is used to determine the Net Present Value (NPV) of each scheme and provide an Internal Rate of Return (IRR). The IRR represents the economic performance of the scheme and therefore determines the type and amount of investment which the scheme may attract. For a public sector organisation, a rate of 3.5% can be assumed in accordance with the Treasury Green Book, whereas for a commercial organisation, a rate of around 10% or more is more typical, representing a larger profit margin and shorter payback. All NPV figures provided in this report are based on a 6% discount rate representing a mix of public and private investment.

The cost and CO_2 effectiveness of schemes is calculated against a counterfactual case of gas boilers at each customer’s site. The capital for these is spread evenly over the assessment period to allow for a range of replacement dates. Whilst this may not represent the exact cost counterfactual for a specific customer, it provides an average counterfactual against which the economic viability of the DH scheme can be assessed.

All economic modelling assumes that development costs (based on an additional 5% of the capital) are incurred in 2012, the system is installed in 2013 incurring all the capital expenditure, and the first heat and electricity sales are made in 2014.

CO_2 emissions are calculated over each of the 30 years. Annual savings are reported on for 2014 (the first year of operation) and the potential income associated with CO_2 emission reductions (for example the Carbon Reduction Commitment) are discounted over the 30 year lifecycle assessment period assuming a price of £12/tonne CO_2.

All assumptions are detailed in Appendix 2.

Capital costs

DH networks

The capital costs of the DH network vary depending on the network layout option. The costs for this are estimated to be:

- £0.9 million for the Base Case option, and;
- £5.5 million for network Options 1 and 2.

It is important to note that these estimates only allow for the pipework as shown in Figure 22, Figure 23, and Figure 24, and does not include the additional network which would be required within some of the sites for the distribution of heat to separate buildings as discussed later.

In addition, this report discusses the potential for locating an energy centre at the Mill Road Depot site for serving either Option 1 or Option 2. The capital cost of this 800m pipe has been estimated to be £1.9 million based on a 400mm diameter pipe.

Energy centre costs

The cost of the CHP system is based on an installed capital of £700 per kWe.

This gives a cost of:

- £1.3 million for 1.9 MWe capacity in the Base Case option, and
- £6.4 million and £6.6 million for Options 1 and 2, assuming the CHP system is sized to meet 70% of the heat load.

The type and nature of the energy centre building is currently unknown. Whether it is a new building, or modifications to an existing building, a cost will be incurred. An allowance of £1000 / m^2 has been assumed for the construction or modification works. Depending on the type and location of the building, the cost of constructing an energy centre may vary considerably. Where a simple building may suffice, for example at the Mill Road depot site, the current allowance may be adequate or even too generous. However it is likely that a high quality building of the type potentially required towards the centre of the City (on the New Museums or Downing sites for example) could cost considerably more due to constrained sites and existing in restructure, and planning requirements. We have not included a land value for the energy centre in our cost estimates.

This provides a capital cost for the energy centre building of between £0.4 million (1 Energy Centre), £0.8 million (1 Energy Centre) and £1.5 million (2 Energy Centres) for the Base Case, Option 1, and Options 2 schemes respectively.

Gas boilers used for peak load and back up are costed at £60 / kW with the total cost depending on the scheme option which determines the connected load.

An allowance has been made of £100,000 for both gas and electricity connections to the energy centre/s. This is based on previous project experience, and a more detailed cost can only be obtained from the utility companies once a detailed study has been conducted by them based on the design proposals and exact site location. Where there is more than one energy entre, these connection costs are assumed to be incurred at each site.

A cost of £0.33 million has been assumed for the thermal store based on an indicative £600 per m^3 from previous project experience.

Connection costs

An allowance of £100 per kW has been included for the connection at each customer's building to the heat network. These costs represent the installation of an interface unit, metering, controls, and pumps. They do not include modification to the customer's existing heating system and should be viewed as a replacement for the existing boiler. The actual costs of installing the connection will depend on the amount of modification required to the existing infrastructure and is building dependent. Therefore the value of £100 per kW is used as a mid-range value and could be higher or lower. It is based on a recent tender received for similar work.

The heat network costs included in the modelling and network designs are based on a heat network providing connections to individual sites. On sites where there are multiple buildings, such as at the Downing or New Museums sites, additional infrastructure will be required within the site for the distribution of heat. This could be from a single large DH connection substation, or a smaller DH network connecting the main network to the individual buildings. It has not been possible to estimate these costs without a much more detailed survey of these sites. As a result the modelling effectively assumes that these site scale local networks would be paid for by the customers even though in practice the ownership is likely to be with the DH developer.

The schematic in Figure 43 shows two examples of connections. On Site A, there is a site level heat sub-station (costed at £100 per kW connection) which takes heat from the DH network. A site level heat distribution system then connects to the individual buildings. This site level system is not included in the cost analysis and it is assumed that it would be borne by the customer. Site B shows the alternative arrangement of having heat sub-stations at each building (again costed at £100 per kW). In this case, the DH network connects to a smaller site-wide network, which is paid for by the customer. In both cases, the connection cost which includes the sub-stations is identical as is the cost of the DH network to the site. Full connection costs are provided in the capital cost summary in Table 8.

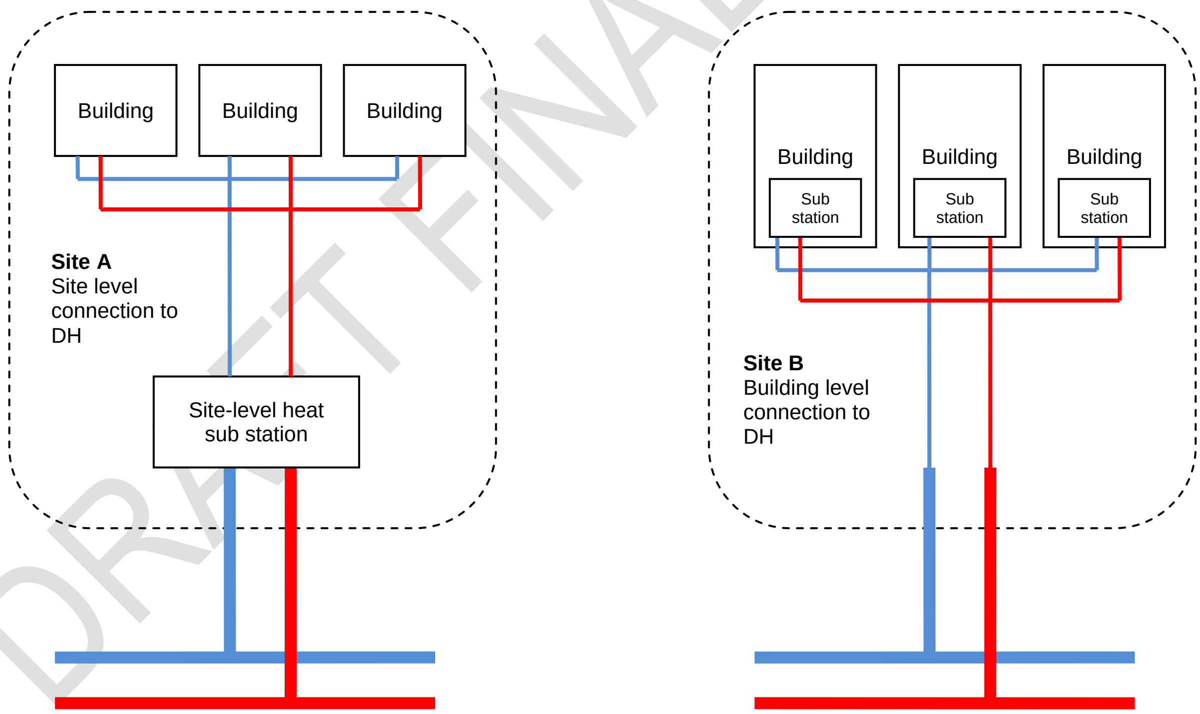

Figure 43: Examples of the two primary connection types. The main heat network (heavy lines) is paid for by the scheme. The heat sub-stations, whether at site scale or building scale are also included in the scheme costs. However the site wide heat or

DH networks (narrow lines) are not included in the scheme costs and are assumed to be paid for by the customer in the current analysis.

It is important to recognise that the installation of site-scale heat networks could be relatively expensive due to the complexities of installing in existing areas and around existing infrastructure. It is also possible that some of these sites already have smaller scale heat connections (for example a single plant room providing heat to multiple boilers) in which case the infrastructure required will be less. A detailed survey of each site is required to inform the technical viability and costs of installing a network on each site.

Private Wire costs

The study includes an assessment of a single private wire connection from the Queen Anne Terrace car park energy centre location to the ARU campus. Based on a 3 MW 11kV connection over the 350m distance, with a step up transformer at the energy centre and associated HV switchgear, a cost of £0.22 million has been estimated.

The modelling also looks at private wire sales to the Parkside swimming pool and the Cambridge University New Museums and Downing Sites. However these connections are assumed to be minimal, and only included when an energy centre is located on or adjacent to these sites. (The New Museums and Downing Sites already have a site distribution system owned by the University to which an energy centre could directly connect).

Counterfactual capital costs

The economic modelling includes an allowance for the replacement of existing boilers on a lifecycle basis. The costs are based on £160 / kW for heating boilers and a 30 year replacement life is assumed. Due to the large number of existing boilers in the identified schemes and unknown ages, it is assumed that they are replaced on an average basis i.e. incurring 3.3% of the total replacement capital cost per year.

Summary of capital costs

Table 8 provides a summary of the capital costs for each network option. The totals for the options as presented all include the £0.2million for the private wire connection to ARU.

Table 8: Summary of capital costs for each network option. All figures are given in £million

Component	Base case £million	Option 1 £million	Option 2 £million
DH network	£0.9	£5.5	£5.5
CHP plant	£1.3	£6.4	£6.6
Energy centre boilers	£0.5	£2.9	£2.9
Energy centre building	£0.4	£0.8	£1.5
Thermal store	£0.3	£0.3	£0.3
DH connections	£0.9	£4.9	£4.9
Gas connections	£0.1	£0.1	£0.2
Electricity connections	£0.1	£0.1	£0.2
Private wire (to ARU)	£0.2	£0.2	£0.2
Preliminaries (at 5%)	£0.2	£1.1	£1.1
Total capital cost	**£5.1**	**£22.2**	**£23.4**

In all the schemes, the DH network costs circa 20% – 25% of the total cost. The other significant components are the CHP plant (slightly more expensive than the corresponding heat networks) and the building connections (comparable with the networks). The energy centre boilers are circa 10% of the overall costs – these could be phased in if existing boiler plant was used until reaching the end of life.

Operational costs and revenues

Operation and maintenance of the DH scheme

Allowance for the operation and maintenance of the scheme is based on the following:

- CHP maintenance costs are assumed to be £0.01 per kWh of electricity produced. This gives an annual cost of circa £0.3 million to £0.4 million depending on the network option.
- The DH scheme operation and maintenance is estimated at 1% of capital expenditure per year.
- An allowance has been made of £150,000 per year for administration of the scheme which includes the development of contracts and billing of customers.
- The annual operation and maintenance for boilers is assumed to be 1% of capital expenditure per year.
- Pumping energy (electricity) for the DH network is assumed to be 1% of the thermal energy delivered in terms of kWh. This is taken off from the electricity generated by the CHP system.

Energy costs and revenues

Gas costs for the CHP engine and energy centre boilers are based on a current price of 2.6 p / kWh (excluding CCL and VAT). This is based on the current price for the largest gas consumer in the scheme. This price is a new contract, and whilst lower prices were obtained from other potential customers it is likely these will rise to more than the figure of 2.6 p/kWh when they need to be renegotiated due to the smaller annual demands. In the economic modelling the gas price is projected to change in line with the central projections for commercial customers from the UK Government's Inter-departmental Analysts Group (IAG)[6]. It is possible that a lower price can be negotiated based on the relatively high total demand at a single connection. However the reduced gas demand of the customers (for other buildings not connected to the DH scheme) may increase their new contract prices. Therefore the selected value represents a mid range scenario.

A range of electricity sale prices are included to test the sensitivity to this parameter. The central retail value is 8.5p / kWh (excluding VAT and CCL), again based on a recently negotiated price for one of the potential scheme participants. This is also projected to change in line with Government central IAG projections for commercial electricity.

Electricity revenue from bulk sale to a licensed supplier is valued at 5 p / kWh (2011 value). This is based on information AECOM has obtained during negotiations regarding other CHP schemes during 2010 and 2011. This again is modelled to change in line with the Government Industrial IAG projections.

Where electricity is sold over the distribution network to customers, a distribution use of system (DUOS) charge is incurred. If the large electricity customers' sites are connected to HV supply, the DUOS charge given by UK Power Networks, the local distribution company, is 0.68p / kWh assuming electricity is exported constantly over the high and medium charge periods. A similar analysis for other sites connected to LV sub-stations provides an average DUOS charge of 1.03p / kWh. Limited information is available on the connection voltages for all potential sites so this study assumes a 50% split between HV and LV, giving an overall average DUOS charge of 0.85p / kWh.

Electricity sales in the modelling also assume that the scheme attains Good Quality CHP status and therefore the gas purchased is exempt from the Climate Change Levy (CCL). This means that the electricity sales value for retail is effectively increased by 0.49p / kWh because this is a cost the customer is avoiding compared with their incumbent supply. The UK Government Consultation on Electricity Market Reform indicates that CCL exemption for Good Quality CHP may be removed. However the Government is examining alternative incentive options to

[6] . Valuation of energy use and greenhouse gas emissions for appraisal and evaluation. June 2010. http://www.decc.gov.uk/assets/decc/statistics/analysis_group/122-valuationenergyuseggemissions.pdf

compensate for this change, and until further information is known, it is assumed that the incentive will be comparable.

The modelling also takes into account the demand profiles of the CHP electrical output. On an annual basis, a “useful electricity” factor is calculated for each network option which describes the match between the CHP electricity generated and the monthly demand of the potential electricity customers. This is then modified by a daily demand factor which calculates the mismatch between the CHP operation hours and the typical daily demand profile. An average daily demand factor of 77% has been calculated, and for the larger schemes, the monthly demand reduced to 77% still exceeds the CHP output, suggesting that for these schemes, all electricity can be sold either via private wire or via DUOS charges directly to customers.

Electricity sales are based on the following hierarchy:

- Sales via private wire first
- Sales over the network incurring DUOS charges
- Remaining electricity sold for wholesale use.

The modelling does not take into account any cost variation in electricity sold to customers via the CHP scheme which needs to be purchased as a top up from another electricity supplier. It is assumed that the CHP scheme will be able to negotiate a bulk purchase price which after the payment of DUOS, is comparable with the customers' current prices and therefore cost neutral.

Counterfactual costs

The counterfactual operational costs include an allowance for maintenance of the existing boiler plant at 1% of capital cost per year, and expenditure on gas (which includes CCL). The average cost of heat is circa 5 p/kWh across the scheme. In practice the counterfactual heat prices will differ by customer depending on their actual fuel prices and so heat sales prices may need to vary by customer to ensure that the revenue is maximised whilst still offering an economic advantage. However across the scheme, the average value can be used for economic analysis.

Discount on sales

The base case modelling assumes that heat sales revenues are equivalent to the counterfactual cost such that there is no economic disadvantage, but neither is there an economic benefit, for customers. This allows potential suppliers to assess the level of discount which may be viable based on the overall IRR of the scheme.

VAT and inflation

All values are shown exclusive of VAT. The modelling is all conducted at 2011 price levels and no inflation is included. All changes (primarily increases) in energy costs are due to wholesale price rises and are independent of inflation i.e. expressed in real terms.

Lifecycle Costs and Internal Rates of Return

In this section, the results from the core scheme options are presented. As previously stated, these assume that there is a 2 year design and build phase with connections made in 2014 resulting in the first electricity and heat sales in that year. For all of the core options, the CHP engines have been sized to provide 70% of the heat on the network, the remainder coming from the top up boilers located in the energy centre. The 70% assumption has been tested to and found to be approximately optimised through providing the highest IRR.

In all cases, it is assumed that the Parkside Pool takes electricity directly from the energy centre. This is essentially a private wire arrangement, but with a minimum amount of infrastructure due to the co-location of the sites.

Options are examined for installing a private wire to the ARU. This is to examine the balance between the additional infrastructure costs versus the higher sales value which can be achieved for the electricity.

All the core scheme options include the impact of CO_2 pricing at CRC levels of £12 per tonne (constant over the 30 years). Good Quality CHP status is achieved to enable gas and electricity from the CHP to be CCL exempt as there is no heat dumping facility included and all heat is recovered for use by the DH scheme.

Table 9 shows the main economic indicators for the core schemes

Table 9. Economic performance of the baseline schemes

Scheme		Base Case	Option 1	Option 2	Base Case - no ARU private wire	Option 1 - no ARU private wire
Capital cost	£ million	£5.1	£22.2	£23.4	£4.8	£22.0
CHP capacity	MWe	1.9	9.2	9.5	1.9	9.2
Total heat sales	MWh / yr	11,175	53,922	53,922	11,175	53,922
Electricity - Private wire sales	MWh / yr	5,603	6,004	31,922	1,456	1,456
Electricity - Sales via DUOS	MWh / yr	-	28,575	4,634	4,147	33,123
Electricity - Wholesale export to the grid	MWh / yr	1,770	-	-	1,770	-
IRR	%	1.4%	6.2%	7.0%	0.6%	6.1%

The base case scheme comprises the energy centre at the Queen Anne Terrace car park and heat connections to the Parkside Pool / Kelsey Kerridge sports centre and the ARU campus. It has a capital cost circa £5.1 million and an IRR of circa 1.4% with a private wire connection to ARU. If the private wire connection is removed, the IRR reduces to circa 0.6%, demonstrating that the cost of installing a private wire connection is outweighed by the increased electricity revenue which can be generated.

The comparison of the base case schemes (with and without ARU private wire) demonstrates the importance of maximising the electricity revenue. With the total electricity demand of buildings connected to the scheme of circa 9,000 MWh / yr, around 76% of the CHP output can be sold to customers via private wire or over the distribution network to customers. The remaining 24% will need to be sold to a licensed supplier at a bulk purchase price unless other customers can be found who are not connected to the heat network. This mismatch in supply / demand is due to the CHP supplying too much electricity in some of the winter months. (It is important to note that the modelling is based on simple daily demand profiles which represent all building types and a detailed analysis examining all of the connected buildings at hourly level would be required to substantiate the analysis).

Overall the modelling suggests that the base-case schemes do not deliver rates of return which are acceptable to any investing sectors, and therefore the schemes need to either increase revenue streams (though higher revenues for heat or electricity) or reduce the capital expenditure. These are examined later in this section as a sensitivity.

The IRR for the larger Option 1 and 2 schemes is increased to between circa 6.2% and 7%, assuming a private wire connection to ARU. Without a private wire connection to ARU, the Option 1 scheme has a slightly reduced IRR of circa 6.1%. The increase in IRR for the Option 1 and 2 schemes is due to the schemes selling heat to the western area of the network which includes the high density University sites. The overall heat density of the network increases and therefore the heat (and electricity) revenues per unit cost of heat network increase. This can be simply observed from Table 9 through the increase in capital cost of around 4 times between the base case and Option 1, but an increase in heat sales of almost 5 times.

The Option 2 scheme has a slightly higher capital cost than Option 1 due to the inclusion of a second energy centre located somewhere in the New Museums or Downing Sites. However the location of this second energy centre results in the potential to export electricity to these two sites using a private wire arrangement (using the sites existing University-owned electricity infrastructure). This increase in revenue outweighs the additional capital cost. Between Options 1 and 2, the proportion of electricity sold via private wire and over the grid is reversed.

The impact of removing the private wire arrangement to ARU has minimal impact for Option 1 (and will be similar for Option 2). This is due to the electricity sales to ARU now being relatively small in comparison with overall sales, and the benefits being correspondingly small. However the private wire connection continues to provide an economic benefit and on this basis, is assumed for all further modelling in this study. Although there is a case for installing the private wire to ARU the benefit is relatively small and may not justify the additional risk and complexity.

The results for the core schemes demonstrate that the larger networks (Options 1 and 2) provide much higher returns than the smaller base case scheme. The IRRs available from network Options 1 and 2 are potentially sufficient to attract public sector finance without further funding if the schemes can operate as assumed, especially concerning electricity sales.

Carbon Dioxide emissions

The CO_2 emissions from the scheme are evaluated for each year of operation over the lifecycle, taking into account gas and electricity CO_2 emission factors. The assessment examines emissions from both the CHP / DH scheme and the counterfactual scheme to calculate the saving achieved.

Table 10 shows the results from the CO_2 calculations and compares these with the current emissions from the boilers which are currently supplying heat. For simplicity, values are shown for 2014 only, although the costs associated with CO_2 discussed later in this section cover the lifecycle of the scheme.

Table 10: Counterfactual CO_2 emissions for heating and the savings achieved with the CHP / DH schemes.

Scheme		Base Case	Option 1	Option 2
2014 Counterfactual emissions for heating	Tonnes / yr	2,937	14,170	14,170
2014 savings with CHP / DH scheme	Tonnes / yr	1,777	8,087	8,058
Percentage reduction	%	61%	57%	57%

By summing up the heating demand per customer and applying the percentage reduction for each scheme, it is possible to examine the impact of the reduction. Table 11 provides a summary of these savings.

Table 11: CO_2 emission reductions by customer for heating consumption

Code	Building Name	Heating	Base Case 61% savings	Option 1 57% savings	Option 2 57% savings	Option 2(60%) 42% savings	Option 2(80%) 64% savings
		[tCO2]	[tCO2]	[tCO2]	[tCO2]	[tCO2]	[tCO2]
E001	Anglian-Ruskin University (ARU)	1,084.62	661.62	618.23	618.23	455.54	694.15
E002	Mackays site	-	-	-	-	-	-
E003	Parkside Pool (PP)	721.07	439.85	411.01	411.01	302.85	461.48
E004	Kelsey Kerridge (KK) sports centre & QAT	100.06	61.04	57.04	57.04	42.03	64.04
E005	Mill Road Depot	473.65	-	-	-	-	-
E006	Redevelopment of the police station site	-	-	-	-	-	-
E007	Brandon Court	128.80	78.57	73.41	73.41	54.09	82.43
E008	Ditchburn Place	177.46	-	-	-	-	-
E009	YMCA	58.96	35.96	33.61	33.61	24.76	37.73
E010	Cambridge Crown Court	59.43	-	-	-	-	-
E011	Civil Justice Centre/Cambridge County Court	110.38	67.33	62.92	62.92	46.36	70.64
E012	Grafton Centre	-	-	-	-	-	-
E013	St Matthew's School	131.49	80.21	74.95	74.95	55.23	84.15
E014	Parkside Community College	-	-	-	-	-	-
E015	Youngs site, ARU Phase 1	14.24	-	-	-	-	-
E016	Youngs site, ARU Phase 2	8.53	-	-	-	-	-
E017	Youngs site, ARU Phase 3	10.09	-	-	-	-	-
E018	Youngs site, ARU Existing Reception	1.52	-	-	-	-	-
E019	Mandela House	88.58	-	50.49	50.49	37.20	56.69
E020	Gonville Hotel	152.77	93.19	87.08	87.08	64.16	97.77
E021	Emmanuel College	925.07	-	527.29	527.29	388.53	592.04
E022	Pembroke College	598.85	-	341.34	341.34	251.52	383.26
E023	Downing College	1,037.74	-	591.51	591.51	435.85	664.15
E024	Hughes Hall	448.74	273.73	255.78	255.78	188.47	287.19
E025	Peterhouse College	558.22	-	318.18	318.18	234.45	357.26
E026	Christ's College	449.20	-	-	-	-	-
E027	New Museum's site (Uni area code M)	704.96	-	401.83	401.83	296.08	451.17
E028	Downing site (Uni area code D)	1,565.18	-	892.15	892.15	657.38	1,001.72
E029	Old Addenbrooke's site (Uni area code E)	1,232.57	-	702.57	702.57	517.68	788.85
E030	Silver Street/Mill Lane site	550.79	-	313.95	313.95	231.33	352.51
E031	Fitzwilliam Museum	197.95	-	112.83	112.83	83.14	126.69
E032	Chemistry, Unilever, Scott Polar Institure	1,528.36	-	871.17	871.17	641.91	978.15
E033	Uni Bdg no 32 - Eng/Uni bdg no 4 – Scroope Terrace (	1,381.32	-	787.35	787.35	580.16	884.05
E034	Royal Cambridge Hotel	-	-	-	-	-	-
E035	Hotel Du Vin, Trumpington Street	-	-	-	-	-	-
E036	Hilton Garden House Hotel	-	-	-	-	-	-
E037	Crowne Plaza Hotel	-	-	-	-	-	-
E038	University Arms Hotel	272.00	-	155.04	155.04	114.24	174.08
E039	Grand Arcade	-	-	-	-	-	-
E040	Lion Yard	-	-	-	-	-	-
E041	Leys School	-	-	-	-	-	-
E042	St Mary's School	-	-	-	-	-	-
E043	St Catherine's College	-	-	-	-	-	-
E044	Queens' College	-	-	-	-	-	-
E045	Corpus Christi College	-	-	-	-	-	-
E046	King's College	-	-	-	-	-	-
E047	Old Schools Site	-	-	-	-	-	-
E048	Clare College	-	-	-	-	-	-
E049	Gonville & Caius College	-	-	-	-	-	-
E050	Trinity College	-	-	-	-	-	-
E051	St John's College	-	-	-	-	-	-
E052	Perse School	-	-	-	-	-	-
E053	St Albans School	26.83	-	15.29	15.29	11.27	17.17
E054	The Corn Exchange	160.80	-	91.65	91.65	67.53	102.91
E055	The Guildhall	405.02	-	230.86	230.86	170.11	259.22

Economic sensitivities

This section presents the results of the financial modelling with varying input parameters to assess the viability of the scheme to a range of sensitivities. These sensitivities in effect represent a level of risk for the scheme, and a value will be placed on the sensitivities by commercial providers, and to a lesser extent, the public sector.

All of the results presented here assume that a private wire connection is included for connection to ARU given the economic benefit provided by this. Outputs are shown for the Base Case, Option 1 and Option 2 schemes where appropriate.

It is possible to examine a number of economic indicators for the scheme. However for simplicity, all results presented here are in the form of the IRR for the scheme.

Sensitivity – electricity revenue

The economic viability of CHP depends heavily on the value of the electricity generated as indicated in the core results in Table 9. Where possible, this should be sold directly to customers at a retail value (with a small discount to attract custom) rather than sold to a licensed supplier at a wholesale price, even though such an arrangement requires additional costs for an electrical connection (private wire) or distribution (DUOS). For this reason the core results assume a preference for private wire, followed by direct sales to customers via DUOS, followed by bulk sales to a licensed supplier.

The results in Table 12 below show the impact of the assumptions relating to private wire and grid sales incurring DUOS on the average electricity revenue value and in turn, the IRRs.

The sensitivity to including a private wire connection has already been examined and demonstrates that for the base case scheme, the IRR is halved (ARU are the main electricity purchaser) but for the larger options, the impact is negligible. There is a much greater impact when the private wire connection is removed from the New Museums and Downing Sites under Option 2 – these sites have a demand around 25,000 MWh which is circa 70% of the CHP output. If a DUOS charge is incurred for exporting electricity to these sites, then the IRR reduces from 6.9% to 5.7%. The impact on average revenue price is 0.6p / kWh on average across the scheme.

A number of assumptions have been made in this study about HV and LV connections to establish an average DUOS charge for export sales. Under a scenario where the DUOS increases to 1.5p / kWh (for example, greater purchase at peak hours and more connections at LV sub-stations than HV sub -stations) the IRRs reduce by circa 1.2% for the Option 1 and 2 schemes. The base case scheme becomes uneconomic.

Under a scenario where all electricity is sold at a wholesale price, all of the schemes become uneconomic.

Table 12: Sensitivity to electricity revenue and assumptions behind electricity sales

	IRR			Average 2014 electricity price (£ / kWh)		
Scheme	**Base Case**	**Option 1**	**Option 2**	**Base Case**	**Option 1**	**Option 2**
Baseline assumptions	1.4%	6.2%	7.0%	£0.090	£0.094	£0.100
No private wire connections to ARU	0.6%	6.1%	6.9%	£0.085	£0.093	£0.099
No private wire connections to ARU and University of Cambridge (all sales to these sites are via grid with DUOS charges at 0.85 p/kWh)	0.6%	6.1%	5.7%	£0.085	£0.093	£0.093
DUOS charges increase to 1.5p / kWh	-0.3%	4.9%	4.4%	£0.082	£0.087	£0.087
All electricity sold at wholesale value	no return	no return	no return	£0.055	£0.055	£0.055

An alternative approach to examining the risk in electricity value is to evaluate with a simple % adjustment on the revenue value. The data in Figure 44 shows the results of this modelling in terms of IRR versus average 2014 electricity revenue value. The two larger schemes are similar with IRRs reducing to zero at a revenue value of circa 7p / kWh, around 15% reduction in average value. However the base case scheme requires a higher income and the IRR reduces to zero at a revenue value of circa 8.5 p / kWh representing less than 10% reduction.

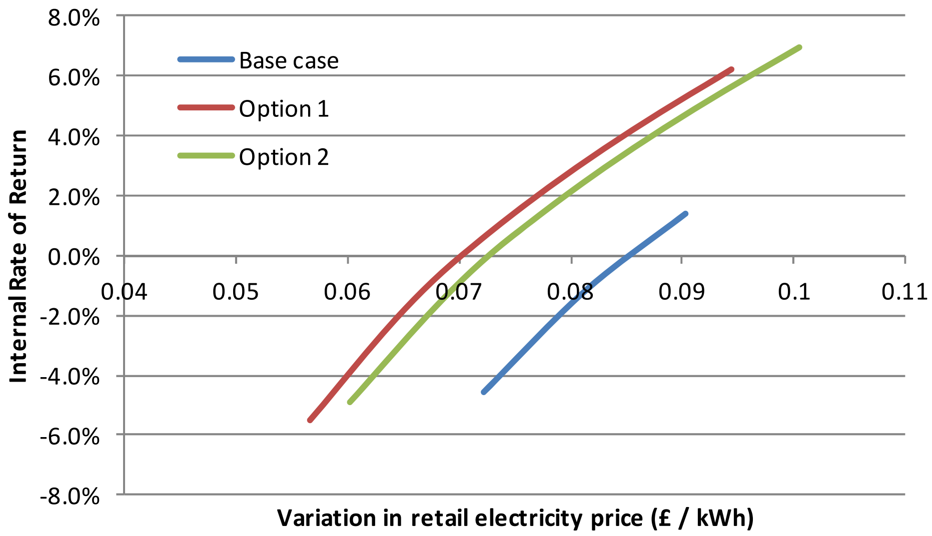

Figure 44: Sensitivity to electricity revenue value to adjustments to electricity revenue

The results from both the scenarios testing examining export and connectivity options, and simple revenue value adjustments, demonstrates the importance in obtaining a good value for the CHP electricity through maximising sales prices to the customer (although potentially allowing a small discount over incumbent supplies) and minimising private wire costs, DUOS charges, and the amount of electricity exported to the grid at wholesale value.

If a sufficient number of customers purchase electricity from the scheme, in particular the University of Cambridge, then the amount sold for wholesale should be minimal. However the modelling in this report assumes an indicative daily electricity demand profile and calculated the CHP mis-match on a monthly basis, and more detailed modelling would be required to substantiate this.

Therefore the main area to increase the value of sales is through direct sales to customers either through private wire (in particular to the University of Cambridge sites) and over the distribution network incurring DUOS charges. The former is partially determined by energy centre location and existing infrastructure – the opportunity to locate an energy centre in either the New Museums site or Downing Site and connect to the existing University owned network is attractive and should be pursued. The DUOS charges will be largely determined by the current connection infrastructure for each of the customers and the ability, taking into account the structure of the energy scheme and licensing arrangements, to export and sell electricity in this manner.

The analysis does not make allowance for any administration charges associated with the direct sales and DUOS costs. This effectively means that we have assumed that a licensing regime currently being developed by DECC and OFGEM (known as 'license lite' and currently being trialled by 4 London Boroughs) will be in place by the time the project commences.

Sensitivity – capital adjustments

The circa £5 million (base case) and £23 million (Options 1 and 2) capital expenditure clearly has a large impact on the overall cash flow of the proposed schemes and the resulting IRR. The values for capital provided in this report are based on benchmarks and therefore may be an under or over estimate. In addition, it is possible that the scheme may attract additional grant funding, potentially from the proposed Cambridge Energy Fund (CEF) or the subsequent Allowable Solutions fund, in addition to other potential sources. These variations in capital cost and potential grants can be simply examined by reducing or increasing the overall capital liability.

Figure 45 shows the sensitivity of the IRR to capital liability for adjustments of up to plus and minus 50% on the central capital cost assumptions. The IRRs for Options 1 and 2 increase to commercially attractive levels (circa 12%) if the capital cost can be reduced to circa 65% - this represents a reduction of around £8 million. This reduction could represent either real capital cost reductions or input from grant funding, or a combination of both. Conversely, the IRRs reduce with additional capital cost (which could represent real cost increases through capital or financing), and the values in Figure 45 suggest that an increase in capital of around 10% will reduce the IRRs by 1%.

For the base case scheme, a reduction in capital of circa 50% (around £2.5 million) is necessary to give rates of return of 6% which may be attractive to public sector funding. Due to the low base case scheme IRRs, an additional 20% capital will render the scheme uneconomic with a zero IRR.

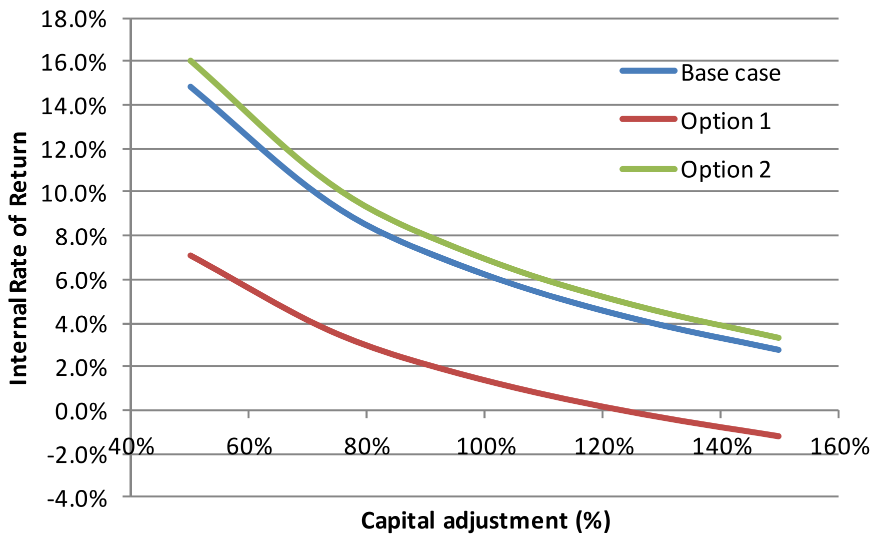

Figure 45. Sensitivity of the IRR to capital liability

Sensitivity to the cost of CO_2

Under the core modelling assumptions, it is assumed that the Carbon Reduction Commitment (CRC) is valued at £12 per tonne CO_2 across the lifecycle of the scheme. It is uncertain how carbon costs will change over time, but it is generally believed that they will increase. In this section an alternative scenario of CO_2 valued at £50 per tonne is examined. This latter value is the similar to the non-traded emissions CO_2 price suggested in the Government IAG and closer the range being discussed for Allowable Solutions.

Table 13 shows a summary of the impact of this price change on the three schemes. The figures demonstrate that an increase in the cost of carbon could have a large impact on the overall economic viability, providing an increase in IRR of circa 3% for all of the schemes, the equivalent of around £4 million additional funding on the larger schemes.

Table 13: Sensitivity of the IRR to carbon pricing

Scheme	Base Case	Option 1	Option 2
CO_2 valued at £12 per tonne	1.4%	6.2%	7.0%
CO_2 valued at £50 per tonne	4.5%	9.1%	9.6%

Sensitivity to CHP operation and sizing

The central assumptions in the modelling for this report are based on the CHP installation providing around 70% of the heat to the DH network, the remainder being provided by the top up boilers located in the energy centre.

If the CHP system is too small, the opportunity for generating revenue from the electricity sales is reduced and therefore the scheme can become less economic. However there becomes a point, determined by the heat demand profiles, where additional CHP capacity will only be required during peaks in heat demand, therefore resulting in low utilisation, but with a high capital cost.

The modelling in this report is based around monthly load profiles and a detailed study of CHP operation on an hourly basis is beyond the scope of this work. Therefore in this section two simple scenarios are examined to see the impact of sizing the CHP engines to meet 60% and 80% of the heat alongside the central 70% assumption. Table 14 demonstrates that the 70% central assumption provides the best rate of return for the three options with a reduction of 0.6% with 60% of heat from the CHP and a reduction of 0.1% for 80% of heat from the CHP. The capital cost variation of plus or minus circa £2 million for these two options represents a change in CHP engine capacity, potentially fewer or more engines, or a change in capacity per an engine.

Table 14: Sensitivity of economics to CHP sizing and operation

Scheme	Capital cost	IRR
60% of heat from CHP	£21.2 million	6.4%
70% of heat from CHP	£23.4 million	7.0%
80% of heat from CHP	£25.9 million	6.9%

Sensitivity to energy centre location

The schemes outlined in this report are based around energy centres located at the Parkside Pool Site (base case and Option 1), and a second energy centre located within the New Museums or Downing Sites (Option 2). There are a number of potential constraints to both these options as outlined in previous sections.

The option of locating a single large energy centre at the Mill Road depot site has attractions – the building will be out of the historic centre and in an area which currently contains industrial uses, potentially allowing a cheaper building to be constructed. There is also adequate land available (currently in council ownership) which will probably have a lower land value than towards the city centre.

The potential disadvantages of locating an energy centre along Mill Road for the network options analysed are the increased length of DH pipe and also potentially the increased private wire connection.

This analysis examines the impact of a Mill Road energy centre on the economics based on a simple adjustment of DH costs for Option 1 and 2 with the same customers. All other costs are assumed to be unchanged.

With a single energy centre at Mill Road, the DH pipe extension will be carrying the entire heat load, and is thus relatively large. The network model suggests a pipe diameter of 400mm which will cost circa £2,400 per metre (assuming hard dig) or circa £1.9 million for the 800 m length. This additional capital cost results in an IRR reduction of almost 1% with the Option 1 scheme reduced from 6.2% to 5.3%.

A more detailed examination of energy centre sites is required, in particular examining the cost implications of each. The Mill Road site results in a reduction in IRR with additional network costs, but a full conclusion can only be drawn once the other offsets including land value and building costs are known. The location also needs to consider the future strategy of the scheme, and early less economical site may be optimal in the longer term.

Summary

This section provides an overview of the economic and environmental analysis.

Assessment of the three central schemes shows that the large network options (Options 1 and 2) provide the most favourable rates of return at around 6% - 7%. These may potentially be attractive to investment by the public sector where low cost finance can be raised. The economic return in the smaller Base Case scheme is much lower at around 1% and will need large amounts of additional funding to become economic.

The analysis in this section demonstrates the importance of maximising the electricity revenue, primarily through making use of private wire where possible and direct sales to customers over the network by paying a distribution charge. The analysis demonstrates that a private wire connection to ARU is economic and that use should be made of the opportunity to connect directly to the University of Cambridge networks on the New Museums and Downing Sites if an energy centre is located there. If private wire connections are not viable, then the revenue is reduced although for the larger schemes, the IRR still approaches 6% and may still be attractive. The actual costs of selling electricity over the local distribution network will need examining in more detail to establish the current connection types for each of the potential customers.

The modelling suggests that all of the CHP electricity in the two larger options can be sold directly to customers with no sales for wholesale. This is due to the overall electricity demand for the customers connected to the heat network being much larger than the CHP output. However if this were not the case and electricity was sold at the wholesale price, then there is a significant negative impact on the economics. The modelling suggests that once more than around half of the electricity is sold at wholesale prices, then the schemes have no economic return.

Other sensitivities include the CHP sizing and operation and the analysis demonstrates that the central assumption of 70% of heat from the CHP engines provides some of the best returns. Further analysis if required to investigate this in more detail at the next stage of design by examining hourly load profiles.

One of the primary drivers for the scheme is the reduction of CO_2 emissions, and the costs associated with CO_2 emissions. The modelling demonstrated that the heating emissions of the connected buildings will be reduced by around 60% reducing the customers' liability to the CRC. The central scenario of £12 per tonne CO_2 for the CRC does not provide a significant incentive, but if the CO_2 was valued at a higher price of of £50 per tonne, then the IRRs increase significantly by around 3%.

6 Governance options

Introduction

This section discusses a number of business structures which could be adopted to deliver a district heating (DH) scheme in Cambridge City. There are a number of important considerations when examining a governance structure for the scheme:

1. The scheme concept is to develop a DH network which will be connected to a number of different customers, largely comprising the University of Cambridge, Colleges, City Council buildings and Anglian Ruskin University (ARU). These large energy consumers will require contractual certainty in relation to energy price and guarantee of provision, and if any one of them do not participate in the scheme then the viability would be significantly impacted.
2. The current network options will require the installation of DH pipes in publicly owned roads and other land which would be subject to wayleaves from the Council for installation and maintenance. However there are also sections of the network which pass through privately owned sites (such as the University's Downing Site). In some cases the network in these areas will be purely for the provision of heat to these areas and so could be owned by the site owner. However in other cases, the network may pass through privately owned sites to supply other areas and as such, would need to remain in ownership of the DH scheme and would require wayleaves.
3. The heat will be partially provided by a gas CHP engine/s located in a central energy centre/s. Top up heat will initially be supported by distributed boilers at each of the customer sites. The ownership and operation of these distributed boilers will need to be considered.
4. Power is also generated by the CHP engines some of which will be available for consumption on site or supplied by private wire to sites in the scheme or be exported into the local electricity grid. The electricity market is heavily regulated, covering the generation, distribution, and the supply of electricity.

The stakeholder organisations must determine a number of key factors during the early stages of the scheme which will influence the successful implementation of the scheme, the business model and structure to be adopted and the appropriate Governance regime. The two related questions that need to be confirmed are:

1. What is the purpose of the Cambridge Scheme and the associated ESCO? Is it primarily to reduce the carbon footprint, mitigate Carbon Reduction Commitment (CRC) or to make financial savings for all the stakeholders? Or a combination of these?
2. What is the appropriate structure of a potential ESCO? Much depends on the sources of finance, the participants and their roles, the objectives and what would be the balance of public and private sector involvement?

The delivery of the scheme will need to consider who finances the energy centre and plant, and the installation of the DH network pipes and associated equipment and how the on-going operational activity will be supported. Governance options will then need to be available which can operate and maintain the plant, purchase fuel, and sell heat and electricity to a number of customers. The heat market in the UK is currently unregulated and therefore the Governance structure also needs to be carefully formed to provide an appropriate level of certainty of technical performance, achievable benefits and scheme transparency to customers through supply contracts and guarantees over time. Without this certainty, it is unlikely that customers will sign contracts.

A range of structures are examined which may be suitable for a DH scheme in Cambridge, to help identify the advantages and disadvantages of each. This can then help inform the LCDI and Cambridge City Council on which route is preferred. Such business models are often referred to as an energy service company (ESCo) which is an organisation set up to provide energy services. The ESCo is usually involved with the financial elements of the project and its construction and operation. From a financing point of view, the basis of an agreement of this type is the transfer of CHP plant capital, infrastructure investment and operating costs, together with all the technical and operating risks of CHP, from the end user to the ESCO contractor, usually in return for all or a share of the long-term commercial benefits.

Due to the immaturity of the ESCO market, there are no standard models, however there are a number of exemplar developments which have been examined and have informed this report. The delivery and governance structures in most of the existing schemes, whilst being loosely based around some of the models discussed here, are usually specific to the scheme taking into account the customer types, scale of the scheme, and level of public and community involvement.

Structure components

In common with the electricity and gas industries there are three clearly identifiable businesses in a district heating scheme:

- A generation business producing the heat and selling electricity (GenCo)
- A distribution business distributing heat through the district heating network (DistCo)
- A supply business buying heat from the producers, selling energy to customers and paying the distribution company for the transport of energy (SupplyCo)

This structure enables competition between heat generators and competition in the supply of energy to customers on the network. The distribution business is a natural monopoly and if privately owned would ideally be subject to regulation to protect customers and to ensure open access for suppliers in a similar way to the gas and electricity networks. In many cases, particularly small schemes, all these businesses have been combined partly to reduce risk and partly for simplicity, however it is helpful to consider each element separately when evaluating options for a scheme.

Energy supply is regulated by OFGEM and it is likely that if heat supply (currently un-regulated) becomes a regulated business, then OFGEM or a similar Government body would be responsible for overseeing the process. At a local level, Local Authorities involvement in schemes can help provide a degree of certainty to customers, but this would not “regulate” heat supply.

The DistCo business may be divided into two levels – the distribution network which supplies energy to customers and the transmission network which will generally only supply energy to the more local distribution network.

The SupplyCo is responsible for reading meters, billing and debt collection although this may be sub-contracted out to a separate company. The ownership of meters at the customer locations has historically been with the DistCo.

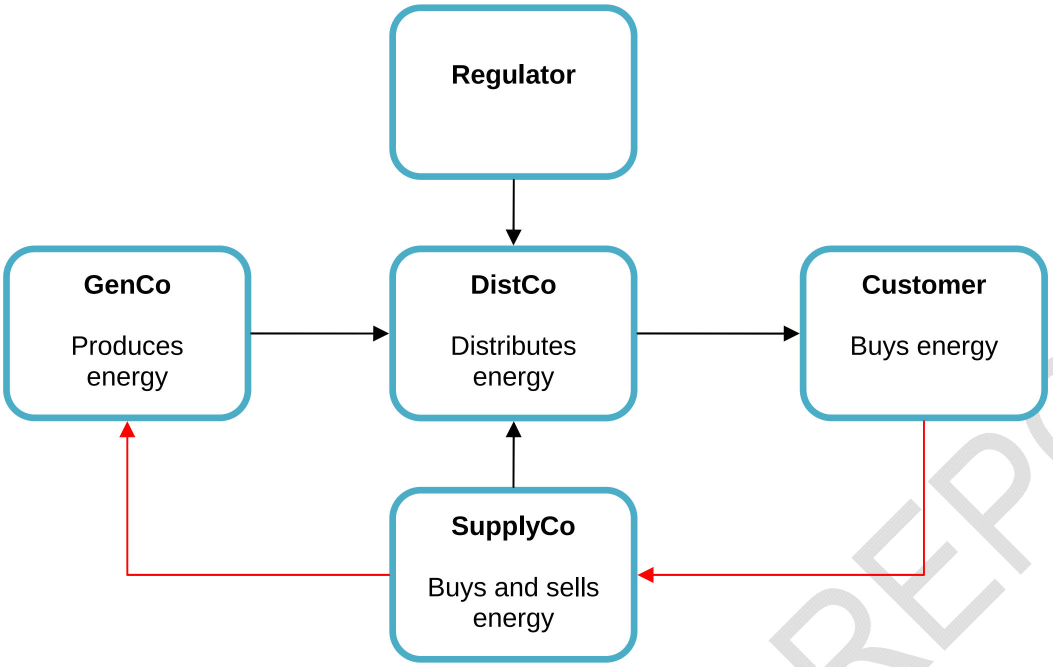

Figure 46. The basic elements of a delivery and governance structure for a district heating scheme.

Structure for district heating companies

The structure previously described was developed when established businesses in electricity and gas were privatised. The development of district heating as a new energy infrastructure has a number of characteristics which mean a direct transfer of the above concepts may not be feasible.

These differences are:

- The district heating networks will be more local than the national electricity or gas grid. In the early days of a heat network or on small schemes, it may not be practical or possible to have multiple energy suppliers who compete to supply a heat market; a single heat energy source is more likely;
- There is currently no system of regulation for the heat network so there is limited consumer protection. As a result there is a stronger desire by the public sector to own the network;
- The district heating network enables CO_2 emissions to be reduced and this objective will be realised through taking a wider strategic view that may go beyond the obligations and economic considerations of a private company; and
- There is a critical need to measure and demonstrate the benefits of the heat network are being achieved and delivered over time and a detailed metering and data gathering strategy at the consumer's sites will be required.

There has been considerable debate about the merits of public sector involvement in developing district heating projects. Typically, options evaluated are:

- Fully private sector model – selecting an Energy Services Company (ESCo) to deliver the scheme;
- Fully public sector model – setting up an internal department to deliver the project. In the case of the Cambridge Scheme, Cambridge City Council could fund, own and operate the DH scheme;

- A Hybrid ("joint venture") scheme where an ESCo is set up as a special purpose vehicle (SPV) with the local authority as one of the stakeholders and other public and private sector partners;
- Further variations within the hybrid scheme may have benefits depending on the circumstances. For example an option might be to include: replacing shareholder ownership with a membership scheme that receives a dividend for investment into the scheme; creating a not-for-profit co-operative scheme; building a number of subsidiary SPVs with specific purposes that draw upon the expertise of the main SPV; separating the district heating network from the generation plant and placing it in either public or private ownership.

All of the ownership models have strengths and weaknesses which are described in the figures below (Figure 47, Figure 48 and Figure 49). In summary the scheme will have to develop the structure that strikes an appropriate long term balance between the:

- Risks and rewards, including:
  - Balance of risk between consumers and the ESCo (some of whom may be the same);
  - The sources of capital funds and grants, both now and in the future might include: :
    - Community energy fund. There may be an opportunity for the project to be part funded from a local community energy fund, such as that examined by Cambridgeshire Horizons. This fund would potentially provide support from monies collected from local developers "allowable solutions" payments which will be required post 2016 for meeting future building regulations.
    - Low cost finance. It is likely that Cambridge City Council has access to low cost loans and Spend to Save, which could be used to provide or to underpin attractive financing options for the scheme.
  - Consumer commitment to long term heat and power sales contracts with price indexation and performance guarantees.

- Consumers expectations:
  - Carbon footprint reduction;
  - CRC mitigation;
  - Attractive heat and power prices;
  - Appropriate returns on commercial investment and capital; and
  - Prevent the potential impact of monopoly practices.

- Allow flexibility to develop the scheme further, in technology type, topography and markets.

Fully Privately Owned SPV

The following schematic describes the strengths and weaknesses of a fully privately owned special purpose vehicle to deliver the scheme

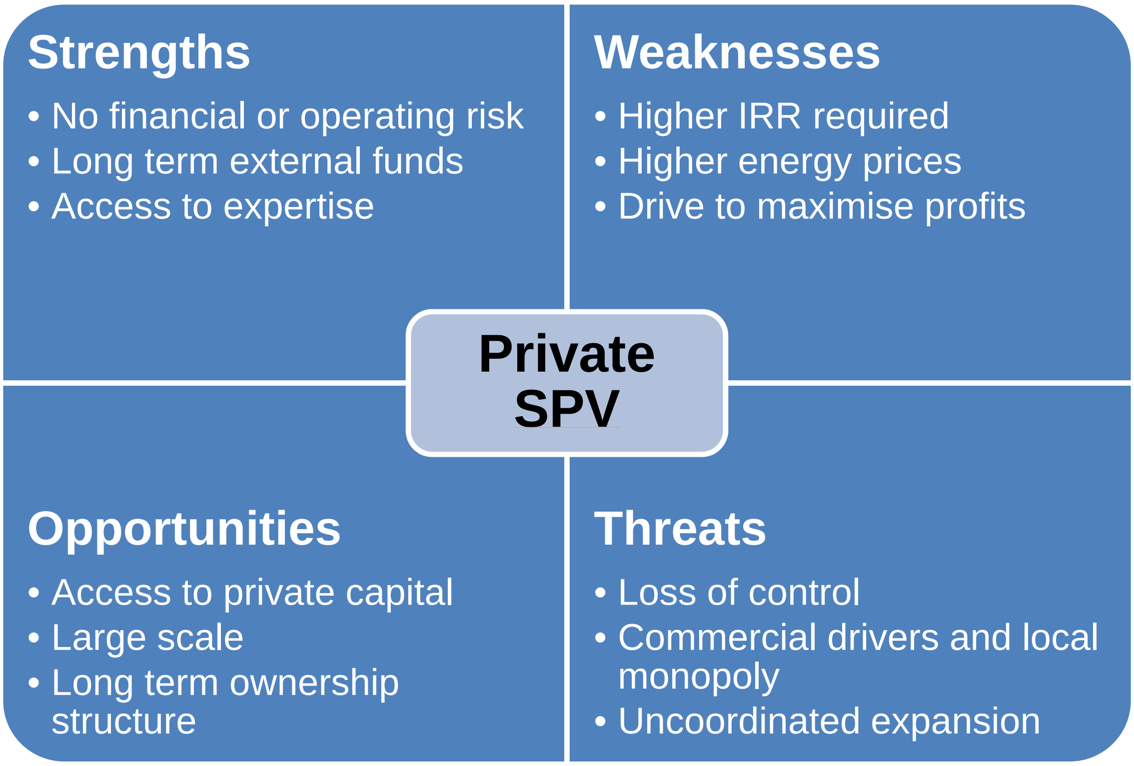

Figure 47: SWOT Analysis of a fully Private ESCo (SPV) that owns the generation capability and the district heat mains

Generally the private sector route provides access to technical and project management expertise, energy trading strength and access to private capital at a market cost, which often requires a higher internal rate of return (IRR) than public capital. The scheme will be driven by commercial drivers which may, over time, diverge from wider public policy and may also impact performance levels and the energy price. The local monopoly of the district heating system has few counterbalances within such a commercial model. The key threat is the loss of control by the public bodies and potential for restricted expansion.

The benefits are that the public sector is relieved of risks in a new area of operation. The full private sector route provides lower financial risk to the scheme stakeholders, but there is correspondingly less control in the direction of the district heating opportunity, lower share of financial benefits returned to the stakeholders, lower reinvestment of the profits in the expansion of the scheme.

Fully Publicly Owned SPV

The following schematic describes the strengths and weaknesses of a fully publicly owned special purpose vehicle to deliver the scheme.

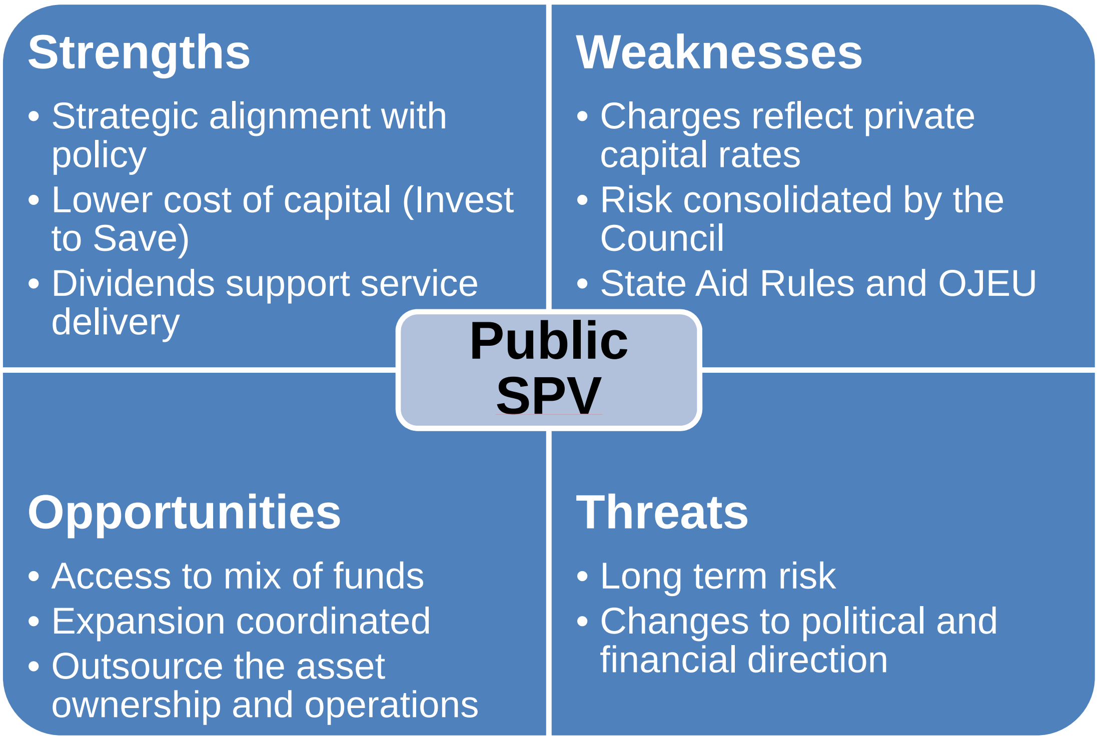

Figure 48: SWOT Analysis of a fully Publically Owned SPV that owns the generation capability and the district heat mains

Generally the public sector route provides access to lower interest rates on capital and permits a more strategic view of the development. It can also help ensure that, in the absence of regulation, customers have certain assurances and can trust the supplier. The downside is that the public sector takes on risks in a new area of operation. A full private sector route provides lower risk to the local authority, but there is correspondingly less control in the direction of the district heating opportunity, and the potential for the public sector to benefit financially is removed.

Even if the ownership of the asset resides with the public sector it is possible for the LA to contract with the private sector for the long-term operation of the energy plant.

Hybrid SPV with multiple ownership

The following schematic describes the strengths and weaknesses of a hybrid special purpose vehicle to deliver the scheme.

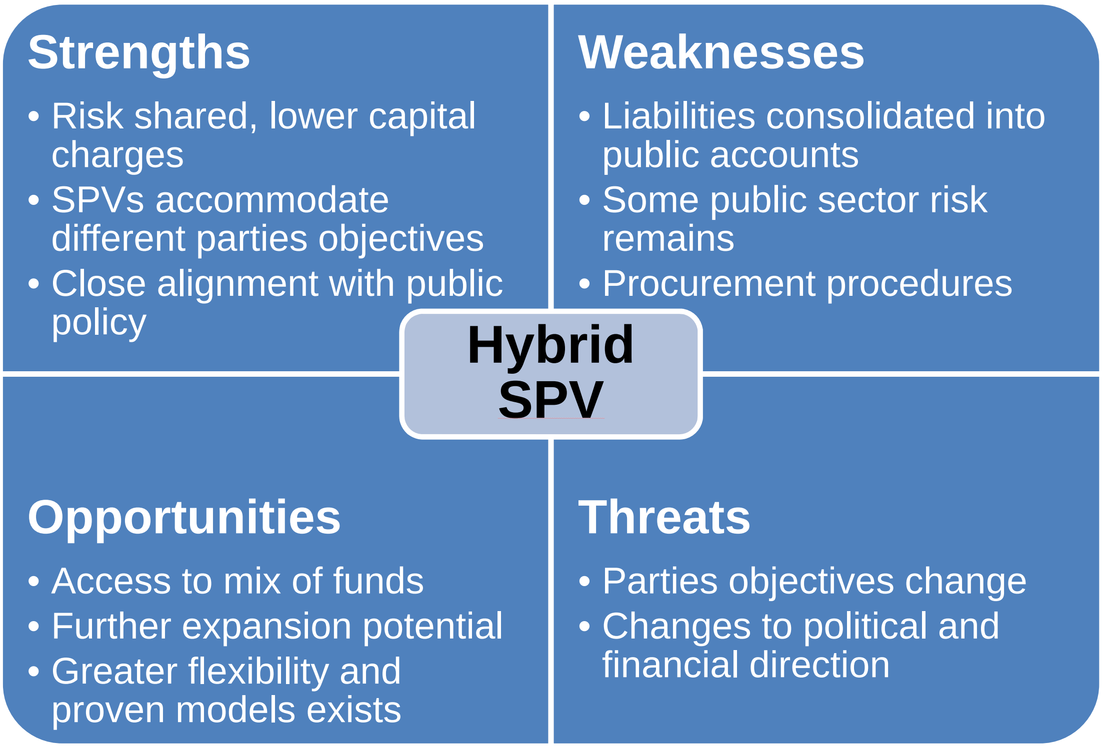

Figure 49: SWOT Analysis of a Hybrid SPV that owns the generation capability and the district heat mains

Generally the hybrid scheme route provides wider access to the scheme for the stakeholders and participants and a more balanced and mitigated approach to the risks and rewards. There are a number of options that can be adapted within the hybrid scheme such as: the roll-out and additional of special purpose vehicles; membership replacing stakeholders; reduces the impact of monopoly practices; promotes long term commitment inclusivity amongst the membership. The main disadvantage is that objectives of the parties may not be aligned in the long-term leading to difficulties in decision-making and potential conflicts.

It can be seen that there are a large number of structures which could be used on a DH scheme. The energy centre and network infrastructure can each be split into “Build”, “Own” and “Operate”, each under public, private or joint ownership. In addition the heat selling function can also fall to each of the three ownership options. The following table shows some of the identified practicable options, there are examples from within the UK for most of these approaches:

Table 15. Delivery and Governance options for a DH scheme

OPTION	CHP			District Heating Network			Organisation selling heat
	Build	Own	Operate	Build	Own	Operate	
A	PSC	PSC	PSC	PSC	PSC	PSC	PSC
B1	CCC	CCC	CCC	CCC	CCC	CCC	CCC
B2	CCC	CCC	PSC	CCC	CCC	PSC	CCC
C1	PPP	PPP	PPP	PPP	PPP	PPP	PPP
C2	PPP	PPP	PSC	PPP	PPP	PSC	PPP
D1	PSC	PSC	PSC	CCC	CCC	CCC	PSC
D2	PSC	PSC	PSC	CCC	CCC	CCC	CCC
E1	CCC	CCC	CCC	PSC	PSC	PSC	PSC
E2	CCC	CCC	CCC	PSC	PSC	PSC	CCC

Key

CCC = Cambridge City Council
PSC = Private sector energy services company
PPP = Joint private/public sector company

Note: Where CCC is indicated as responsible for any of the functions, this does not preclude contracting with the private sector for actual delivery of this function.

Delivery Strategy

The following is a schematic[7] of the ten indicative steps to deliver a special purpose vehicle. It indicates that the SPV has entered the "Options assessment" phase (rose coloured button) and the next phase is expected to be the signoff of the Feasibility study (red button). Iterations are also planned into the development process to test assumptions and accommodate any changes to the environment.

[7] King, M. and Shaw R, .Community Energy, Planning Development and Delivery, 2010, Ashford Colour Press, Fareham Road, Gosport, Hants PO13 0FW.

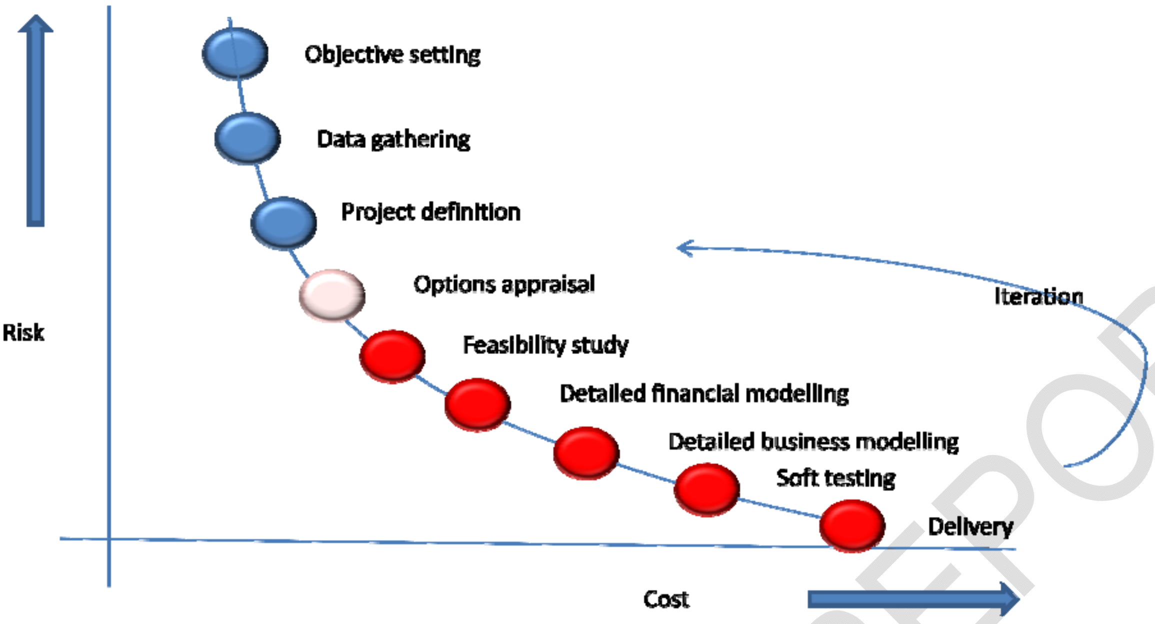

Figure 50: This shows the project development process, or 'flightpath', of a project, illustrating how the risk reduces and expenditure increases the further along the process the project proceeds

Council Authority and Exemplar schemes

Recent changes in primary legislation and white papers have empowered Local Authorities to act to facilitate the delivery of the Low Carbon Transition Plan and specifically to introduce special purpose vehicles to generate heat and power. Key milestones include:

- **Local Government Miscellaneous Goods and Services Act 1976 Section 11** gives Local Authorities (LA) the legal power to generate heat and electricity, the restriction on the sale of electricity was lifted by Secretary of State for Energy and Climate Change (DECC, Sept 2010)
- **Local Government Act (2000)** section 2 empowers all Local Authorities to act in the interests of their citizens in order to secure their social, economic and environmental well-being.
- **Local Government Act (2003)** empowers councils to charge for their services on a "not for profit" basis. Can hold an equity stake in a local government commercial trading company which returns the profit as dividends to the shareholders (SPV).
- **Local Government White Paper (2007) encourages** a strategic role to coordinate investment in the regeneration of neighbourhoods.

Local authority driven schemes, such as Aberdeen, Birmingham, Nottingham, Southampton and Woking are operating to deliver carbon reduction and energy savings using private sector ESCos or special purpose vehicles: each has successfully attracted the long-term investment required for a CHP and district heating scheme. There are differences between the models that are reflected in the level of risk and the objectives of the special purpose vehicles.

The schemes are flexible and are able to expand; each is fuel agnostic and in this case Cambridge is using a low risk natural gas feedstock to provide heat into the network and which can be augmented by alternative feedstocks such as biomass as the time, finance and technology becomes appropriate.

Technical and operational quality

The CHP technology has quality benchmark known as CHP Quality Assurance (CHPQA) or Good Quality CHP, The certificates accredits the efficiency of the technology by measuring the energy inputs and outputs against a calculated benchmark that aims to define, assess and monitor CHP Schemes on the basis of energy efficiency and environmental performance. Achieving the benchmark means that the scheme currently qualifies for the following benefits:

- Climate Change Levy Exemption
- Enhanced Capital Allowances
- Exemption from Business Rating of CHP Plant and Machinery.

Licensing

The provision of heat energy through a heat main is unregulated, but the generation, export and sale of electricity into the grid from a CHP is highly regulated. It is important to note that the area of licensing is complicated and until the exact details of the scheme are known, there will be an element of uncertainty.

A CHP scheme requires that the useful heat is able to be utilised locally. The heat is either onsite in the majority of instances, exported direct to a adjacent heat customer or supplied to a number of users via a district heating network. The electricity generated is also used onsite, or exported to the grid.

The Electricity Act 1989 (as amended) prohibits certain activities unless the person carrying on that activity is licensed or exempt from the requirement for a licence. The licensable activities relating to this scheme, as currently proposed and sized, are:

- **Generation Licence**: This allows the licensee to generate electricity for the purpose of giving a supply to any premises or enabling a supply to be given; and
- **Supply Licence**: This allows the licensee to supply electricity to premises. An electricity supply licence can be for supply to either: domestic and non-domestic premises, or to non-domestic premises only.

Those who carry out licensable activities are obliged to comply with the terms of their licence (including Standard Licence Conditions) and any relevant industry codes from the date their licence is granted.

Ofgem considers all electricity licence applications and decides whether or not to grant a licence in accordance with a set of published objectives, procedures and non-discriminatory criteria . There are a number of questions to be considered:

- What activities in the electricity markets will be undertaken;
- Is the proposed activity ‘licensable’; and
- If the activity is ‘licensable’ does it falls within an exemption, exception or special category.

A key step in this process is to contact the licensing team at Ofgem and to seek independent advice.

Exemptions

Some activities, whilst falling within the definitions of a licensable activity given in the Electricity Act 1989, are exempt from the need to hold a licence. The Acts allow the Secretary of State to make orders giving exemptions from the need to hold licences. Exemptions can apply to individual cases or can be on the basis of a class or type of activity and where granted may be unconditional or subject to certain conditions including length of time.

- Exemptions from the requirement to hold an Electricity Generation Licence are defined in The Electricity (Class Exemptions from the Requirement for a Licence) Order 2001 Schedule 2 Exemptions From Section

4(1)(A) Of The Act (Generation Exemptions). Independent legal advice must be sought to determine whether the Cambridge scheme as described maybe exempted under the provisions of one of the classes.

- Exemptions from the requirement to hold an Electricity Supply Licence are defined in The Electricity (Class Exemptions from the Requirement for a Licence) Order 2001 Schedule 4 "Exemptions From Section 4(1)(C) Of The Act (Supply Exemptions)". Independent legal advice must be sought to determine whether the Cambridge scheme as described maybe exempted under the provisions of one of the classes.

Connection to the local electricity grid

The connection to the local grid is governed by a Connection Agreement between the site and the local Distribution Network Operator (DNO), for this scheme, UKPN. It is anticipated that all the sites in the proposed scheme are buying their electricity from an electricity Supplier and will have a Connection Agreement for the import of the electricity through those designated meter points (MPAN).

A generation scheme is classed as Distributed Generation (DG) if it operates while electrically connected to the distribution network and may also be called "Embedded Generation". The electrical output could be consumed by the site and thus reduce the electricity consumption from the local grid network. Alternatively some of the electricity could be exported into the Distribution Network Operator's (DNO) network. There are three classes of distributed generation as follows:

- Small Scale Embedded Generation (SSEG) or G83/1-1 Stage I Generation connections;
- Multiple Small Scale Embedded Generation (SSEG) or G83/1-1 Stage II Generation connections; and
- Large Generation or G59 Generation connections.

This Scheme is likely to be connected to the local grid and be of sufficient size as to require a Large Generation (G59) connection and Connection Agreement. It is a requirement that the Local Distribution Network Operator (DNO) is contacted and undertakes a technical assessment of the connection proposal and an impact assessment on the grid. Any works: for example to control the export; mitigate the impact on the grid; or to maintain safe operations, will be defined by the DNO at this stage.

Once the Connection Agreement is in place the DNO will award an Export MPAN – which is the controlled point of electricity export to the local grid.

Worked Examples of the Governance options and solutions are outlined below.

A. <u>All private sector.</u> A private sector company constructs, owns and operates the CHP and the new heat network and sells heat to each customer on the new network at each building connection. There is no public sector involvement.

B. <u>Predominantly public sector.</u> Cambridge City Council (CCC) constructs, owns and operates the CHP and the new heat network, and sells heat to customers on the new network (Option B1) with no private sector involvement. The day to day operational risk to CCC can be reduced if the operation and maintenance of the CHP and DH network are contracted to experienced private sector companies (Option B2).

C. <u>Public private partnership (PPP) ownership.</u> A PPP is formed between CCC and a private sector company to jointly build and own the scheme and sell energy to customers. To reduce the public sector risk in operation, a private sector company could be contracted for the on-going operation requirements (option C2).

D. <u>Split assets – network in public ownership.</u> A private sector company constructs, owns and operates the CHP plant. The heat network is constructed, owned, and operated by CCC who either sell heat directly to the customers (option D1), or who charge the private sector company a rental on the network on the basis of capacity and units of heat transferred in return for the private sector company selling heat to the customers (option D2).

E. <u>Split assets – network in private ownership.</u> CCC construct, own and operate the CHP plant, whilst a private sector company construct, own, and operate the heat network. The private sector company can purchase heat off CCC and sell to customers over the network (option E1) or alternatively, CCC can sell heat to customers by paying the private sector company network owner/operator a distribution charge (option E2).

In addition to the above options and as detailed in Table 15, there are many other theoretical options. However we believe the above represent the most practicable, and are the most fruitful to pursue further.

The options raise differing issues with respect to procurement and risk management and are discussed in more detail below.

<u>Option A - All private sector.</u> A private sector company constructs, owns and operates the CHP and the new heat network and sells heat to each customer on the new network at each building connection. There is no public sector involvement.

In this option the private sector company (PSC) procures the CHP and heat network and operates the scheme. As a result the PSC will take on most of the risks.

There will be a contract between the PSC and CCC for the supply of heat at the point of connection to any public sector buildings on the scheme. The PSC would also sell heat to any other heat customers with a similar contractual arrangement.

The PSC will also require a long-term contract with the public sector customers and the other key customers including ARU, the University of Cambridge, and the College for the sale of heat so that their return on investment is assured and the risks are reduced. The heat would probably be charged in three parts: a one-off connection charge, a standing charge and a unit charge.

The PSC would be able to claim enhanced capital allowances on the CHP investment.

It is expected that the PSC would require the heat supply contracts to be agreed in advance of construction and as a result the heat selling price would be agreed in advance. This would mean that the construction cost risk is effectively transferred to the PSC as they would procure the system.

The disadvantage of this option is that CCC will have little control over the strategic direction and expansion of the scheme although a separate co-operation agreement could be used to enable joint actions to promote the scheme.

It will take time to procure this option as there will firstly be a procurement process to select the PSC (ESCo) and then the PSC will need to procure the design and construction contracts.

Examples of this approach are: the City of London DH scheme where Citigen Ltd are the PSC, the Southampton DH scheme where Utilicom Ltd are the PSC and the Barkantine scheme in Tower Hamlets where EDF Energy are the PSC (this was a PFI contract).

The main legal issue would be the need to comply with public procurement rules in the selection of the PSC to supply heat to public sector buildings on a long-term contract.

<u>Option B - Predominantly public sector.</u> Cambridge City Council (CCC) constructs, owns and operates the CHP and the new heat network, and sells heat to customers on the new network (Option B1) with no private sector involvement. The day to day operational risk to CCC can be reduced if the operation and

maintenance of the CHP and DH network are contacted to experienced private sector companies (Option B2).

In this option, CCC take the full responsibility for the CHP plant and heat network, and their operation and long-term maintenance. CCC would be responsible for the customer interface, metering and billing and debt recovery. For a small scheme with a few customers, this level of administration would be relatively small. However if the scheme expands with more customers, in particular domestic customers, then the level of administration would significantly increase.

CCC would have to develop the skills needed to carry out both the construction and the operating functions and this could be relatively costly for this small scheme. It is likely that this will require the procurement of experienced staff.

CCC would be responsible for the construction of the new heat network and the resulting construction risks, cost overruns, programme delays.

CCC would purchase gas for the CHP and sell the electricity generated probably to a licensed supplier who would sell on to others.

CCC could reduce the operational risks of the scheme by contracting with the private sector for the operation and maintenance of the CHP and heat network (option B2). This could be achieved by tendering the operation and maintenance contract at the same time as the construction contract, thus enabling an element of risk transfer. This is common practice with the provision of a CHP unit where typically the supplier carries out the maintenance work for a 10 – 15 year period with some form of availability guarantee.

The advantage to CCC of bringing in an outside PSC operator is that CCC retain the ownership of the assets and operating surplus, whilst transferring the operational and supply guarantee risks. If CCC have access to capital at low interest rates or the possibility of grant funding from Allowable Solutions, then the scheme will be more likely to be financially viable.

The ownership of this asset could be transferred at a later date to a joint public-private ESCo or sold to a private sector ESCo. In order to facilitate such future transfers and for clarity in the financial performance of the scheme CCC may wish to set up an CCC-owned ESCo as an arms-length management organisation.

An example of this approach would be the Pimlico District Heating Utility which is part of the Westminster City Council ALMO[8] City West Homes. Although the majority of the heat demand is the ALMO's own property there are also a number of private sector heat customers. Another example is the Lerwick District Heating scheme.

A potential legal issue in addition to public procurement rules is the provision of State Aid. The scheme should not be subsidised by the public sector if this prevents private sector competition. Nor should the local authority make a profit although funds can be established for future maintenance needs and investment in other infrastructure which achieves the same goals as the ESCo was set up for, primarily CO_2 reduction in this case.

<u>Option C - Public private partnership (PPP) ownership.</u> A PPP is formed between CCC and a private sector company to jointly build and own the scheme and sell energy to customers. To reduce the public sector risk in operation, a private sector company could be contracted for the on-going operation requirements (option C2).

This option gives a greater role for the private sector in the future development of the network but makes the new joint company responsible for the heat supply.

[8] ALMO = Arms Length Management Organisation

As the joint company is involved in buying and selling heat CCC would have a greater role in determining the heat selling price to customers than in Option A whilst retaining reduced risk due to shared ownership. However this could create conflicts of interest because the primary responsibility of the company will be to maximise return to shareholders, and not to deliver low cost heat.

There would be considerable time and cost needed to procure a partner and set up the PPP. Therefore this could be an option to be pursued at a later date after the initial scheme has been established. It would be more cost-effective to pursue this option for larger schemes in view of the high development costs. It is also more likely that if a small phase 1 scheme is developed and shown to be viable, a PCS partner could be procured on more favourable terms for CCC due to the reduced level of risk.

The PPP could contract with a private sector company to operate and maintain the scheme and this may or may not be the PSC who part owns the PPP (option C2).

In this option CCC shares risk and reward in proportion to the shareholding and will be able to influence but not directly control the strategic development of the scheme.

An example of this Option is the Sheffield Heat and Power scheme which was initially set up with Sheffield City Council being a part owner of the scheme together with two private sector partners. Sheffield City Council subsequently sold their shares.

A further option is a community-owned scheme where the customers for the heat are shareholders in the company. Due to the presence of a small number of large potential customers, the University of Cambridge in particular, it could be advantageous to the scheme and customer if they became part of the partnership. In the case of the University of Cambridge, becoming a shareholder will provide them with a degree of control over the scheme which is important for their long term energy supply, but will also ensure that they are tied into the scheme helping to de-risk it. Due to the proposed network layouts passing though University land, the involvement of the University in the PPP could be important for access to, and the strategic development of the network.

The approach of including key customers in the PPP can provide a sense of local ownership and commitment to the scheme, but the number of partners needs to be limited due to complexity. For a Cambridge City centre scheme, the most obvious partner would be the University, and it is unlikely that the other customers are as strategically important.

<u>Option D - Split assets – network in public ownership.</u> A private sector company constructs, owns and operates the CHP plant. The heat network is constructed, owned, and operated by CCC who either sell heat directly to the customers (option D1), or who charge the private sector company a rental on the network on the basis of capacity and units of heat transferred in return for the private sector company selling heat to the customers (option 2).

In this option the heat production is separated from the heat distribution businesses. The PSC is responsible for the construction and operation of the CHP plant and the network is owned and operated by CCC.

The advantage of this arrangement is that CCC can develop the network to deliver their strategic objectives and yet retain competitive bidding for the heat generation plant. The PSC would be better placed to construct and operate the Energy Centre which requires more specialist knowledge and experience. The PSC would also be better able to manage the contracts for the purchase of fuel and sale of electricity, reducing the supply guarantee risk to CCC.

Option D1 involves the PSC being the heat supplier which would mean CCC taking a more passive role as network owner, collecting rental payments for its use. This is similar to the electricity distribution model.

Option D2 would involve CCC being the active heat supply organisation buying heat from the PSC at the Energy Centre and selling to its customers. The latter has commercial risks as it is likely that the Energy Centre contract will be a long-term contract to provide a degree of certainty to the energy supplier, but at least some of the heat supply contracts will be short-term. Initially the heat may be purchased from a single Energy Centre but over time there could be multiple heat sources in competition if the scheme expands to cover a larger proportion of Cambridge.

Examples would include: the Nottingham DH scheme where Nottingham City Council own the network, supply heat and buy heat from an energy from waste plant operated by the private sector, and the proposed London Thames Gateway Network taking heat from Barking power station.

Option E - Split assets – network in private ownership. CCC construct, own and operate the CHP plant, whilst a private sector company construct, own, and operate the heat network. The private sector company can purchase heat from CCC and sell to customers over the network (option E1) or alternatively, CCC can sell heat to customers by paying the private sector company network owner/operator a distribution charge (option E2).

This is the reverse of Option D where the network is owned by the PSC who rents it out and CCC own and operate the Energy Centre supplying energy to the network. The PSC may buy heat from CCC and sell to the customers, or is could distribute heat for sale by CCC for a distribution charge. For a large scheme there could in principle be several heat supply companies renting capacity on the network, one or more of which is owned by CCC.

It is unlikely that this option will be preferred for Cambridge unless a DH company can offer a low cost finance route to install the network that is unavailable to CCC. This option also removes the long term strategy for the network from the Council and therefore could limit future expansion if it is seen as less than commercially attractive.

Examples: There are a few companies who offer this model as they are currently Independent Distribution Network Operators in electricity and gas and see the potential for offering a similar proposition for district heating. The main application is likely to be for large new build schemes where the company is already involved in electricity or gas distribution work and there would be construction benefits for the developer of having a single infrastructure services company. Another example might be where there is an existing heat source in public sector ownership.

Assessing the options for Cambridge City

The range of options discussed above show that there is a balance to be made between maintaining control of the scheme, its future strategy, and having access to the potential revenues, versus the level of risk taken on board financially and contractually.

For the Cambridge City scheme, there are a range of potential stakeholders who could be included in the categories of public sector, and private sector.

- Cambridge City Council. CCC is the clear central public sector interest in the scheme, being the local authority for the area, and driving force behind CO_2 reduction across the City. Cambridge has strong aspirations for improving the environment and the Council will provide the strongest push for a scheme covering different customers.
- Cambridgeshire County Council. The County Council has no direct technical involvement with the scheme apart from the St Matthew's Primary school and the St Albans Catholic Primary school. However the county may support the financing of the scheme, particularly through funding from the proposed county-wide Community Energy Fund (CEF).
- Private sector energy service companies. The use of private sector ESCos is referred to in the outline descriptions and these could cover a variety of purposes as described.

- University of Cambridge. The University will potentially be the largest heat consumer if the Downing Site and New Museums site are connected. In addition University land may be required for both the construction of an energy centre (in the western area for layout options 2) and the installation of transmission pipes (which will need to remain in the ownership of the scheme). The scheme could therefore benefit from the University being a partner, but also the University will secure a level of control of the scheme reducing the risk of connecting.
- Anglia Ruskin University. In the schemes connecting to ARU, they remain a large consumer and as such may wish to become involved in the scheme. From a network perspective, the scheme only needs to connect to the ARU site, and network ownership within the site could remain with the ARU.

Forming a governance structure

The strategic development of district heating in Cambridge will certainly need to be promoted by the City Council over the development of an initial scheme, if not beyond. The mix of customers, in particular individual colleges, means that someone is required to coordinate the scheme. The University sites are large enough alone to support smaller scale DH networks with CHP, but even on its own estate, the University has struggled to get past the feasibility stage for DH despite a keen interest. Therefore the involvement of the City Council will be vital.

The University is a large consumer and is strategically important in the development of the network through land ownership. There are also large benefits to the University in having some control over the scheme for securing long term energy supplies. Therefore it is possible that the University may also become part of the delivery structure.

It is likely that a suitable delivery structure would be a joint venture between the Council and the University for the development and operation of the scheme. Private sector specialists can be potentially contracted for the administration in terms of billing and purchasing (although this is something the University or Council both have expertise in). A private sector specialist would be used for the day to day operation and maintenance of the plant and network.

7 Conclusions and recommendations

Conclusions summary

This report has assessed the technical and economic feasibility of a number of District Heating (DH) scheme options in the centre of Cambridge. It demonstrates that there are potential schemes which can deliver a 60% CO_2 reduction for heating for a number of customers, whilst providing an economic return in the region of 6% to 7%. The success of the scheme will rely on a strong governance structure being formed, and it is likely that a special purpose vehicle combining both public sector (the City Council and potentially University of Cambridge) and private sector / commercial organisations will be best suited.

DH Network options

The initial concept for a DH scheme in central Cambridge was based around the Parkside swimming pool and linking to Anglia Ruskin University (ARU). This allows City Council land at the pool to be used to house the energy centre, providing low carbon heat to the pool, and exporting heat and possibly electricity to the ARU campus. However this report also looks at options which extend to the west of the original scheme, connecting to the large University of Cambridge sites including New Museums, the Downing Site, the Old Addenbrookes site, and a number of other individual buildings. The high heat demands of these sites and relatively dense nature means that the overall heat density on the DH network is higher which should improve the viability.

The economic analysis off the schemes demonstrates that the larger schemes (Options 1 and 2) incorporating the large University site both have similar IRRs of around 6% - 7%, with a capital cost of circa £22 million to £23 million. This could be attractive for public sector investment, and with some additional funding, potentially private sector investment. However the base case scheme centred around the pool and ARU is much less economic with an IRR of around 1% (a capital cost of circa £5 million) which is unlikely to attract investment without significant additional funding. This suggests that any further assessment of DH options in the centre of Cambridge should consider the large scale scheme options, and will need close collaboration with the University of Cambridge in particular to ensure that the proposals are compatible with its current sites and demands for heat. In particular further work is needed to assess the technical viability and costs of providing distribution networks within some of the complex university sites.

Electricity sales

Achieving a good value for the CHP electricity output is central to improving the economics of the schemes. There will be a mis-match in the output profile from the CHP engines and the demand from customers, but due to the scale of demand from customers connected to the heat network, between 90% (base case) and 100% (Options 1 and 2) of the CHP electricity could be used to meet their demand.

Private wire is one method by which electricity can be sold for the maximum revenue value and this study demonstrates that a private wire connection to ARU from an energy centre located in the Parkside Pool area is viable, providing the greatest IRRs. The cost effectiveness of a private wire is determined by the length (and thus cost) of connection and the amount of electricity sold over the connection. Therefore if private wire was to be used on other parts of the scheme, such as at the New Museums site, where the ratio of electricity sales to infrastructure cost was higher, the economics would improve further. But in situations where the ratio may reduce, for example with an energy centre located further away from ARU, then the economics will need re-calculating.

Where a private wire arrangement is not possible, it will be important to maximise the revenue through sales over the electricity grid. The effective cost penalty of this as modelled in this report is the payment of distribution charges. However an arrangement needs to be sought as to how this can be achieved. This could be though either negotiating a power purchase agreement with a supplier which reflects negotiations with local electricity customers (in particular the University of Cambridge, associated colleges, and the Council), or by having a partner in the scheme who is a licensed electricity supplier (assuming that this scheme is not license exempt). Another option is the use of a license-lite arrangement although there are no current examples of this in operation.

When electricity is sold for bulk supply to the electricity grid, there is a significant reduction in the revenue obtained and none of the schemes are economic. It is therefore vital that electricity can be sold to customers, either directly, or via the grid, for the success of the scheme.

Energy centre location

Establishing a suitable location for an energy centre will be key to furthering the technical development of the scheme.

The initial concept of an energy centre located on the roof of the Queen Anne Terrace car park is attractive, making use of Council assets which are currently not optimal (the roof cannot be used in some periods due to ice). The location is close to the ARU, providing potential for a private wire connection, and can provide electricity directly to the Council owned swimming pool. The use of the car park may be possible but it is likely that structural modifications will be required for the car park to take the increased loading from the CHP engines. There would also be no scope for further expansion on this site. The costs of these modifications have not been calculated but could be significant.

Other locations around the Parkside pool are available, but have restrictions. The current temporary boiler location is extremely limited for space, and using the basement / ground floor of the car park is unfavourable due to height restrictions and would result in a loss in revenue to the Council.

In the Option 2 scheme, a second energy centre is included located within the New Museums / Downing Site area. This reduces the amount of plant required at the car park site, and importantly provides good access to the privately owned University of Cambridge electricity networks on these two sites for electricity sales. Further work is required to identify a suitable location – both of these sites are relatively dense – and other considerations such as planning and the cost of building also need to be examined.

Taking a long term strategic view of a DH scheme in Cambridge, it may be desirable to have a larger energy centre site away from the City centre, and the Council Depot along Mill Road adjacent to the railway may be one possibility. This offers advantages of adequate land availability (in Council ownership) with potentially fewer planning restrictions. However the pipework along Mill Road incurs an additional £1.9 million reducing the IRRs by circa 0.9%. Further analysis is required on the cost benefits of developing an energy centre at this site, and the longer term economic benefits to the DH scheme for future expansion.

Carbon savings

One of the prime drivers for the creation of a DH scheme in Cambridge is the potential CO_2 reduction which can be achieved. Overall CO_2 reductions are achieved by the cogeneration of heat and electricity resulting in high efficiencies. Compared with a counterfactual of gas boilers, customers connected to the DH network will typically reduce CO_2 emissions from heating by circa 60% (assuming 2014 grid electricity intensity) for their heating. This brings not only environmental benefits, but also economic benefits through the reduction on current and future carbon taxes. At a current price of £12 per tonnes CO_2, the CRC is an important, if not primary driver for the scheme. However a general view is that carbon taxes will rise, and if a higher cost of £50 per tonne is included (which is closer to the Government projections for non-traded carbon prices), then the IRRs increase by around 3% to circa 9% - 10% which may attract further investment in the scheme alongside attracting more customers.

Governance

There are a large number of governance options open to the scheme each of which has merits and disadvantages. The most important factor when deciding on governance is to determine the key drivers for the scheme, and keep these central to the operation of the scheme. The governance structure also needs to consider the types of customer who may be connected to the scheme, and how the scheme will operate economically in terms of the purchase and sales of energy, and the need to access finance and make an acceptable rate of return.

The discussion in this report suggests that some form of special purpose vehicle comprising the City Council, private sector expertise, and potentially the University of Cambridge, could be the most suitable governance model:

- The public sector involvement will be important both from a financing perspective, enabling low cost finance to be used to develop a scheme which is not deemed commercially attractive, but also importantly to provide the Council with a strategic hold over the future development and direction of the scheme. The involvement of the Council would also lend a degree of credibility to the scheme, particularly in light of the lack of regulation over heat, and this will be increasingly important if the scheme expands to include domestic connections in the future.
- Private sector expertise will be important in the operation of the scheme, and can bring with it benefits such as licensing for electricity sales. Whilst the scheme may not be commercially attractive without additional funding, the operation of a scheme in Cambridge connected with the University could have a high kudos.
- The University of Cambridge, as potentially the largest customer, could see involvement in the governance structure as a way of ensuring the scheme performs to its benefit and is strategically aligned with future University plans.

One option for a SPV could be to develop a membership based model, providing all customers with a degree of ownership of the scheme. This again provides additional security in a market where there is no regulation.

Recommendations

A DH scheme can clearly offer benefits to Cambridge though reduced CO_2 emissions from gas CHP, developing infrastructure which provides flexibility for future plant upgrades, and potentially providing lower cost energy to a wide range of customers. Through this work we understand that there is a strong support within the council, but also generally a good level of interest from the potential customers. To take the scheme further, there are a number of recommendations:

7. To engage further with supply companies. This report can be used for market testing with supply companies and investors. Discussions with these will be important to establish the level of interest in the scheme, the type of involvement they may desire, and to gain feedback on the scheme options. Whilst outline ideas for a governance structure have been given, discussions with suppliers will allow these to be worked up further to a stage where some form of organisation can be formed.
8. Engagement with customers. The signing up of customers for heat and potentially electricity sales is vital for the economics of the scheme, and to reduce risks for investors. The size of some customers (in particular the University of Cambridge) provides benefits in terms of loads, but also a risk if they pull out. Therefore it will be important to commence discussion on both how contractual arrangements may be formed and the levels of tariff which may be attractive, but also to examine further the technical issues around connection, in particular the development of networks on the individual sites.
9. Sales of electricity. Achieving a good revenue value for electricity is key to the economic success of the scheme. Further technical analysis will help establish the potential for private wire, in particular on the University of Cambridge sites if an energy centre was to be located there. However the licensing implications needs to be examined in more detail, both through discussions with potential suppliers, and further examination of the electricity loads and output in relation to licensing exemption. At present little is known about the license lite proposals and further examination of these is required.
10. Energy centre sites. A number of site options have been outlined in this report but further examination is required, especially for energy centres located within the University of Cambridge sites. This further work needs to consider the availability of land and current ownership, planning constraints, the costs (which may be higher for City centre locations), and infrastructure requirements.

11. Financing. It will be important to establish a source of financing to feed into further work on governance structures and design refinement (the level of funding available may have an impact on the size of the first phase of the scheme). Work should be conducted to examine funding sources from within the Council and public sector, the potential customers (who may wish to invest) and from commercial funding sources. A financial model is required to determine the cost implications of the different governance structures and procurement methods.
12. Policy. National policy and regulation is constantly changing in the area of sustainability and low carbon energy. It will therefore be important to constantly update the assumptions used in this report with the latest knowledge around current and future policy. In particular, it is believed the Government will be examining ways of incentivising heat networks and CHP.

Appendix 1: Information received

The site energy demand is used to determine the size of the decentralised energy scheme and therefore its economic viability and environmental benefits. To this end, it is paramount that site energy demand information attained can reliably represent the site under consideration and correctly inform the decision making process.

In general, whilst the process of obtaining the necessary data has not been completely straight-forward and efficient; the end result is nonetheless useful data in most cases, received in a variety of formats. Where the required data was not available or unattainable, it was necessary to employ a set of assumptions and methodology to tailor energy profiles based on accepted internal and industry practice to a reasonable extend. This section sets out to highlight the information received for each site considered in the study and where relevant, all assumptions made are also listed.

ID	Building/Site	Included in study?	Description on information received
E001	Anglian-Ruskin University (ARU)	Yes	Following a meeting with the estate manager Simon Chubb, sets of energy data and relevant information were received. These are monthly meter reading of gas and electricity across the campus site.
E002	Mackays site	No	This site has been excluded from the study as there is insufficient information and the future plans and time scales cannot be properly determined.
E003 E004	Parkside Pool (PP) Kelsey Kerridge (KK) sports centre & QAT	Yes	The pool is the council's largest CO2 emitter in the city and therefore this pool of buildings would be ideal anchor load for the scheme. Various versions of the metered energy data have been received from both the city and the county council. These are in the form of annual and monthly data from the NI185 database. In instances where consumption figures were missing for certain months, energy figures for the corresponding months from another metered year were used as direct replacement.
E005	Mill Road Depot	Yes Phase 2	Whilst this site has been included in the study as the extension to the network proposed as future phases, very little is known of the site development and regeneration. The time scale was also unclear. Therefore, without any further information, the energy demand estimate was made based on the previous e-On study.
E006	Redevelopment of the police station site	No	This site has been excluded from the study as there is insufficient information and the future plans and time scales cannot be properly determined.
E007 E008	Brandon Court Ditchburn Place	Yes	Both sites are council-own and energy data was received as part of the NI185 database, in monthly meter reading resolution. In instances where consumption figures were missing for certain months, energy figures for the corresponding months from another metered year were used as direct replacement.
E009	YMCA	Yes	Whilst this building is situated next to the proposed energy centre (EC01) site and therefore it would be rational to include in the study. However, due to unresponsive The time scale was also

			unclear. Therefore, without any further information, the energy demand estimate was made based on the previous e-On study.
E010 E011	Cambridge Crown Court Civil Justice Centre/Cambridge County Court	Yes	Whilst interested to be part of the scheme, the response fell short of a prompt provision of metered energy data in both cases. As public buildings, the building Display Energy Certificates (DEC) are available on the public domain and through this, the building floor areas and annual energy consumption figures were used to estimate.
E012	Grafton Centre	No	This building has been excluded as it was concluded that there is no suitable local heating connection available.
E013	St Matthew's School	Yes	The county council own this school and therefore was able to provide full year's worth of monthly consumption figures
E014	Parkside Community College	No	No response was received from this stakeholder. Hence, it was concluded that no interest is shown to buy into the scheme, so excluded from the study
E015 E016 E017 E018	Youngs site, ARU Phase 1 Youngs site, ARU Phase 2 Youngs site, ARU Phase 3 Youngs site, ARU Existing Reception	Yes	ARU site manager has provided snippets of pages from the planning submission, detailing building floor plans, floor area and activities. This information was used to approximate energy demand based on floor area pro-rated benchmark figures
E019	Mandela House	Yes	This is a city council building and full year monthly energy consumption data has been provided via the NI185 database
E020	Gonville Hotel	Yes	The only hotel to show genuine interest and full year monthly energy consumption data has been provided
E021 E022 E023 E024 E025	Emmanuel College Pembroke College Downing College Hughes Hall Peterhouse College	Yes	LCDI was able to obtain energy data from the colleges, where gas consumptions were in full year monthly figures, derived from metered readings straddling across a range of months for several meters for each site. Some manual re-sorting of data was required to apportion the energy correctly to the respective months. Electricity consumptions were available in half-hourly resolution. Some sorting was carried out to again apportion the energy to the corresponding months. Boiler house location and some information on boiler sizes were also available for Emmanuel and Pembroke College.
E026	Christ's College	Yes Phase 2	Similar to the above case, gas consumption figures were available however, no electricity data was received
E027 E028 E029 E030 E031 E032 E033	New Museum's Downing site Old Addenbrooke's site Silver Street/Mill Lane site Fitzwilliam Museum Chemistry, Unilever, ScottPolarInstiture Uni Bdg no 32 – Eng Uni bdg no 4 – Scroope Terrace	Yes	UoC estate manager has provided a comprehensive set of monthly energy figures covering a full year for individual buildings within the university precinct. This included buildings outside the scope of the scheme. The irrelevant energy data were therefore filtered out and for the relevant sites. Energy data for individual buildings have been aggregated to form site wide energy figures. Exception was made for the Fitzwilliam Museum, Chemistry, Unilever and the Scott Polar Institute buildings where they have been individually named identified by LCDI for consideration. The New Museums Site energy demand has been adjusted to take into account the projected reduction after the refurbishment and redevelopment work taking place currently. Without any more information, this adjustment was carried out on the basis of percentage of reduction in gas and electricity use by the Arup Building, it being one of the main energy consumer in that site.

E034	Royal Cambridge Hotel	No	No response was received from this stakeholder. Hence, it was concluded that no interest is shown to buy into the scheme, so excluded from the study
E035	Hotel Du Vin, Trumpington Street	No	No response was received from this stakeholder. Hence, it was concluded that no interest is shown to buy into the scheme, so excluded from the study
E036	Hilton Garden House Hotel	No	No response was received from this stakeholder. Hence, it was concluded that no interest is shown to buy into the scheme, so excluded from the study
E037	Crowne Plaza Hotel	No	No response was received from this stakeholder. Hence, it was concluded that no interest is shown to buy into the scheme, so excluded from the study
E038	University Arms Hotel	Yes	The only energy information received is the annual figures over 3 year period. The gas consumption data also included process consumption. Therefore, an estimate was carried out by assuming 35% of gas usage was for process and final energy figures were averaged of the 3 year period.
E039	Grand Arcade	No	This site was excluded after difficulty with obtaining useful information and energy data
E040	Lion Yard	No	This site was excluded after difficulty with obtaining useful information and energy data
E041	Leys School	No	Whilst interest was shown, the site manager was not able to response with provision of required energy data within the time frame of the scope. Hence, site was excluded from the study
E042	St Mary's School	No	Site is outside the boundary considered within the scope of the scheme hence, it was excluded from the study
E043 E044 E045 E046 E047 E048 E049 E050 E051	St Catherine's College Queens' College Corpus Christi College King's College Old Schools Site Clare College Gonville & Caius College Trinity College St John's College	Yes, Phase 2	These are colleges located further afield along the north side of Trumpington Street, which were brought onboard to consideration by LCDI. As they form Phase 2 of the scheme, no energy demand assessment were carried out involving these buildings. Therefore, no energy data was formally requested and received.
E052	Perse School	No	Site is outside the boundary considered within the scope of the scheme hence, it was excluded from the study
E053	St Albans School	Yes	The county council own this school and therefore was able to provide full year's worth of monthly consumption figures
E054 E055	The Corn Exchange The Guildhall	Yes	Both council own, information received from part of the NI185 database, in monthly meter reading resolution

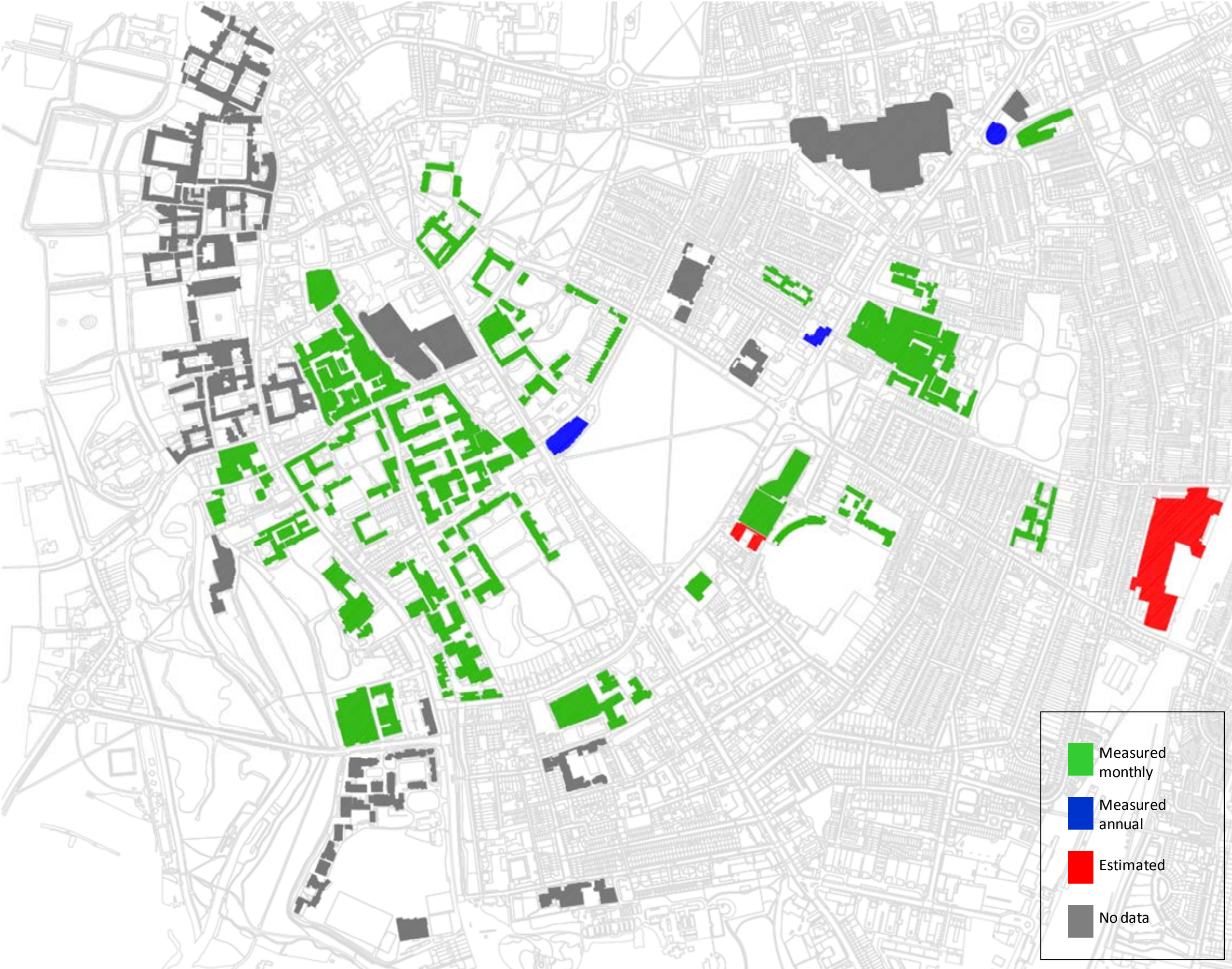

Figure A2.1 Map shows the level of quality of information received for buildings considered in the study.

Appendix 2: Modelling assumptions

DH network costs

The study looks at the primary network only. The secondary network, which is the part beyond the Heat Interface Unit flatstation has not been fully taken into account also contingency has been built into the model for this. This is because this is a highly variable parameter to model due to large unknown about local boiler house conditions and plans by individual site/building management in terms of strategy of connection to the heat sub-station when the DH scheme becomes live.

The study assumes nominal figures for cost for hard-dig and soft-dig scenari on for pipe laying, which takes into account:

Civil work all inclusive:

- excavation and reinstatement per meter of trench
- exclude special surfaces, close shoring, dewatering & traffic management

Supply & installation all inclusive:

- supply, delivery, offloading, installation, hydraulic testing, 10% NDT
- rates per single pipe and need to double up for flow and return
- includes fittings, site joints, termination seals

The proposed DH routes on the maps are indicative routes, where possible the following considerations have been made:

- to reduce disruption to traffics on main transport trunks and busy access routes around the city
- where possible, a more cost-effective route has been considered, e.g. soft-dig alternative than hard-dig was proposed
- where relevant and possible, routes have been proposed to optimise on pipe size to reduce both material and excavation costs
- proposed DH routes have not taken into account some excavation issues such as:
    - the presence of other underground services already in place (electricals, sewage, water pipes)
    - presense of asbestos in old pipeworks where excavation might take place, which require additional cost for removal or re-routing of DHN pipes

DH pipe costs for excavation work in some existing sites and in particular historical sites can be considerably more due to complexity of and alignment with existing services, coordination with other services operators, disruption on main traffic trunks around city, historical/archaeological implication with some sites in the city. It is anticipated that on average this will be accounted for, although a small level of contingency has been built into the analysis to account for this.

Also, DH pipes have been slightly over-sized to account for potential future connection, however, it is difficult to quantity the level of over-sizing as energy demand is very variable parameter in a DH scheme.

CHP sizing

CHP plant is sized to meet 70% of total scheme heat demand. The sizing methodology assumes availability of thermal store and scheme is heat-led. Multiple CHP engines are assumed for following reasons:

- more flexibility in modulation to cater to variable heat demand and minimise heat dumping/rejection
- multiple smaller engines specify to distribute energy centre weight and reduce weight density considering the structural loading limitation on the QAT car park top floor level where a site for energy centre has been proposed by the client
- due to structural concerns, study looks are possibility of a scheme with remote and distributed BackUp/TopUp boilers (not centralised)
- as there were no comprehensive structural survey carried out and this is not within the scope of the study, the study assumes it is feasible to place an energy centre on the proposed location, but has included some high level consideration and comments regarding the suitability of this site and, if any, accompany with some technical recommendations

Energy demand

Building energy demand (MWh) are analysed on monthly resolution over a typical year. Where possible, ideally hourly/half-hourly energy data sets are used. Alternatively, the following approaches are used to estimate building energy demand:

- monthly meter reading of gas and electricity consumption in kWh
- if a lumped annual gas and electricity consumption is obtained for a building, the figures will be pro-rata across 12 months using the appropriate benchmark profile set up for the relevant building/activity type. These profiles could be derived from knowledge based thermal models or benchmarked against other metered reading for similar types of buildings.
- gas consumption figures are adjusted to reflect heating demand figures by assuming a nominal heat generator efficiency based on building type and age, and on information of any recent plant replacement

For building peak load demands (kW), which are used to inform DH pipe sizing, the following approaches are used:

- determine peak demand from half-hourly/hourly data
- where the above is not available, but information on boiler capacity is available, use boiler kW taking into account of morning start-up over-sizing and back-up unit
- where all above are not available, use either benchmark of 100W/m² building floor area or W/m² from knowledge based building models to estimate peak demand. W/m² from similar building types could also be used if deemed suitable

Building floor area

- where this is not provided, a nominal floor area is assumed by dividing building annual energy demand by benchmark demand density kWh/m² for the relevant building type

- alternative approach is to measure off approximate building foot print from the Ordinance Survey map provided by the council and multiply up to account for multiple floors, observing details from GoogleMaps or Microsoft BingMaps

Economic modelling assumptions

Energy cost and CO_2 assumptions

Year	Energy prices			CO2 intensity		Carbon price	
	Gas - retail (excl VAT and CCL)	Electricity retail	Electricity wholesale	Electricity	Gas	CRC	High CO2 price
	£ / kWh	£ / kWh	£ / kWh	kg / kWh	kg / kWh	£ / tonne	£ / tonne
2011	£0.026	£0.085	£0.050	0.541	0.198	£12	£50
2012	£0.028	£0.089	£0.052	0.532	0.198	£12	£50
2013	£0.030	£0.095	£0.055	0.523	0.198	£12	£50
2014	£0.033	£0.097	£0.055	0.513	0.198	£12	£50
2015	£0.034	£0.096	£0.055	0.504	0.198	£12	£50
2016	£0.034	£0.098	£0.055	0.495	0.198	£12	£50
2017	£0.032	£0.099	£0.055	0.486	0.198	£12	£50
2018	£0.030	£0.099	£0.053	0.476	0.198	£12	£50
2019	£0.030	£0.101	£0.054	0.467	0.198	£12	£50
2020	£0.031	£0.104	£0.055	0.458	0.198	£12	£50
2021	£0.031	£0.108	£0.058	0.449	0.198	£12	£50
2022	£0.031	£0.110	£0.059	0.439	0.198	£12	£50
2023	£0.031	£0.110	£0.059	0.430	0.198	£12	£50
2024	£0.032	£0.114	£0.063	0.430	0.198	£12	£50
2025	£0.032	£0.117	£0.065	0.430	0.198	£12	£50
2026	£0.032	£0.118	£0.065	0.430	0.198	£12	£50
2027	£0.032	£0.120	£0.068	0.430	0.198	£12	£50
2028	£0.032	£0.120	£0.069	0.430	0.198	£12	£50
2029	£0.033	£0.120	£0.069	0.430	0.198	£12	£50
2030	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2031	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2032	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2033	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2034	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2035	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2036	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2037	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2038	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2039	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2040	£0.033	£0.122	£0.071	0.430	0.198	£12	£50
2041	£0.033	£0.122	£0.071	0.430	0.198	£12	£50

Capital and operational costs and performance

	Value	Units
Energy Centre		
EC boilers cap ex	£60	£ / kW
EC boiler efficiency	82%	
Capex	£1,000	/m2
Thermal store		
Volume	550	m3
Capital	£600	/m3
CHP		
Capex	£700	/kWe
CHP maintenance	£0.01	per kWhe
DH network building connections		
Capital cost	£100.00	/kW
Operation	£1.00	/kW
DH network		
Pumping energy	1%	kWh
DH maintenance	1%	capex per year
Administration	£150,000	per annum - 2 people
Development costs	5%	additional cap ex
Counterfactual heating		
Existing boiler average efficiency	75%	
New boiler efficiency	80%	
Maintenance	1%	of capex per year
Distributed boilers	£150	£ / kW
Lifetime	30	years