Report

Outline Energy Statement: Energy Comparison for Outline Planning

RICHMOND-UPON-THAMES COLLEGE

Richmond upon Thames College

Report

CONFIDENTIAL

Revision: 8.0 - Submission
Issued: 17 June 2015

Norman Disney & Young

Table of Contents

Record of Amendments

Revision	Amendment details	Revision prepared by	Revision approved by
1.0	Draft issue for discussion	Stefano Corbella	Martin Dabnor
2.0	Draft issue for discussion	Juris Prods	Michael Lewis
3.0	For submission	Juris Prods	Michael Lewis
4.0	Draft	Juris Prods	Michael Lewis
5.0	For submission	Juris Prods	Michael Lewis
6.0	For submission	Juris Prods	Michael Lewis
7.0	For submission	Juris Prods	Michael Lewis
8.0	For submission	Martin Dabnor	Michael Lewis

1 EXECUTIVE SUMMARY

The project is a mixed use development at Richmond upon Thames College Campus (hereafter referred to as the Proposed Development).

At this stage architectural design is limited to building massing so it is the intention that this report will be updated in the next stage of design.

The mixed use development will include a new campus for education and enterprise comprising a college, a secondary school, a secondary school for children with special education need (SEN), a technical hub (including photographic studios, technical testing labs, archive, offices & meeting rooms, private gallery and creative industries incubator business units), a sports centre to serve the college and the wider community. The proposed development will include a residential development of up to 25,000 square metres with a mix of dwelling sizes. There will also be car parking spaces and landscaping elements.

This energy strategy complies with Part L 2013 Building Regulations, Approved Document (AD) L1A and follows the energy hierarchy set out in policy 5.2 in the London Plan (2011) and GLA guidance on preparing energy assessments (2014).

- Be Lean - use less energy;
- Be Clean – supply energy efficiently;
- Be Green – use renewable energy.

Thermal modelling of the concept design of the building against the above objectives results in the following conclusions

Energy Efficiency Measures

- High performance facade balancing natural day lighting with minimum heat gains and losses;
- Low air permeability rates;
- High efficiency LED lighting with daylight linked dimming, zone and timer control;
- Air source Heat pumps with high seasonal efficiency;
- High efficiency condensing boilers;
- Heat recovery on fresh air ventilation units

Renewable Energy

The feasibility of a range of renewable technologies has been assessed in the context of the London Plan. The analysis has concluded that the provision of an extensive series of energy conservation, energy efficiency measures and use of air source heat pumps and solar thermal, could be the most effective method of achieving the required reduction in carbon dioxide emissions over and above Part L (2013).

Calculated Site Wide CO_2 Emissions

Based on the proposed building massing preliminary calculations indicate that the following CO_2 emission reductions could be targeted:

- Notional buildings - 1546 tonnes/annum
- Lean buildings - 1307 tonnes/annum or 15.5 % reduction from notional
- Lean and clean buildings -1307 tonnes/annum or 15.5 % reduction from notional

- Lean, clean and green building - 1052 tonnes/annum or 32.0 % reduction from notional

There is some scope for further reductions due to use of PV cells although the available roof area is limited due to solar hot water heaters occupying a significant part of the available roof area.

The above figures indicate that compliance with items 4 and 5 of the Borough of Richmond upon Thames Sustainable Construction Checklist is achievable in that there is a 15.5% CO_2 emissions reduction due to design of the buildings and their services for minimum energy use (lean building) and a further 16.5% reduction due to use of on-site renewable energy (lean, clean and green building).

An overall 32% reduction in CO_2 emissions compared to notional values appears achievable and further enhancements could be targeted in future design in order to achieve the GLA target of 35% CO_2 emission reductions.

2 INTRODUCTION

2.1 Purpose

The report is prepared by Norman Disney & Young for the Richmond-Upon-Thames College (RuTC) to address the objectives set out in the local (London Borough of Richmond upon Thames), regional (London Plan) and the national planning policies. This report provides preliminary assessment of heating and cooling strategies to assist in the development of an energy strategy.

The building services system sizing has been carried out for comparative purposes in assessing the suitability of alternative renewable energy technologies for this development. The report outlines sustainability measures likely to be employed and the feasibility of renewable energy in order to deliver a design which achieves the greatest reduction in carbon dioxide emissions while remaining consistent with the objectives of the client and aligning with the Mayor of London policy requirements within the London Plan 2011.

It draws directly on the requirements set out in the London Renewables Toolkit and outlines proposals in a consistent method to those outlined in the document. Measures considered and those ultimately recommended for incorporation within the development for energy savings are categorised under three broad headings as:

- Be Lean - Energy-efficient design and construction;
- Be Clean - Supply energy efficiently (low-carbon technology);
- Be Green - Use of renewable energy systems (zero-carbon technology).

Renewable energy technologies are assessed for their technical and economic viability.

2.2 Building Description

The mixed use development will include a new campus for education and enterprise comprising a college, a secondary school, a secondary school for children with special education need (SEN), a technical hub (including photographic studios, technical testing labs, archive, offices & meeting rooms, private gallery and creative industries incubator business units), a sports centre to serve the college and the wider community. The proposed development will include a residential development of up to 25,000 square metres with a mix of dwelling sizes. There will also be car parking spaces and landscaping elements.

It is envisaged that all building will be provided with space heating and hot water, the technical hub will be air conditioned and that some areas of the college will have cooling.

Table 1: Functional description and use class

	Functional areas description	Use Class	Area	Likely number of occupants
1	Replacement College	D1	20,000 sq.m	3,000 students
2	Five form entry Secondary school	D1	6,000 sq.m.	750 students
3	Secondary school for children with Special Education Needs (SEN)	D1	3,000 sq.m.	175 includes students and staff

	Functional areas description	Use Class	Area	Likely number of occupants
4	New Technical Hub for Haymarket Media (ancillary use includes photographic studios, technical testing labs, archive, offices & meeting rooms, private gallery and creative industries incubator business units	D1	2,000 sq.m.	20
5	Sports Center	D2	4,000 sq.m.	Unknown
6	Residential (2-4 storey, low rise, varying sizes)	C3	25,000 sq.m.	416

2.3 Guiding Principles for System Selection

The general principles applied in selection of technologies include:

- The mix of technologies (“low carbon “and “conventional” engineering) should be selected to reduce design complexity;
- Limiting the number of different heat generating technologies;
- Selecting systems that are easy to maintain. This approach ensures that systems are more likely to run at maximum efficiency and be quickly repaired when they fail, leading to the projected CO_2 emissions savings being more likely to be achieved.
- Maintenance: systems should ideally be no more complex to maintain than conventional systems: this is to ensure that there is a pool of expertise to fix a system when it goes wrong.

3 POLICY REVIEW

3.1 European Union (EU) Directives

The following are EU directives concerning the energy policies for the built environment:

Limiting Global Climate Change to 2°C – The way ahead for 2020 and beyond, Communication from the EU Commission, 10 January 2007, which recommends the following measures for energy usage:

- Improve the EU's energy efficiency by 20% by 2020;
- Increasing the share of renewable energy to 20% by 2020;
- Developing an environmentally safe carbon-capture and geological storage policy;
- Directive 32/2006 recommends employees to save energy.

3.1.1 Energy Performance of Buildings Directive

The directive requires all member states to have in place legislation covering the following:

- Produce feasibility studies for application of Combined Heat and Power (CHP) and community heating for all new developments greater than 1000 m² (gross area).
- Ensure that Energy Performance Certificates (EPCs) are in place for all buildings on construction, sale, or let by 2009. EPCs must be produced by accredited energy assessors, and accompanied by a recommendation report on how to improve cost effectively the Energy performance of the building.

Design of buildings and services shall take equal account of renewable energy solutions as to building fabric and plant efficiency measures. This must include assessment of the technical, environmental and economic feasibility of systems such as:

- Decentralised energy supplies from renewable energy sources;
- Combined Heat and Power;
- District or block heating and/or cooling;
- Heat pumps.

Regimes must be in place to allow for the inspection of air conditioning systems greater than 12kW, and the servicing, inspection and testing of boiler plant.

3.2 United Kingdom Legislation

The following legislation relevant to the development location has been identified at both national and local level.

3.2.1 National

- The Building Regulations Act 2000 (as amended 2010), Articles 3, 4, and 5 of the European Energy Performance of Buildings Directive, including the adoption of the National Calculation Methodology for the assessment of the energy performance of buildings, and the requirement for improvements in existing buildings.
- The Energy Performance Regulations (England and Wales) 2007 implements Articles 7, 8, 9 and 10 of the European Energy Performance of Buildings Directive, including the requirements for Energy Performance

Certificates on construction, sale or let of all buildings, and for inspections of all air conditioning installations greater than 12 kW capacity.

- National Planning Policy Framework provides guidance on how local government authorities should implement their powers of planning approval to implement the national government's energy policy.

3.2.2 Regional

Regional - Greater London Authority (GLA)

The London Plan 2011, prepared by the Mayor of London, has specific requirements for energy efficiency and renewable energy for developments. The London Plan July 2011 prepared by the Mayor of London's office, deals with matters that are of strategic importance to Greater London. The London Plan is the overall strategic plan setting out an integrated social, economic and environmental framework for the future development of London, looking forward 20–25 years. Revised early minor alterations to the London Plan and draft further alterations to the London Plan (January 2014) suggests further improvements to support the delivery of Mayor's vision to tackle Climate change. Draft Supplementary Planning Guidance, Sustainable Design and Construction (July 2013) provides framework for implementing the London policies. On 10 March 2015 the Mayor published Further Alterations to the London Plan incorporating the further alterations.

The relevant policy extracts are below:

Policy 5.2 - Minimising - Carbon Dioxide Emissions

A. Development proposals should make the fullest contribution to minimising carbon dioxide emissions in accordance with the following energy hierarchy:

   - Be lean - Use less energy
   - Be clean - Supply energy efficiently
   - Be green - Use renewable energy

B. The Mayor will work with boroughs and developers to ensure that major developments meet the following targets for carbon dioxide emissions reduction in buildings. These targets are expressed as minimum improvements over the Target Emission Rate (TER) outlined in the national Building Regulations leading to zero carbon non-domestic buildings from 2019.

Year	Improvement on 2010 Building Regulations
2010 – 2013	25 per cent
2013 – 2016	40 per cent
2016 – 2019	As per building regulations requirements
2019 – 2031	Zero carbon

**** Greater London Authority) requires all applications received after 6th of July 2014 to achieve 35 percent reduction in carbon emissions beyond Part L 2013 Building Regulations (GLA guidance on preparing energy assessments 2014).***

Policy 5.6 - Decentralised Energy in Development Proposals

A. Development proposals should evaluate the feasibility of Combined Heat and Power (CHP) systems, and where a new CHP system is appropriate also examine opportunities to extend the system beyond the site boundary to adjacent sites.

B. Major development proposals should select energy systems in accordance with the following hierarchy.

   - Connection to existing heating or cooling networks

- Site-wide CHP network
- Communal heating and cooling.

C. Potential opportunities to meet the first priority in this hierarchy are outlined in the London Heat Map tool. Where future network opportunities are identified, proposals should be designed to connect to these networks.

Policy 5.7 - Renewable Energy

Within the framework of the energy hierarchy (see Policy 5.2 above), major development proposals should provide a reduction in expected carbon dioxide emissions through the use of on-site renewable energy generation, where feasible.

Policy 5.9 - Overheating and Cooling

Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy.

- Minimise internal heat generation through energy efficient design
- Reduce the amount of heat entering a building in summer through orientation, shading, fenestration, insulation and green roofs and walls
- Manage the heat within the building through exposed internal thermal mass and high ceilings
- Passive ventilation
- Mechanical ventilation
- Active cooling systems (ensuring they are the lowest carbon options).

3.2.3 Local

Local – London Borough of Richmond upon Thames

The Borough of Richmond upon Thames planning policy incorporates the requirement to comply with their Sustainable Construction Checklist.

The items impacting directly on this report are:

Item 4 – Design building and its services for minimum energy use

Item 5 – Reduce predicted site CO_2 emissions by at least 10% through the use of site renewable energy

4 METHODOLOGY

4.1 Basis

The methodology is set out under Policy 5.2 of the London Plan.

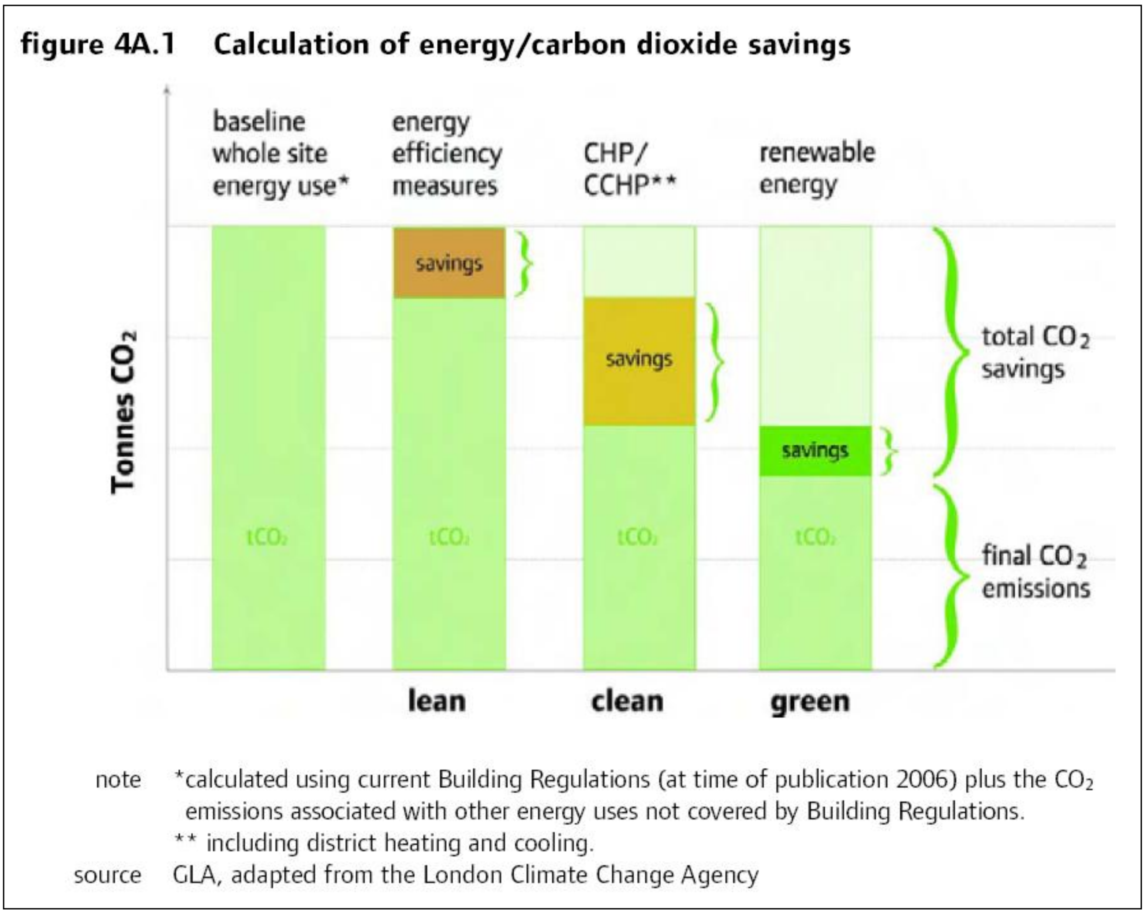


Figure 1: Calculation of Energy/Carbon Dioxide Savings

The calculation methodology used to predict energy consumption and carbon dioxide emissions is the same as that approved for demonstrating compliance with Part L 2013 of the Building Regulations:

- For non-dwellings, Approved Document L2A explains how building improvements have to be carried out to achieve energy efficiency.
- Using a Simplified Building Energy Model (SBEM) it provides an analysis of buildings energy consumption.
- The actual building modelled in the thermal analysis software (TAS) is compared to the notional building.
- The notional building is defined in the National Calculation Methodology (NCM) modelling guide. In essence, it is a building of the same size, shape and zoning arrangements as the actual building, with the same conventions relating to the measurement of dimensions. U-values etc must be calculated following the guidance in BR443.

The Building Regulations only control the certain end uses of energy (heating, hot water, cooling, fans, pumps and controls; and lighting) whereas the London Plan requires all end uses to be taken in to account. The approved software also calculates the major non-controlled end uses:

- For non-dwellings, small power (required to calculate heat gains).

4.2 Lean Measures

Improvements to the building fabric and building services, in comparison to the “reference” or “notional” performance criteria used to calculate the TER are the most viable solution to reduce energy and carbon emissions.

4.3 Clean Measures

The technical and economic feasibility of the following heating and cooling systems are then considered sequentially:

- Connection to existing CCHP/CHP distribution networks;
- Site-wide CCHP/CHP or hydrogen fuel cells;
- Communal heating and cooling.

The highest ranking feasible option is selected, where viable.

4.4 Green Measures

The technical and economic feasibility of the following renewable energy technologies listed in the *London Plan* are then considered:

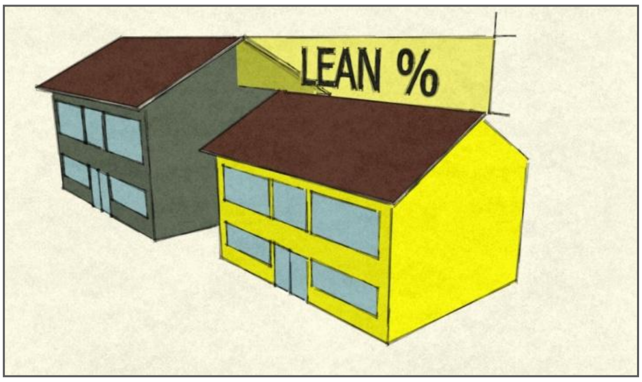
- Wind turbines;
- Photovoltaic cells;
- Solar water heating;
- Biomass heating;
- Hydrogen fuel cells;
- Ground-coupled heating and cooling;
- Air Source Heat Pumps.

Other technologies such as hydroelectric may be considered on a site specific basis but have not been included in this study due to the obvious constraints of the site and lack of available hydroelectric potential.

5 BE LEAN - ENERGY EFFICIENT DESIGN AND CONSTRUCTION

5.1 Energy Efficiency Design

The development will aim to meet the requirements of Approved Document L of the Building Regulations (Part L 2013) energy performance target, by implementing a combination of passive building design features and active building services systems. The design has endeavoured to reduce energy demands through energy efficient design.



5.1.1 Demand reduction through passive design measures

The South, East and West facades should be targeted due to its orientation towards the sun path. The glazing performance should be with very low solar admittance value. The glazing structure might also provide a further element of shading.

5.1.2 Apply the cooling hierarchy

The cooling hierarchy in Policy 5.9 of the London Plan (2011) applies to major development proposals.

- Minimise internal heat gains
- Reduce the amount of heat entering the building in summer through orientation, shading, insulation, etc
- Manage the heat within the building through exposed thermal mass and high ceilings
- Mechanical ventilation
- Active cooling system ensuring they are the lowest carbon options.

5.1.3 Demand reduction through active measures

The proposed development will incorporate high efficiency plant and equipment throughout. Key aspects are as follows;

LED lighting should be used in all of the areas to provide up to a 30% reduction in energy use for this element which is a considerable portion of the overall building energy consumption. LED luminaires are now becoming much more viable in terms of design and cost and will provided a significant energy saving.

Heat recovery will be employed on the fresh air ventilation, with incoming fresh air being pre-heated via a heat exchanger by the exhaust air. Heat recovery efficiency in the region of 70% can be achieved, which reduces both energy cost and capital expenditure on heating plant.

5.1.4 U- Values and façade performance

A high-performance building envelope should be considered. Stringent U-values (overall heat transfer rate) and G-values (solar transmittance rate through glazing) should be adopted, in particular for the South, East and West facade.

The building envelope should also be designed to eliminate thermal bridging (heat loss through conduction directly to the external environment) and promote the continuity of insulation, thus minimising the building's fabric energy losses.

5.1.5 Air permeability of building envelope

The building envelope could also be designed to limit the air leakage through the building fabric to a rate of approximately 3.5 $m^3/hr/m^2$ at a test pressure of 50 Pa, noting that for a large proportion of the year, air leakage could be considered as energy leakage; the air in the building having been heated or cooled to provide comfort conditions. This target leakage rate is in line with the Part L requirements.

5.1.6 Light fittings & controls

The lighting design could incorporate high efficiency fittings that will exceed the requirements laid out in Part L. A lighting control system will be installed to allow lighting levels to adjust according to daylight levels, and reduced occupation levels in the building.

5.1.7 Ventilation heat reclaim

The ventilation system shall be designed to incorporate a heat reclaim system, transferring the heat energy from exhaust air, to pre-heat the building's fresh air supply, thus, minimising energy consumption.

This energy saving measure will achieve efficiency levels of approximately 70%, thus regaining more than half of the heat that would have been lost via the extract system.

5.1.8 Variable speed pumps

Variable speed or multiple staged pumps shall be proposed for the heating and cooling water circuits, allowing only the volume of water required to match the heating / cooling load and for correct plant operation to be pumped around the system.

A study undertaken by BRECSU for the Department of the Environment suggest that energy saving of 66-86% can be achieved in such installations.

5.1.9 Automatic controls

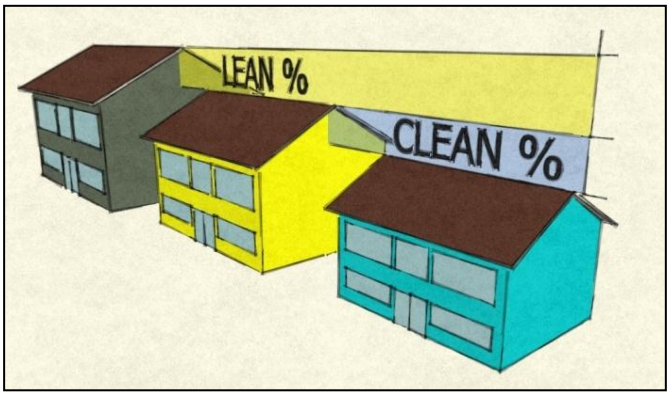
The Building Management System (BMS) will provide control and monitoring of the various building services systems. Intelligent outstations will be positioned throughout the development in strategic locations adjacent to the services being controlled/monitored. The controls strategy will optimise the operation of the systems to ensure efficient performance.

A user interface will be provided via a personal computer, providing a point for central monitoring and adjustment of the controls

The BMS system will be flexible to allow tenants to extend it to include the addition of new equipment into the system.

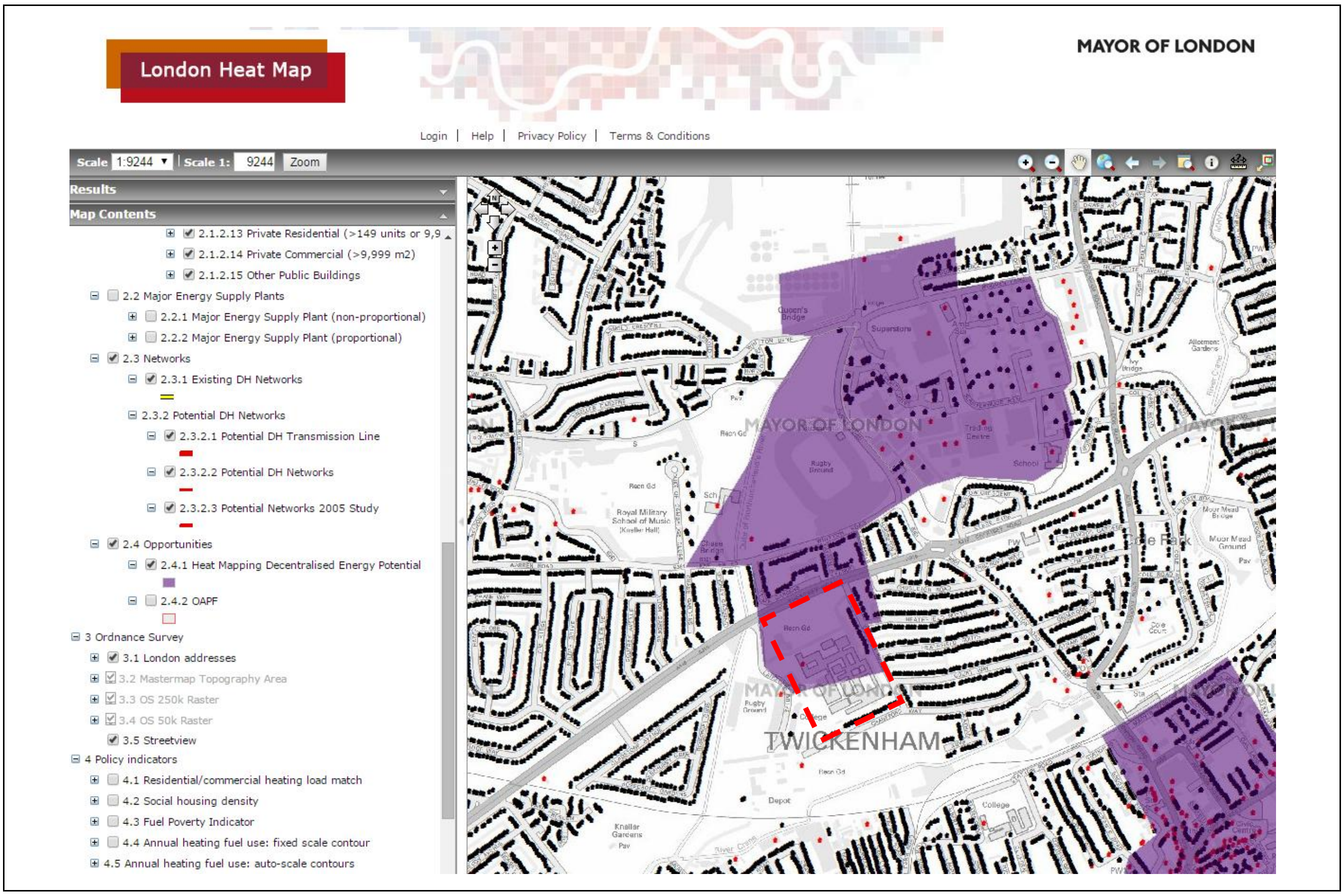
6 BE CLEAN - COMBINED HEAT & POWER

In compliance with the existing and draft London Plans the development will address the feasibility of connection to district Combined Heat and Power (CHP) and Combined Cooling, Heat and Power (CCHP) and Community Heating System schemes.



6.1 Connection to Heat Distribution Network

The site, located in Twickenham area does not have existing heat distribution network although the London Heat Map indicates that part of the site is on the edge of an area with decentralised energy potential. The image below shows an abstract of the London Heat Map in which there are no existing or planned heat networks.



As there are no existing or planned networks at present this option is not applicable to the proposed development. However, where feasible, it is proposed to select equipment compatible with future connection to a heat distribution network.

6.2 Combined Heat and Power

Although there is an increased interest to include district heating schemes linked to CHP, on the basis of a preliminary assessment it is found that a CHP solution would not be appropriate for this development as explained in the reasoning below.

This report so far identifies that technologies such as solar hot water and heat pumps, if incorporated in the proposed development, have greater potential to reduce carbon dioxide emissions in comparison to other technologies available to this site; thereby mitigating climate changes. In order to understand the reasons for not including district heating linked to CHP we need to examine the following:

- the comparison between CHP and air source heat pumps
- the incompatibility of CHP with solar hot water (these systems compete to provide the same hot water)
- the ability of a CHP system to cater for the remaining load once solar thermal and heat pumps are accounted for.

6.3 Communal Heating System

The proposed residential component alone is too small (likely to be considerably less than 400 dwellings and possibly constructed over an extended period) to warrant a standalone communal heating system. The seasonal operation of the college and school does not appear suitable for combining with a residential development as this would result in large central plant operating at low load for a significant part of the year. Consequently a communal heating system is not envisaged at this stage.

6.4 Comparison Between CHP and Air Source Heat Pumps

In the previous section it was concluded that heat pumps are a suitable option for this site. This section makes a comparison between CHP and heat pumps to identify the most appropriate technology.

The approach used to describe the differences is similar to that in the book “energy without the hot air” by David MacKay.

If primary energy consumption is considered then the conventional way of producing electricity and heat is to burn gas in a boiler to produce heat and to burn gas in a gas fired power station to produce electricity.

A good condensing boiler has an efficiency of approximately 90% and a good gas fired power station has an efficiency of approximately 50%. In the figure below these points are plotted on a graph of heating efficiency against electrical efficiency. If we want to obtain a mix of heat and electricity then we can achieve it by burning the appropriate mix in either a boiler or a power station and the line between the two shows the efficiency if a mix is used.

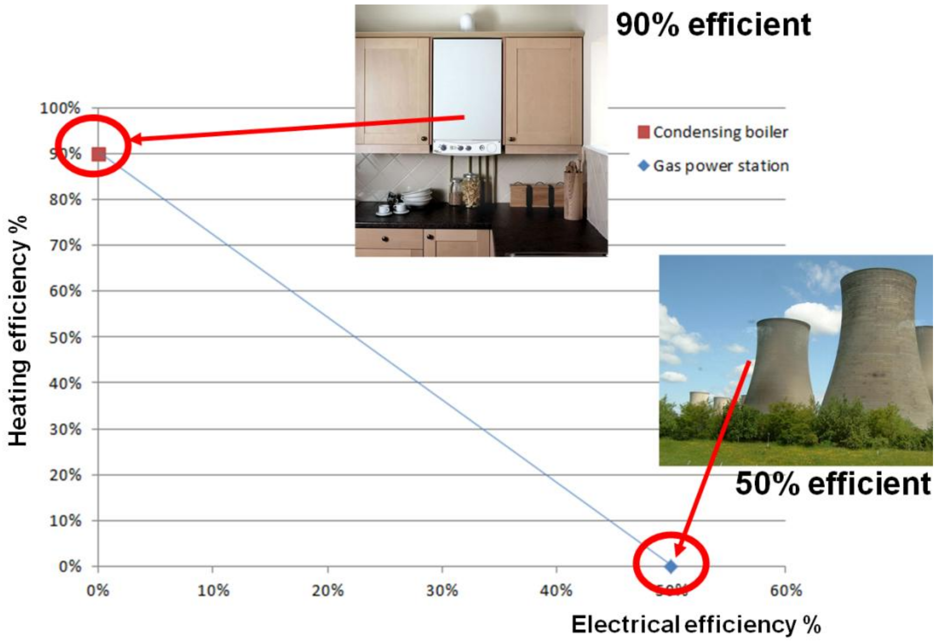


Figure 2 Heat from boilers – electricity from a power station

On top of this graph points can then be plotted to show where CHP systems of various sizes sit and if they are above the line then the CHP system is a better use of primary fuel, and if below the line then it is worse.

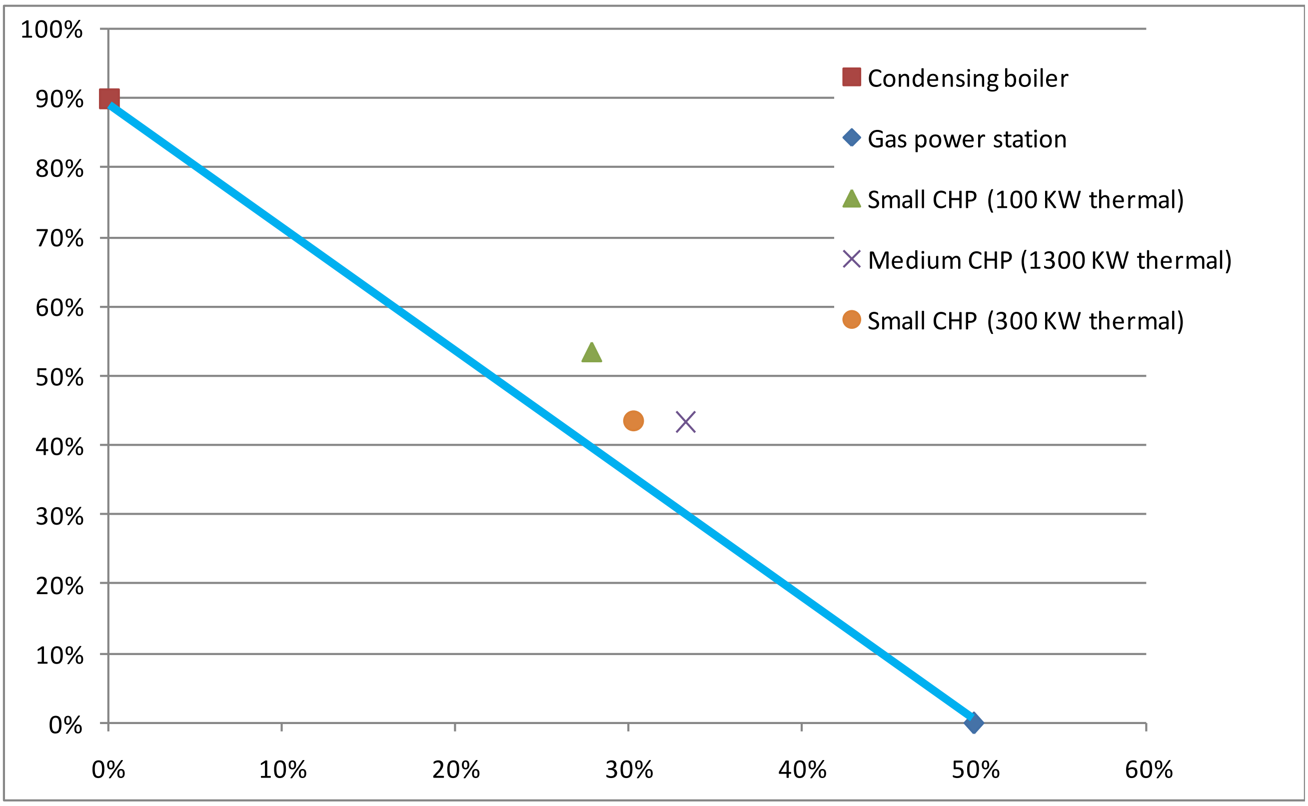


Figure 3 CHP vs Gas power station and condensing boiler

It can be seen that the CHP systems are above the line and so are a better use of primary energy when compared to burning fuel in a power station and a gas boiler.

To this graph a line can now be added to represent an air source heat pump. Manufacturers literature indicates that an air source heat pump generating heating water at 45°C can be expected to have a COP varying from 4.1 at 15.0°C ambient temperature, 3.8 at 10°C ambient, 3.5 at 5°C ambient and 3.3 with 2°C ambient. With a COP of 3.8 and grid electric power efficiency of 50% the overall heat efficiency from a heat pump is 190%. This can then be added to the graph as per the figure below.

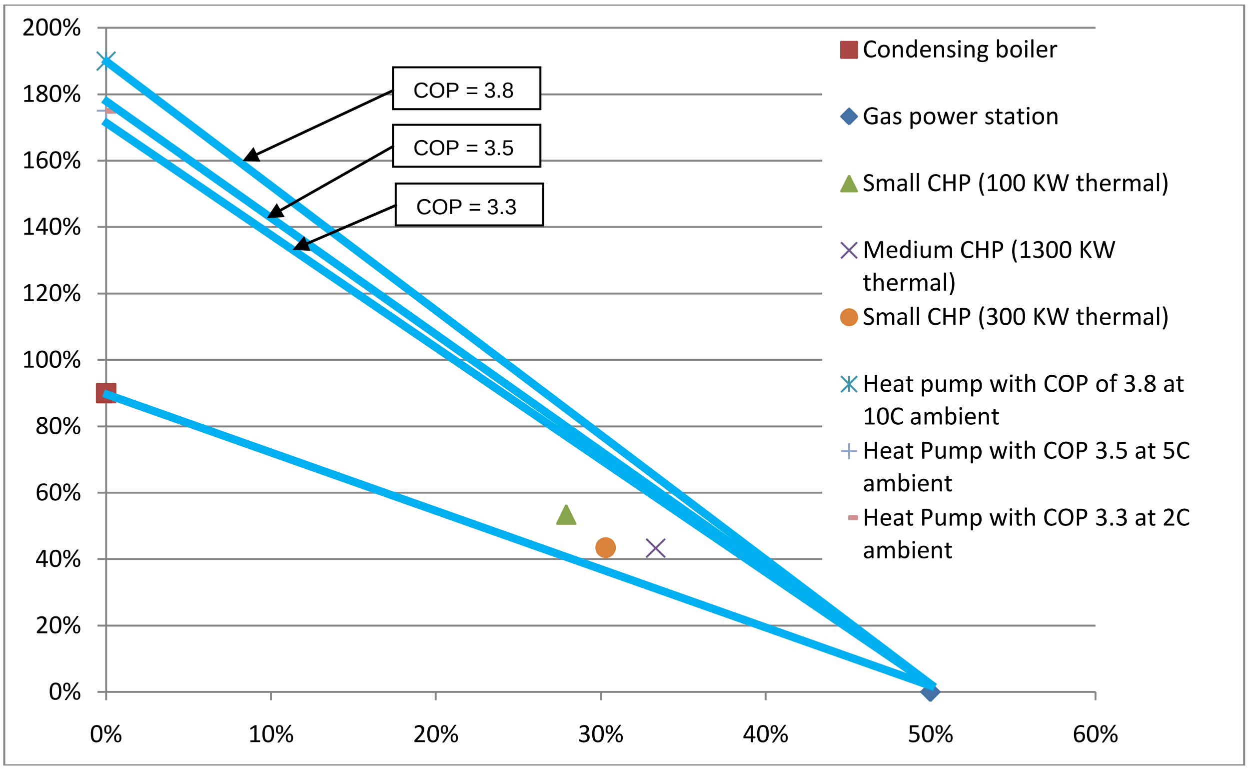


Figure 4 Comparison between air source heat pumps and CHP

From the above figure it is clear that a heat pump is a more energy and carbon efficient way to provide heat.

It is also important to think about how the efficiencies of these systems will change over time. The UK has mandatory obligation to reduce carbon emissions to 80% of 1990 levels by 2050. This will lead to a significant decarbonisation of electricity over time which will further widen the gap between heat pumps and CHP systems.

Additionally with advancement in technologies it is a reasonable assumption to expect increases in heat pump COPs. Heat pump technology is at an early stage of development and as the market matures it is likely that greater efficiencies will be achieved. CHP systems on the other hand are a mature technology, will be locked into fossil fuel use and offer limited potential in terms of future system efficiency improvements.

The trend of these future changes is shown on the figure below.

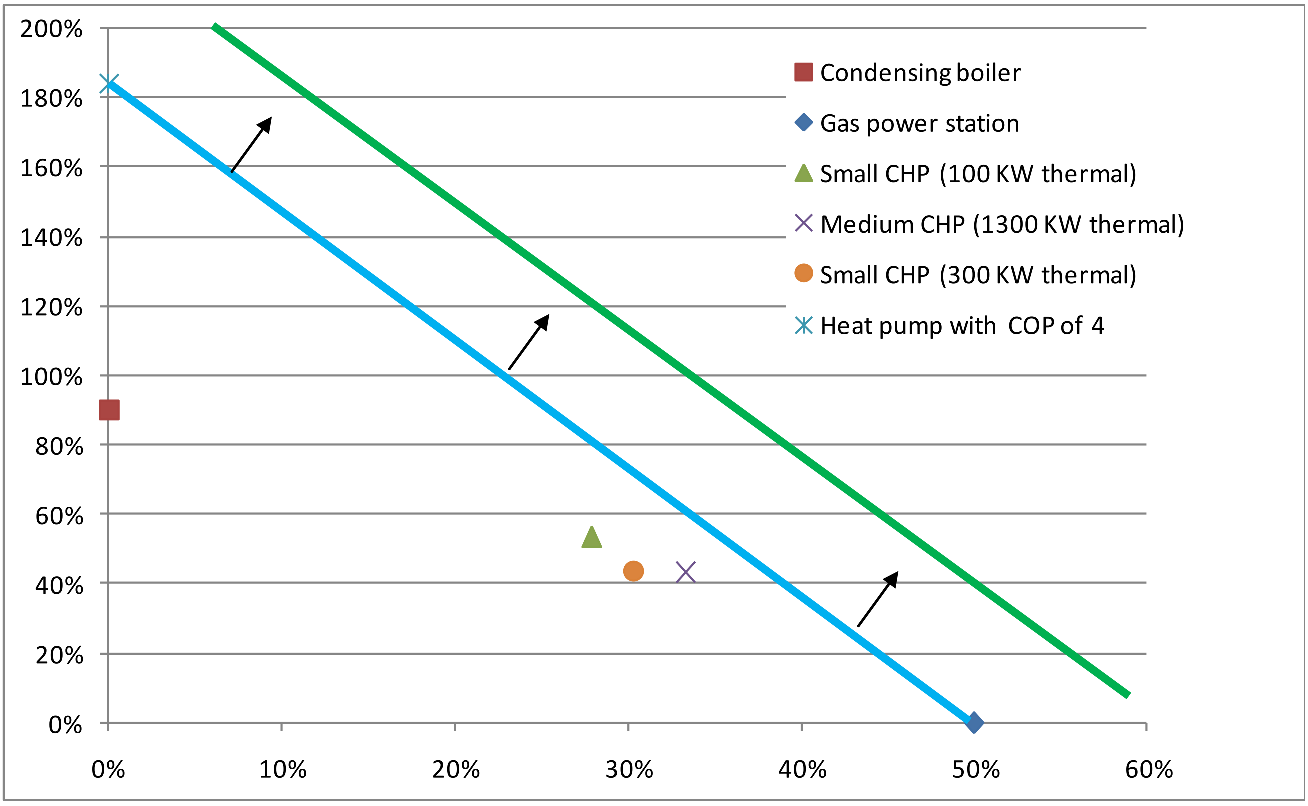


Figure 5 Effect of time on heat pump efficiencies

One of the disadvantages of a heat pump is that the COP is sensitive to both the outside air temperature and the supply water temperature. The lower the outside air temperature and the higher the supply water temperature the lower the COP will be.

To achieve a COP of approximately 4 means that the supply water temperature needs to be limited to 45°C maximum and the heat pump can only operate in outside air temperatures down to approximately 2°C. Another source of heating would be needed to supplement the system when the conditions fall below this range. Ambient temperature is below 2°C for less than 5% of operating hours so that operation of supplementary condensing boilers for space heating is small compared to heat pump operation.

6.4.1 Conclusion

The discussion in the sections above has shown that air source heat pumps are a more efficient, lower carbon heating source than CHP assuming that the operating envelope of the heat pumps system is set to maintain a supply water temperature at or below 45 °C, and that it will only operate if the outside air temperature is at or above 2°C.

Over time the difference between heat pump and CHP efficiencies will become more pronounced in the favour of heat pumps.

6.5 Compatibility of CHP with Solar Hot Water

It has been identified that solar hot water would likely be a suitable solution for this site. There are a number of factors that make the site suitable for solar hot water:

- The development will have a large domestic hot water demand due to the high proportion of residential accommodation proposed. This means that there will be a relatively high demand for heating even in the summer.
- The geometry of the buildings means that they have a reasonable ratio of roof area to building volume meaning that there is space available to install the modules on the roof.
- The height profile of the buildings (maximum of 5 storeys has been indicated on the drawing) across the site, with the buildings tapering down to the south so as not to create over shading of other buildings makes the roofs ideal location for installing the modules. They will not be shaded by other buildings enabling the yield to be maximised.

The potential annual contribution to the domestic hot water load generally accepted to be between 30 and 40%. The graph below shows the annual contribution to the development assuming that sufficient roof area is available on each building to install the correct size installation.

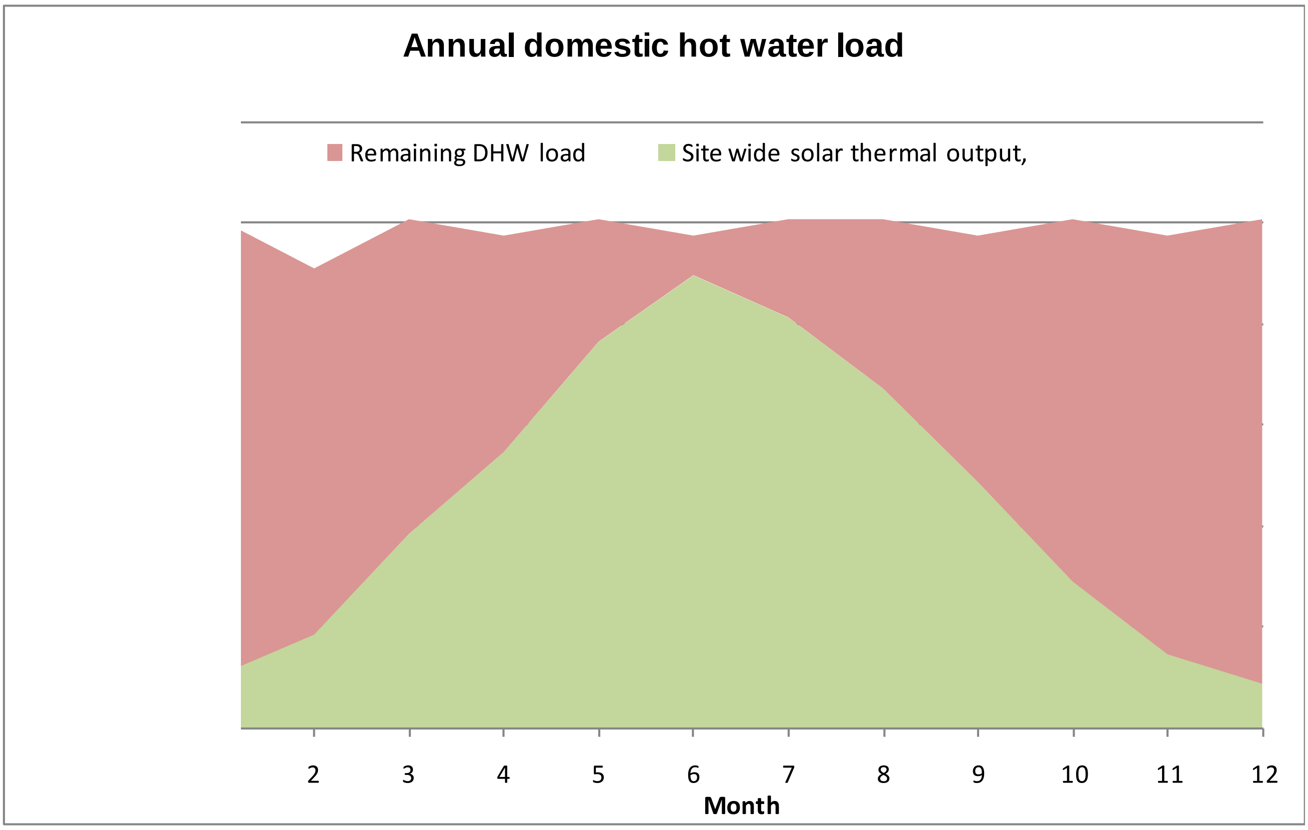


Figure 6 Contribution to annual domestic hot water load from solar hot water

This shows that in the summer months the solar hot water system can provide almost all the domestic hot water required. There will be summer days for which the solar hot water system will provide all the heating required.

Industry best practice suggests a solar hot water system be used in preference to CHP as the heating from the solar hot water system is effectively free.

The annual contribution to the heating loads that could be made by heat pumps and solar hot water is shown on Figure 7 below.

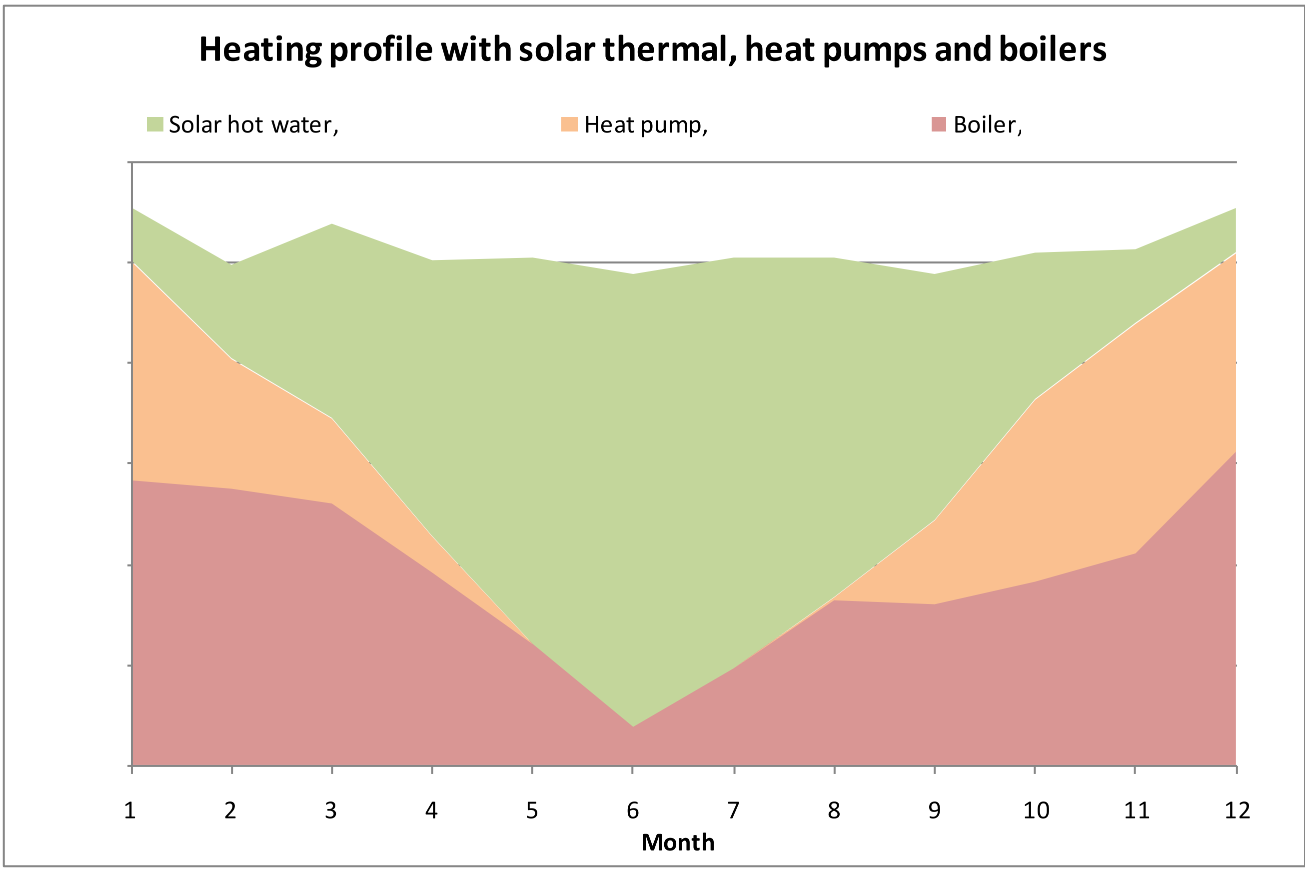


Figure 7 contribution to total heat demand from different heat sources

6.5.1 Conclusion

The above has shown that if heating is available from a solar hot water system then it should be used as it is effectively "free" heat.

6.6 Ability of a CHP System to provide the remaining Heating Load

The above sections have established that a priority of heat sources should be as follows:

- Use solar hot water heating if available as it is "free"
- If solar hot water heating is not sufficient to meet the demand then a heat pump should be used to "top up" the heating providing that it is within its operating envelope
- If solar hot water heating is not available, and the heat pump is not capable of meeting the heating then an alternative heat source should be used.

The impact of this hierarchy of heating strategies is shown on Figure *7* above.

The red slice that remains in Figure *7* is the annual contribution to heating that needs to be made from either a gas boiler or a CHP system, and this section will examine if a CHP system is appropriate to provide this.

Typically a CHP system is sized to provide a constant base load to maximise the run hours and minimise the number of starts and stops which lead to reductions in efficiency. Incorporating solar hot water will mean that there will be periods where there is no base load and the demand would be sporadic at other times of the year.

In this case a reasonable solution would be to provide a CHP system that would be switched off in the summer months, from June to August. During this period it can be expected that the majority of the load will be met by the solar thermal, and if not then the sporadic nature of the remaining load would be unsuitable for CHP. Generally CHP systems are sized to operate for a minimum of 4000 hours to make them commercially viable. If the system is switched off for 3 months of the year then it puts pressure on the system to obtain high utilisation for the remainder of the year (9 months or 6570 hrs).

Bearing in mind that the solar hot water system will still provide all the heating required on some of the days outside of this 3 month summer period it should be assumed that the CHP system will operate 24 hours per day for the remaining period.

Assuming that the heat pump is capable of providing hot water at 45 °C then almost all of the space heating can be met by the heat pumps. The space heating system will be low temperature and so the only limitation on the use of heat pumps will be the outside air temperature (generally it is less than 2°C for about 5% of the year). However, the domestic hot water load will require an additional source of heat to boost the temperature from 45 °C to 60 °C. This is a requirement to comply with the Building Regulations to protect against legionella growth.

This means that there will be a base load outside the summer months when an additional heat source will be needed to boost the DHW temperature to 60 degC.

To operate a CHP system that will operate for 24 hrs each day during the remaining 9 months of the year means that a thermal store will have to be included to smooth out the load demand for the CHP

The figure below shows the possible contribution from various elements to meet the DHW load for a typical day.

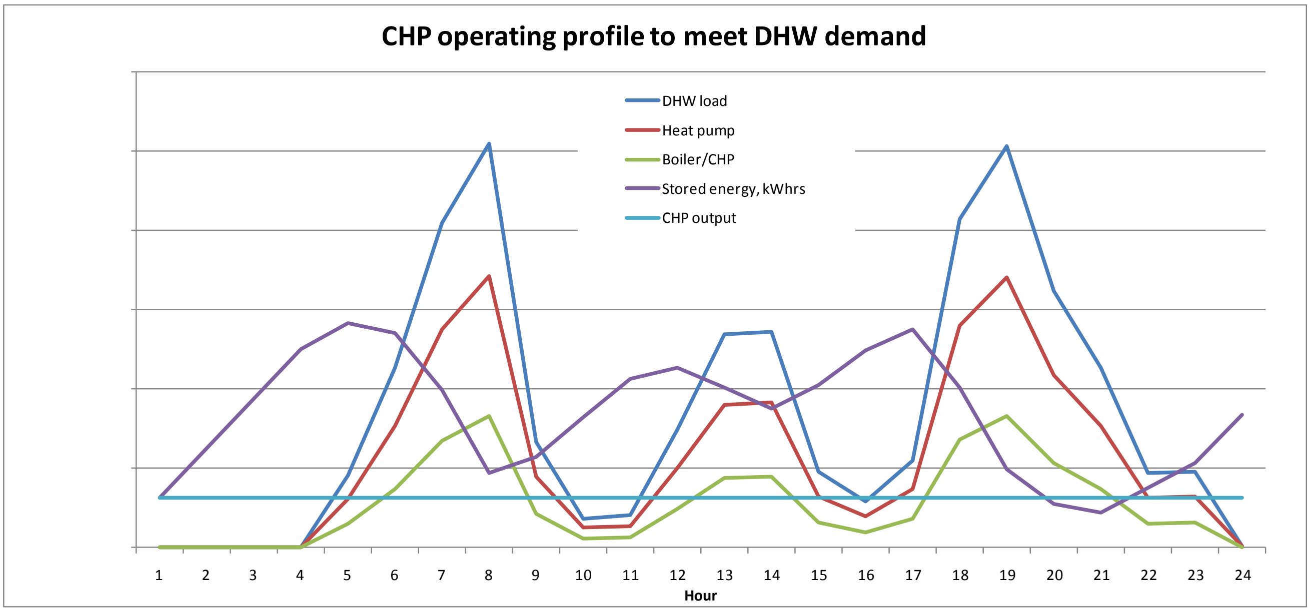


Figure 8 Makeup of DHW heating loads

There are 2 factors that will have a major impact on the feasibility of a CHP installation of this small size on a large site:

- The first is that over such a large site the thermal distribution losses will be high. The length of pipe required would be extensive and a standing loss of 15 kW/km pipe would lead to a high distribution heat loss.
- The second is that to pump the water around such a length of pipe will lead to a relatively high pressure drop and high pumping energy requirements.

These two factors allow the efficiency to be updated and plotted as per the above example on Figure *3*2. The updated plot is shown in the figure below.

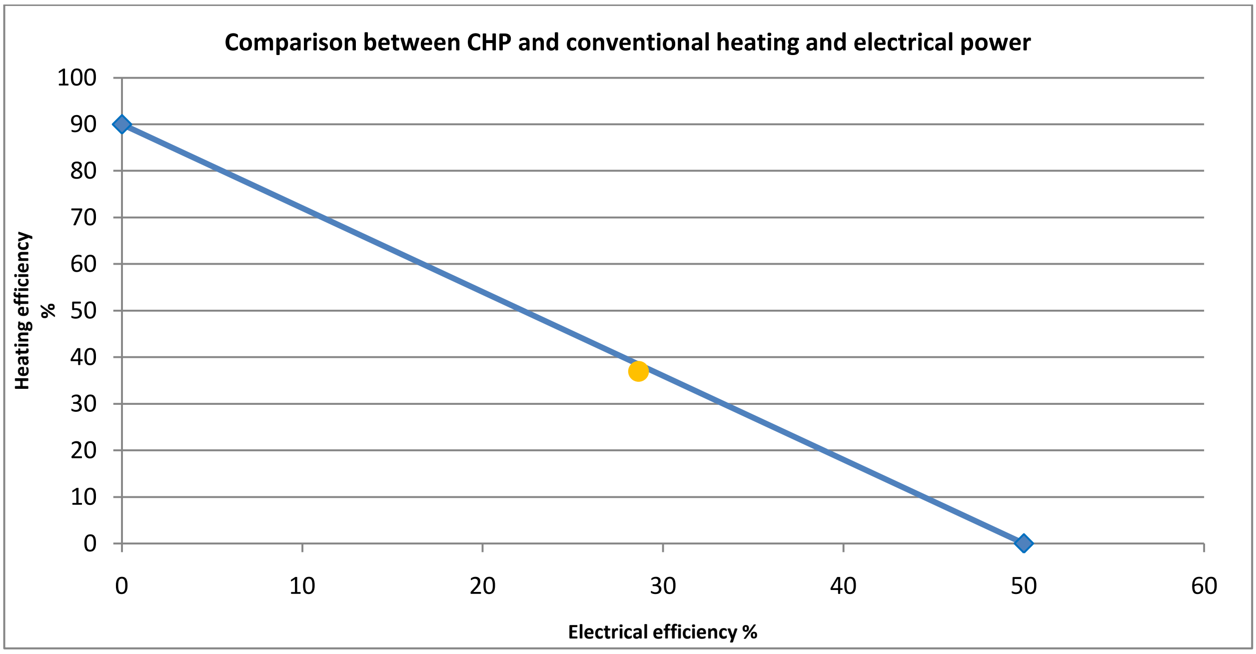


Figure 9 Appropriately sized CHP compared to heat generated with a gas boiler and electricity from a gas fired power station.

This demonstrates that a CHP system at this small scale will not provide any carbon or energy benefits. This is due to the low efficiency of CHP systems at small scales and also the size of an appropriately sized plant relative to the scale of the development. At these scales the standing and pumping losses are not insignificant.

It needs to be kept in mind that this analysis has been carried out with current data for carbon intensities of electricity and, as per the discussion in the previous section, a significant decarbonisation of grid electricity can be expected over the lifetime of the plant. The effect of the decarbonisation will lead to the point representing CHP in Figure *9* moving further below the line over time as the performance of CHP relative to the alternatives deteriorates.

Conclusion: An appropriately sized CHP system will not provide any carbon or energy benefits at current carbon intensity values. In the future the performance of CHP will decline relative to the alternatives.

Essentially, whilst larger scale CHP may be marginally more carbon effective than condensing boiler/gas power station combination its operation reduces/displaces the ability to of solar collectors to provide even more carbon effective hot water for much of the year. Consequently solar hot water, heat pump space heating supplemented by condensing boilers is more carbon effective than a combination of CHP and boilers.

7 BE GREEN - RENEWABLE ENERGY

This section summarises the appraisal of the renewable options that has been undertaken. Technologies that are feasible are assessed using the methodologies outlined in the GLA Toolkit.

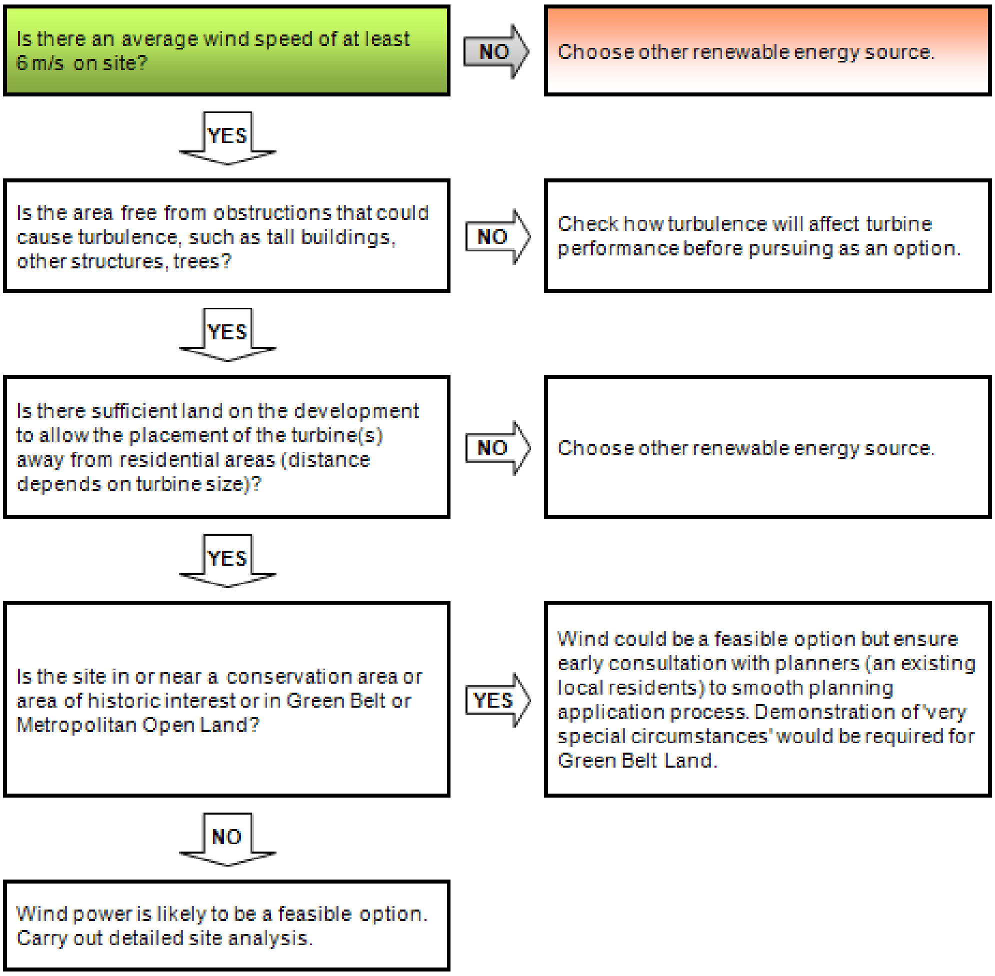
The system sizing suggested in this report is suitable only to provide an early indication of energy contribution and carbon-dioxide emissions reduction.

7.1 Renewable technologies

The following technologies were evaluated for incorporation on the site.

- Wind turbines;
- Biomass boilers;
- Biomass combined heat and power;
- Photovoltaic's;
- Solar water heating;
- Ground Source heat pumps;
- Air Source Heat pumps.

7.1.1 Wind Turbine



Department
of Energy &
Climate Change

HomeMeeting Energy DemandWindWindspeed database

WINDSPEED DATABASE QUERY RESULTS

FOR THE 1KM GRID SQUARE 515 173 (TQ1573)

Wind speed at 45m agl (in m/s)

6	6	5.8
6	5.9	5.8
5.9	5.8	5.8

Wind speed at 25m agl (in m/s)

5.6	5.5	5.3
5.5	5.4	5.3
5.4	5.3	5.2

Wind speed at 10m agl (in m/s)

4.8	4.7	4.5
4.7	4.6	4.5
4.6	4.5	4.5

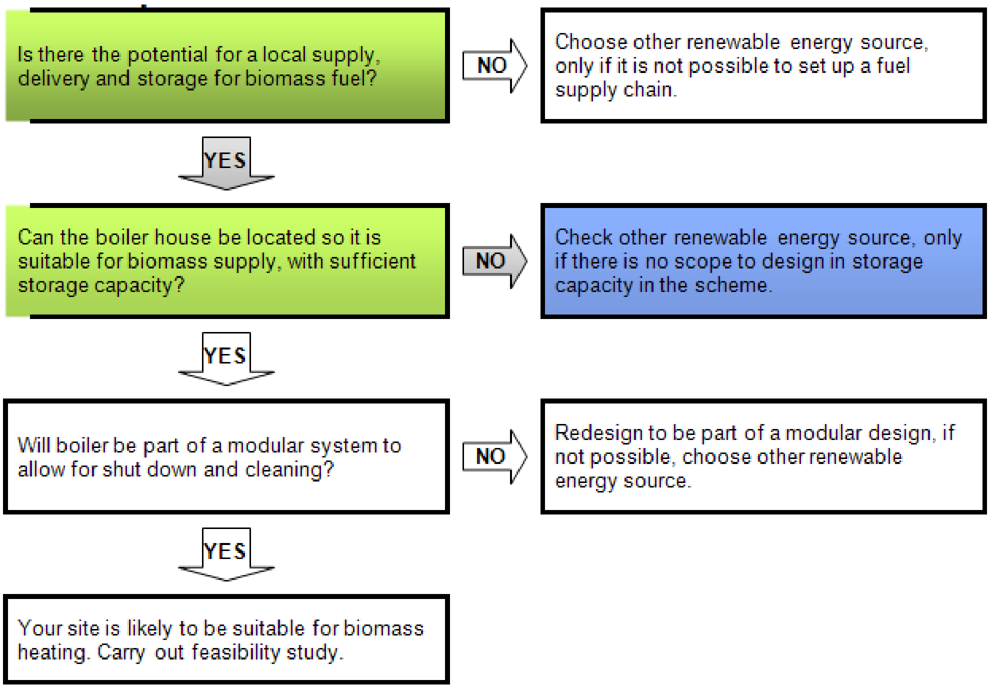
Blank squares indicate areas outside the land area of the UK - i.e. areas at sea or of neighbouring countries.
agl = above ground level.
Squares surrounding the central square correspond to wind speeds for surrounding grid squares.

A search of the wind database for the site postcode TW2 7SJ indicates the average wind speed is low and less than the recommended 6m/s to make wind a viable technology. The average wind speed on the site has been queried using the Department of Energy & Climate Change's Wind Speed Database.

Wind turbines would need to be large scale to have a meaningful carbon savings for this development and as such are not deemed to be suitable. A search of the wind speed database for the site location indicates the wind speed is low.

Due to the predicted site wind speed being below the recommended limit, the effect of turbulence within the urban environment, and the questionable efficiency of small scale units, wind turbines are not deemed appropriate as a renewable technology for the development.

7.1.2 Biomass heating viability



Biomass heating is an established technology on the continent and is increasing in use in the UK. The supplier market is growing and there is increasing interest in the use of biomass for heating in cities.

Biomass for boilers can be supplied in the form of wood chips or wood pellets. There are numerous suppliers for each fuel around London, with the number of suppliers growing as the demand increases. However, for a development of this size a large amount of fuel storage would be required in order to keep the boiler running between deliveries. Reducing storage results in an increase the frequency of deliveries and could become problematic for residents of both the proposed development and the local area.

While biomass is of increasing interest owing to the assumed low carbon nature of the fuel, there are increasing concerns being voiced publically. These include noise and emissions associated with delivery of the fuel and also the impact of combusting an organic fuel in cities in terms of NOx, SOx and particulate matter (PM10) in their flue discharge emissions. Additionally, the true low carbon nature of sustainable forestry is being questioned thus the possibility of increased emissions due to wood are being cited.

Germany and Austria have much experience in biomass and generally they do not favour small scale plant on site, rather larger scale installations away from dwellings which are connected to a district heating system.

Due to the plants space requirements to locate the bio mass boilers, filter, fuel store and associated equipment and delivery, biomass heating is not a suitable renewables option for this development.

7.1.3 Biomass Combined Heat and Power

Biomass combined heat and power can be run on a selection of biomass fuels from woodchip, to digester biogas. The carbon reductions that can be achieved from biomass CHP are the greatest of the renewable technologies, and although capital costs are high, the cost per carbon saving is reasonably low.

The generation of biogas on site could be through anaerobic digestion of kitchen waste. However, the physical constraints of the site would prevent this happening as the generation of an inflammable gas would in all likelihood present difficulties; this option has therefore not been considered further.

Biodiesel is an increasingly interesting alternative to mineral oils and capacity is increasing in the UK. However, the majority of Biodiesel is already destined for an alternative to transport diesel and is therefore likely to be expensive and scarce in the short-term. A conventional reciprocating CHP engine can be run on Biodiesel with minor modifications; there is an increase in the maintenance costs and the overall efficiency drops a little.

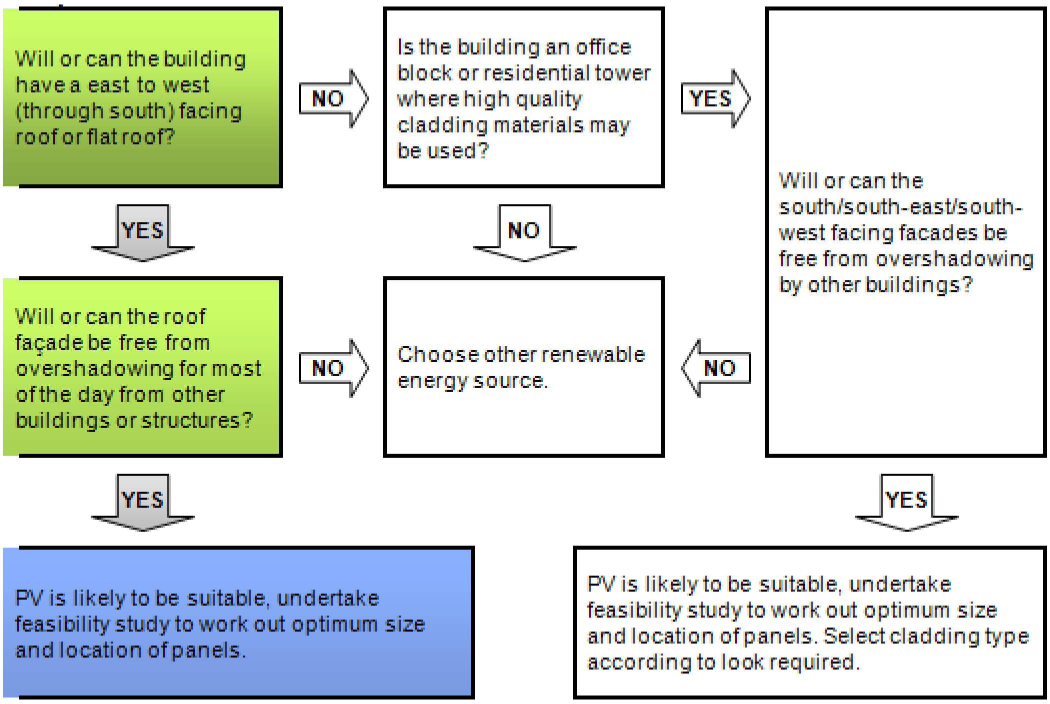
It should be noted that there are currently quite serious environmental concerns regarding the use of Biodiesel owing to the embodied energy and the displacement of both food-crops and virgin land.

Biomass CHP using wood and waste is an established technology on the continent, especially in Austria and Finland. Installations tend to be far larger than the scheme considered here and current technology in the 100's of kW is not generally widely available at present.

Unfortunately, the size of Biomass CHP which would be suitable for this development is simply too small to be commercially viable at present.

Biomass Combined heat and power is not a suitable renewables option for this development.

7.1.4 Photovoltaic viability



Photovoltaic arrays can be installed as standalone pitched units with both roof integrated products available. The optimum positioning for photovoltaic arrays in the UK is typically a southerly orientation at a 30° pitch, with efficiency decreasing moving away from the configuration. The array efficiency can also be greatly affected by shading and the shadow path throughout the day must also be considered. Standalone pitched arrays must be spaced to avoid shading between units.

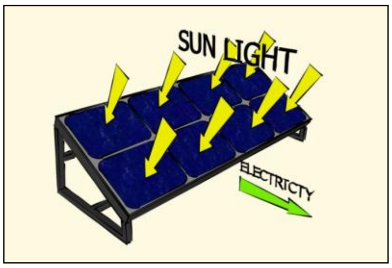


Figure 9: Typical Photovoltaic Solar Array

PV modules are an established technology. However, this system suffers from requiring significant equipment but with low efficiencies. For the proposed development, an example area has been assumed to indicate the likely carbon dioxide savings.

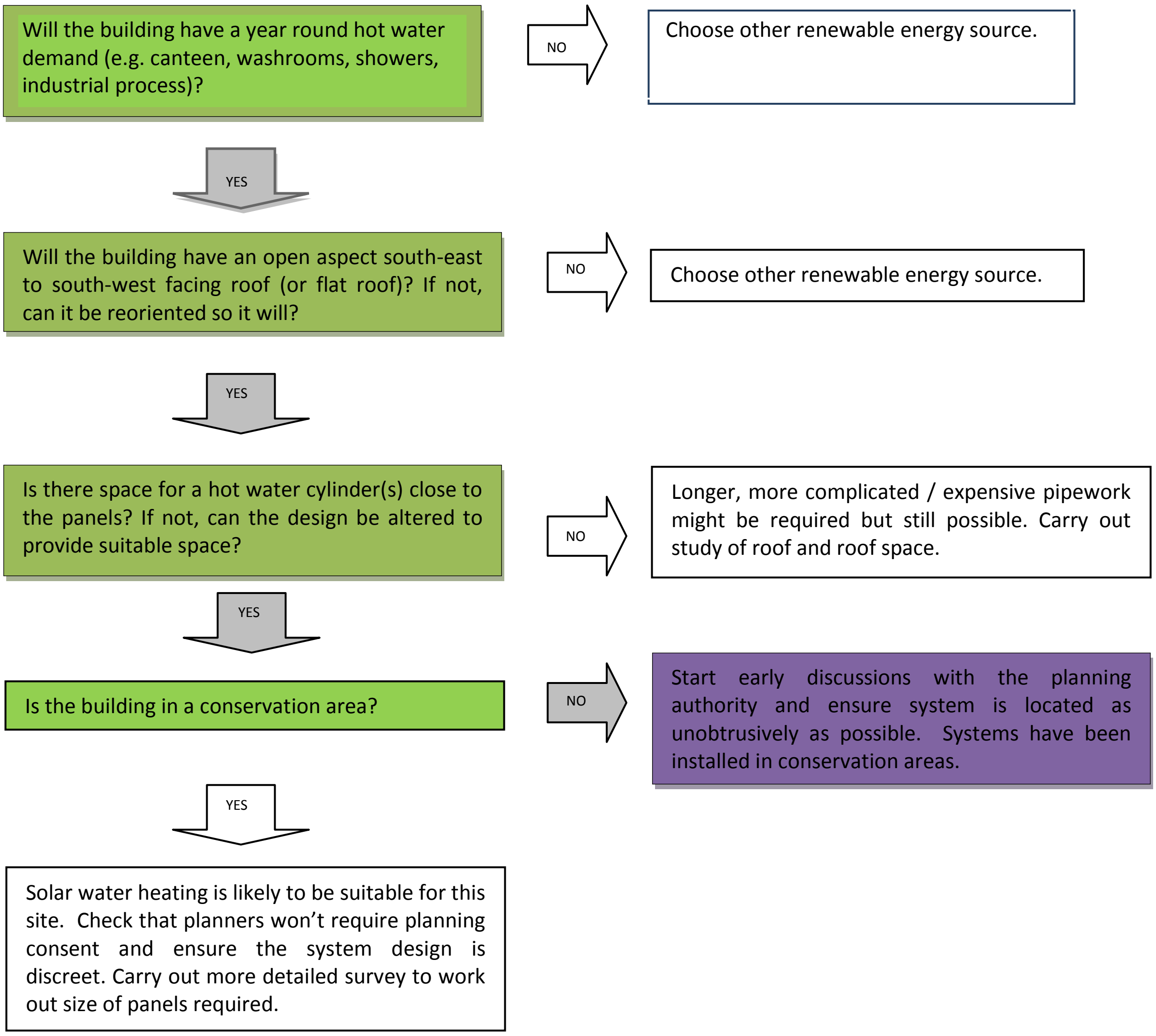
Further considerations regarding PV are:

- The mean time to failure for inverters is 10 -15 years. As these represent up to 25% of installed cost, the owner of the building would need to set aside monies to cover these costs.
- PV panels need to be cleaned periodically and therefore staff and resources would need to be made available over the lifetime of the installation

The embodied carbon and energy associated with Monocrystalline photovoltaics can be very high and certain countries (e.g. Germany) are moving towards the low efficiency, low environmental impact amorphous and thin film technologies. If improved efficiencies were applied to the above estimation of carbon savings, the carbon savings would be reduced by up to one third.

PV modules are suitable for the development. The extent of the application of PV modules will be looked at in more detail at the end of this section.

7.1.5 Solar water heating viability



The use of solar water heating has the potential to make a significant contribution to the domestic hot water demand. As a high proportion of the site will be for residential use there will be a high domestic hot water load throughout the year.

The load profile of domestic hot water on a residential development has usage peaks in the early morning and in the evening when people wake up and people get home from work respectively. However, solar energy is only available during the day and therefore needs to be stored in order to meet the usage peaks. This means that storage tanks will be required on a plot by plot basis in order to reap the benefits of solar thermal. The use of the other heating sources in line with solar hot water would also have to be carefully controlled in order to maximise the benefit from the solar hot water heating.

Solar hot water heating is suitable for the development. The extent of the application of solar water heating will be looked at in more detail at the end of this section.

7.1.6 Ground Source Heat Pump

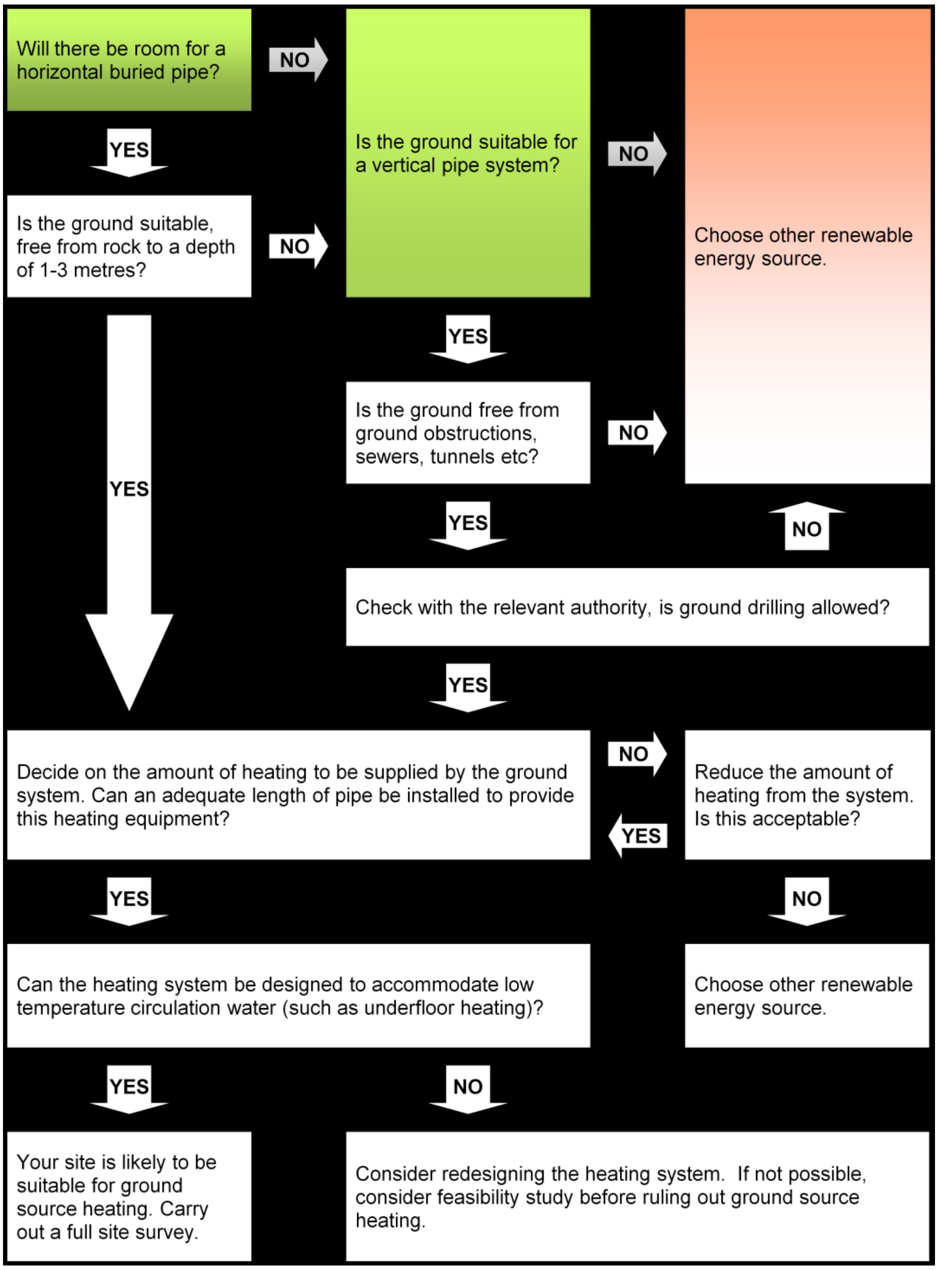


Figure: Guidelines for viability of Ground source heating systems

The relatively constant temperature of the ground makes it a possible heat source and heat sink to which a heat pump can be coupled to amplify its heating/cooling capacity. Coupling is achieved via a buried closed loop pipe circuit through which water is circulated, either in dedicated vertical boreholes or horizontal trenches, or as part of the structural piles of the building.

Pipes buried within dedicated boreholes or trenches incur a relatively large capital cost due to the extra excavation required. Incorporating the pipe work within the reinforcement cages of the building's piles requires no additional excavation but may add some complexity to the structural design. Boreholes can be made deeper than energy piles and so provide a bigger yield however their positioning is restricted by the building's structure, particularly at the perimeter. Furthermore, there is a risk that adding boreholes may alter the geotechnical loading in the area.

Thermal balancing restricts output of GSHP systems in order to maintain their long term usage. This is because an imbalance has the potential to alter long term ground temperatures. Balancing is achieved by limiting the amount of heat rejected to the ground during the warmer months to equal the amount of heat extracted in the winter months. However, the proposed development will use significantly less cooling than heating and therefore balanced ground conditions cannot be maintained.

When a new-build takes place, it is often wise to consider using new piles as heat exchangers. In this case, the piles will be relatively short and therefore only offer a small amount of area for heat collection. Therefore this solution cannot be applied.

Consideration was also given to the use of open-loop boreholes for the site. While there are instances of the application of this technology in the UK, it is by no means prevalent. A number of boreholes are drilled well into the aquifer (circa 150m) and water is abstracted from one or more and re-injected into other sited a distance away. Again thermal balancing is required an the proposed development will use significantly less cooling than heating and therefore it will not be possible to achieve balanced conditions in the aquifer.

Ground source heating and cooling is not a suitable renewables option for this development.

7.1.7 Air Source Heat Pumps

Air source heat pumps strip heat stored in the air typically above 2°C. The air is run through coils and refrigerant is used to take the heat or coolth out of the air. The refrigerant is then used to heat or cool the building. The carbon benefits of the heat pump are only taken into account when the system is in heating mode. These systems are commonly used in offices and are considered typically beneficial where there are simultaneous heating and cooling demands.

Considering the site is a mixed use development with cooling and heating load demands, there is an opportunity to use air source heat pumps and achieve carbon benefits of this type of system.

The following provisions will be required in the design for air source heat pumps:

- roof plant spaces

Air source heat pumps are deemed suitable for use due to low carbon.

7.2 Renewables Summary

Of the renewable technologies studied above a mix of solar water heating, air source to water heat pumps, possibly supplemented by photovoltaics provide the most appropriate for solution in the proposed development. The application of solar water heating has the potential to make a significant contribution to the annual domestic hot water heating and is more carbon efficient in terms of space take than PV.

For example the annual output per m^2 of solar hot water is in the order of 640 kWhr/m^2/yr compared to approximately 140 kWhrs/m^2/yr for PV. For this reason the application of solar hot water should take priority on the available roof space.

Assuming that the roof of a particular plot is large enough for an appropriately sized solar hot water system then any additional space available should be used for PV modules.

The typical contribution that solar thermal will make in terms of the total annual heating demand is shown on the figure and the impact that this renewables strategy will have on the whole site building carbon emissions are shown on the following figures.

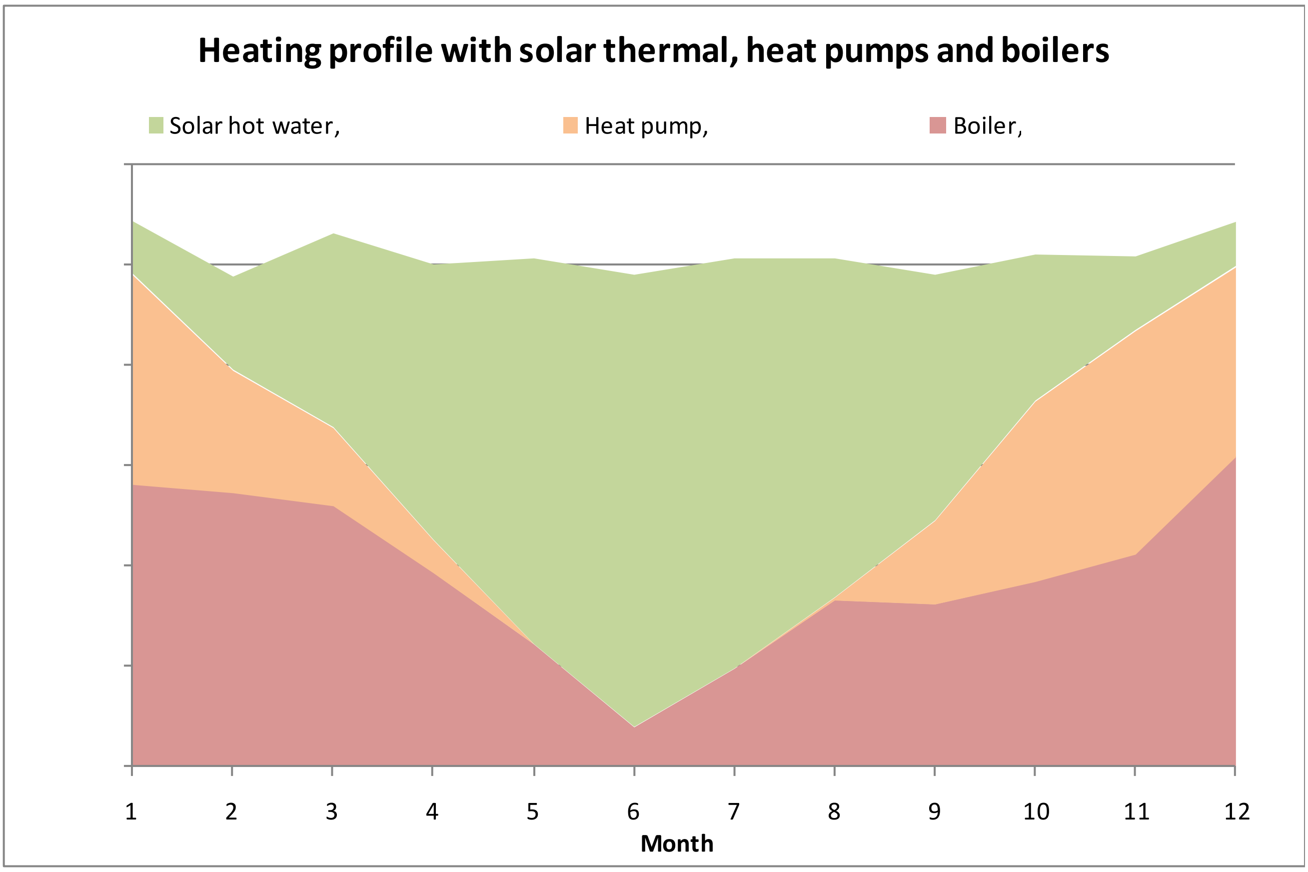


Figure 10 contribution to total heat demand from different heat sources

8 CO_2 EMISSION CALCULATIONS SUMMARY

The preceding sections outline the relative merits of the various technologies.

Based on the feasible technologies we have performed preliminary thermal modelling based on the proposed building massing and likely occupancy. In the absence of building envelope construction detail and details of internal subdivision of building areas into different usage categories at this preliminary stage, we have assumed that the notional buildings would be in conformance with the minimum requirements of Building Regulations 2013 Part L and made reasonable assumptions regarding building internal subdivision and the improvements achievable in actual lean building construction in terms of building envelope and services equipment efficiencies.

It should be recognised that the thermal modelling are based on preliminary information so that the carbon emission reduction percentages should be regarded as a target which could be subject to change as the project design is further developed.

The results of the thermal modelling are as follows:

	Option 1- Heat pumps, solar hot water and condensing boilers		Option 2 – CHP and Condensing Boilers	
	CO_2Emissions tones/year	Emission reduction compared to notional	CO_2Emissions tones/year	Emission reduction compared to notional
Notional building	1546	base	1546	base
After lean measures	1307	15.5%	1307	15.5%
After lean and clean measures	1307	15.5%	1111	28.1%
After lean, clean and green measures*	1052	**32.0%**	1111	28.1%

**There is limited scope for further improvement by use of photovoltaic cells as it is envisaged that solar hot water panels will occupy a significant percentage of roof areas. 100m² of PV cells would result in approximately 3.25 tonnes per annum or 0.21% reduction in CO_2 emissions.*

The above table indicates that compliance with items 4 and 5 of the Sustainable Construction Checklist is achievable in that there is a 15.5% reduction due to design of the buildings and their services for minimum energy use (lean building) and a further 16.5% reduction due to use of on-site renewable energy (lean, clean and green building).

The above table indicates that the option incorporating air source to water heat pumps, solar hot water in conjunction with condensing boilers is appropriate for this development and that, together with the appropriate building construction standards and services equipment, efficiencies provides the greatest opportunity for reducing CO_2 emissions. A reduction of 32% appears achievable and further enhancements could be targeted in further design in order to achieve the GLA target of 35% CO_2 emission reductions.

NORMAN DISNEY & YOUNG
CONSULTING ENGINEERS

NDY CONSULTING LIMITED
A Registered Company in England and Wales. Company Registration No. 3890617
180 Old Street
London EC1V 9RQ

Telephone: +44 20 7553 9494
Facsimile: +44 20 7553 9499

www.ndy.com

OFFICES

Australia:	Sydney, Melbourne, Brisbane, Perth, Canberra, Adelaide, Darwin, Gold Coast
New Zealand:	Auckland, Christchurch, Wellington
United Kingdom:	London
UAE:	Dubai
Malaysia:	Kuala Lumpur (NDY Licensee)

NDY QA SYSTEM

Revision No:	8.0
Revision Date:	17 June 2015
Reason Description:	Submission
File Location:	W:\U134xx\U13450\001\A-\24_Reports
Filename:	rp141013u0009
Client Name:	Richmond upon Thames College
Client Contact:	Claire Pitcher
Project Co-ordinator:	Allen Williamson
Editor:	Stefano Corbella

Authorisation By: - Martin Dabnor

Verification By: - Michael Lewis

NDY Offices:

AUSTRALIA
Adelaide
Brisbane
Canberra
Darwin
Gold Coast
Melbourne
Perth
Sydney

UNITED KINGDOM
London

NEW ZEALAND
Auckland
Christchurch
Wellington

MALAYSIA
Kuala Lumpur
(NDY Licensee)

UAE
Dubai

www.ndy.com

Norman Disney & Young