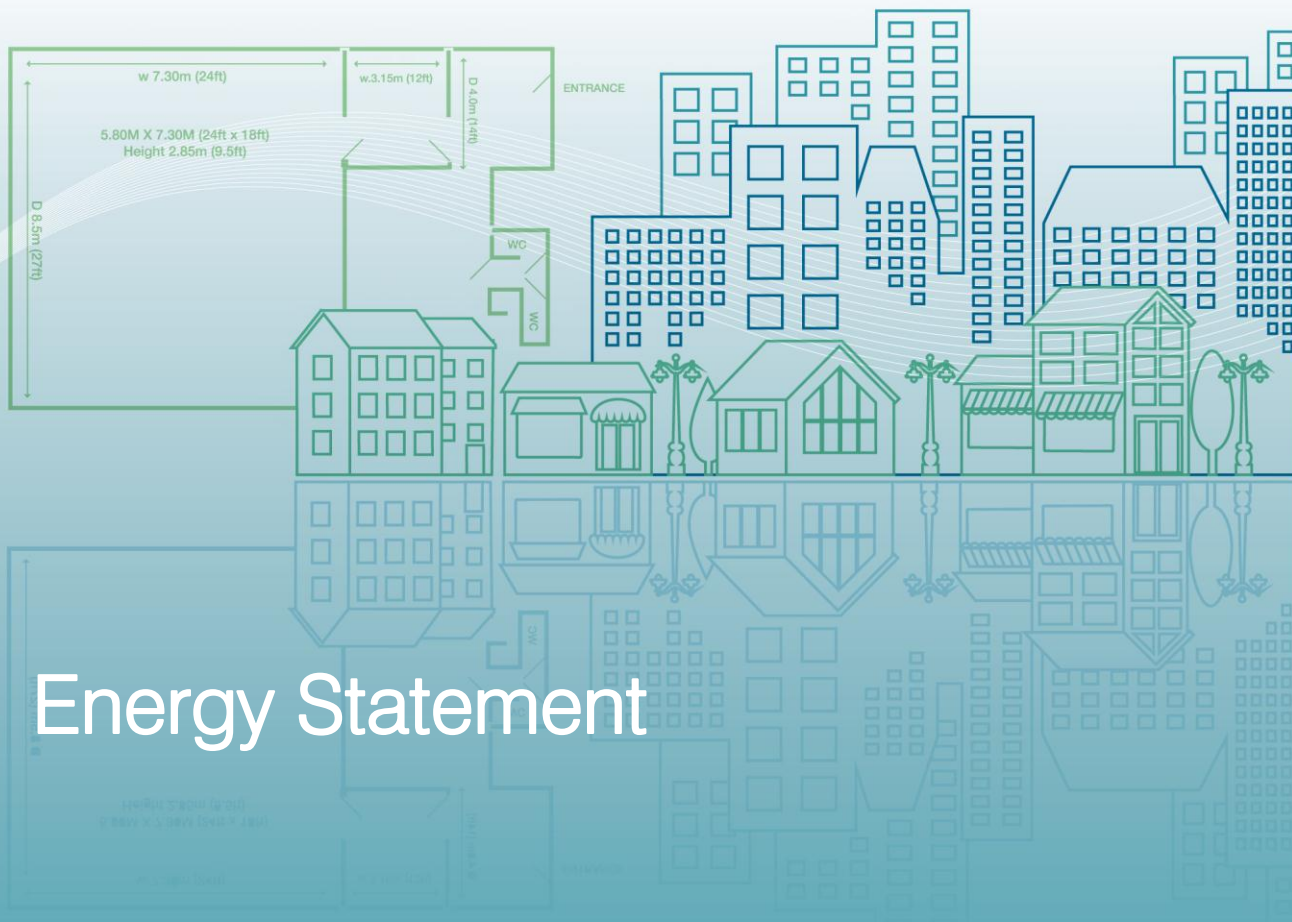




Energy Statement

Grainger plc

Woodcroft Farm

Submission

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This report has been prepared by Richard Hodkinson Consultancy (RHC) using all reasonable skill, care and diligence and using evidence supplied by the design team, client and where relevant through desktop research.

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EXECUTIVE SUMMARY

The proposed energy efficiency measures will enable all dwellings to meet the Building Regulations (2010) baseline and the Code Level 3 energy requirements through energy efficiency measures alone. This represents a very high level of sustainable design and construction and prioritises the reduction in energy demand over the generation of renewable energy.

The full spectrum of low carbon and renewable energy technologies has been assessed. It has been concluded that solar thermal panels are the most appropriate technology for the proposed development. The 59 affordable houses have been prioritised for the specification of solar thermal panels. Further provision of renewable energy technologies for the private homes would compromise the economic viability of the proposed development.

It is estimated that the specification of solar thermal panels will enable 3% of the development's total energy demand to be generated from renewable energy technologies. This responds positively and meets the policy requirement that renewable energy technologies should be provided for major development.

The Summary Table, below, shows the overall reductions expected from the combination of energy efficiency measures and renewable energy technologies.

Summary Table		
	Regulated CO ₂ (kg/yr)	Total Energy (kWh/yr)
Building Regulations (2010) Baseline	454,500	2,510,400
Proposed Energy Efficiency Specification	442,000	2,437,300
Proposed Renewable Energy Generation	428,008	2,366,600
Total Reduction over Baseline	5.8%	5.7%

It can be seen that a reduction of 5.8% in Regulated CO₂ emissions and 5.7% reduction in Total energy demand is expected through a combination of energy efficiency and renewable energy generation. This represents a high level of sustainable design and construction, which substantially exceeds the mandatory energy requirements of Level 3 of the Code for Sustainable Homes.

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1. INTRODUCTION

- 1.1** This Energy Statement has been prepared by Richard Hodgkinson Consultancy (RHC), a specialist innovation, sustainability and energy consultancy, in support of the planning application for the proposed development at Woodcroft Farm in Havant.
- 1.2** The formulation of the energy strategy for the proposed development takes into account several important concerns and priorities. These include:
- > To achieve the maximum viable reduction in Regulated CO₂ emissions with an affordable and deliverable strategy
 - > A focus firstly on energy efficiency prior to considering the application of renewable energy technologies.
 - > To minimise the negative impact of the proposed development on both the local and wider climate.
 - > To achieve the highest viable level of the Code for Sustainable Homes (Level 3 in this instance).
- 1.3** This statement first establishes a baseline assessment of the total energy demands and associated CO₂ emissions for the development based on current Building Regulations (2010). The report will then examine the energy efficiency and low carbon / renewable energy technologies that are appropriate to the development.

2. DEVELOPMENT OVERVIEW

- 2.1** The application site is located within Havant Borough, to the north west of the Town Centre and immediately north of Wecock. The site is bounded to the north by East Hampshire District and to the west by Winchester District. The application site benefits from good connections to the strategic road network with the M27 to the south and A3(M) to the east, with national railway connections served from Havant Station.
- 2.2** The site is allocated within the Havant Borough Core Strategy as a location for approximately 340 homes.
- 2.3** It is proposed that the development will provide a total of 293 homes of mixed tenure and retained farmhouse. These are to be a mixture of flats, and two, three and four bedroom houses.
- 2.4** A Site Layout is provided below (Diagram 1).



Diagram 1 - Site Layout

- 2.5 Further details regarding the scheme and the wider sustainability measures are to be found in the Design & Access Statement and Sustainability Statement submitted with the application.

3. PLANNING POLICY & PROJECT REQUIREMENTS

Climate Change Act (2008)

- 3.1 The Climate Change Act (2008) requires the UK Government to “ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline.”
- 3.2 This legal commitment sets the overriding objective for sustainability: the reduction of CO₂ emissions.

National Planning Policy Framework

- 3.3 The National Planning Policy Framework (NPPF) was published on 27th March 2012. This document states that:

“At the heart of the NPPF is a presumption in favour of sustainable development, which should be seen as a golden thread running through both plan-making and decision-taking.

For decision-taking this means:

- > Approving development proposals that accord with the development plan without delay; and
- > Where the development plan is absent, silent or relevant policies are out-of-date, granting permission unless:
 - > Any adverse impacts of doing so would significantly and demonstrably outweigh the benefits, when assessed against the policies in this Framework taken as a whole; or
 - > Specific policies in this Framework indicate development should be restricted.”

3.4 Paragraph 95 of the NPPF states that:

“To support the move to a low carbon future, local planning authorities should:

- > Plan for new development in locations and ways which reduce greenhouse gas emissions;
- > Actively support energy efficiency improvements to existing buildings; 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.”

3.5 The document also makes it clear that the delivery of a wide choice of well-designed high quality homes is central to delivering sustainable development.

Local Policy: Havant Borough Core Strategy (adopted March 2011)

3.6 Policy CS14: Efficient Use of Resources states: -

“Major areas of development must ensure that their on-site renewable energy production is maximised and resource efficiency is maximised”

3.7 The renewable energy generation for the site will be shown as a percentage of total energy: Regulated uses of space heating, hot water and lights pumps & fans; as well as the unregulated energy associated with cooking and appliances .

3.8 Furthermore: -

“Planning permission will be granted for [residential] development that...on completion, unless proven to be financially or technically unviable, meets...Level 3 of the Code for Sustainable Homes”

3.9 Code for Sustainable Homes Level 3 requires, inter alia, that Building Regulations Part L (2010) to be achieved.

- 3.10** In addition to Policy CS14, the Site Specific Profile for Woodcroft Farm within the Core Strategy seeks for the relevant Code for Sustainable Homes requirements to be met and renewable energy generation to be provided.

4. BUILDING REGULATIONS (2010) BASELINE

Methodology

- 4.1** This statement first establishes a baseline assessment of the energy demands and associated CO₂ emissions for the development based on current Building Regulations (2010). The report then examines the energy efficiency and low carbon & renewable energy technologies that will enable the maximum viable renewable energy generation and reductions in Regulated CO₂ emissions over the baseline.
- 4.2** The estimated annual energy demand for the proposed development has been calculated using Standard Assessment Procedure (SAP 2009) methodology. SAP calculates the regulated energy demands associated with hot water, space heating and fixed electrical items. Energy demands for unregulated appliances and cooking have been taken from our analysis of NHER demand assessments on similar developments.
- 4.3** Calculations have been performed on representative dwelling types.

Building Regulations (2010) Baseline

- 4.4** The Building Regulations compliant baseline case provides that the building just meets the Target Emissions Rate (TER). Table 1 shows the Building Regulations (2010) compliant Regulated CO₂ emissions and total energy demands for the development. These are shown in greater detail in Appendix B which summarises the SAP calculations.

Table 1: Building Regulations (2010) Baseline

	Regulated CO₂ (kg/yr)	Total Energy (kWh/yr)
Site Total	454,500	2,510,400

5. ENERGY EFFICIENCY MEASURES

In line with the priorities for the energy strategy it is planned to prioritise energy efficiency measures ahead of renewable energy technologies.

The following energy efficiency measures illustrate a possible route to ensuring that the proposed development meets Building Regulations (2010) with energy efficiency measures alone.

Insulation Standards

5.1 The buildings will incorporate enhanced insulation in the building envelope (walls, roofs, floors and glazing) to achieve average U-Values better than those required by Part L (2010) Building Regulations. These are likely to include:

- > Low E glazing with a U-Value of 1.4 W/m².K.
- > External Wall U-Values will be improved to 0.2 W/m².K (likely to require 350mm wall).
- > Party walls to be fully insulated and effectively sealed to achieve an effective U-Value of zero.
- > Ground Floor U-Values will be improved to 0.15 W/m².K (120mm rigid insulation).
- > Roof (joists) U-Values will be improved to 0.1 W/m².K (400mm mineral wool insulation)
- > Roof (rafters) U-Values will be improved to 0.15 W/m².K.

Air Tightness and Ventilation

- 5.2** It is proposed to install Parts L & F compliant (System 3) centralised mechanical extract ventilation (MEV) systems to the flats, with intermittent extract fans being utilised in the houses (System 1). These systems will remove stale air and odours from kitchens and bathrooms. MEV is illustrated in Figure 1.
- 5.3** The selected MEV units will have a Specific Fan Power (SFP) lower than 0.25 W/l/s to maximise energy efficiency.

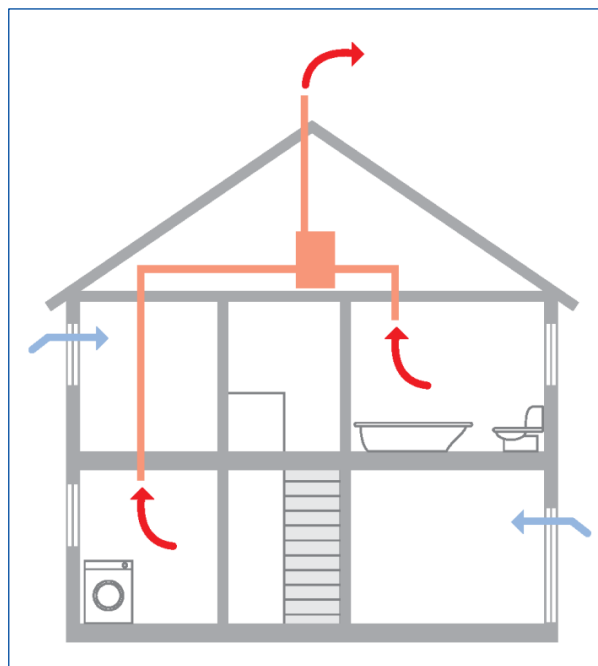


Diagram 2 - MEV System

- 5.4** Additionally, all dwellings will have openable windows and therefore the ability to naturally ventilate should the occupant desire.
- 5.5** Air tightness standards will conform to, and exceed, Approved Document Part L requirements. By reducing air leakage loss and convective bypass of insulation, an improvement of design air permeability rate from $10\text{m}^3/\text{hm}^2$ to less than $5\text{m}^3/\text{hm}^2$ will further reduce space heating requirements.

Thermal Bridging

- 5.6** In well insulated buildings, as much as 30% of heat loss can occur through thermal bridges, which occur when highly conductive elements (e.g. metal studs) in the wall construction enable a low resistance escape route for heat. It is proposed that the development will be designed to the meet

Accredited Construction Details for thermal bridges¹. Diagram 1, below, illustrates how attention to thermal bridging details can reduce heat losses.

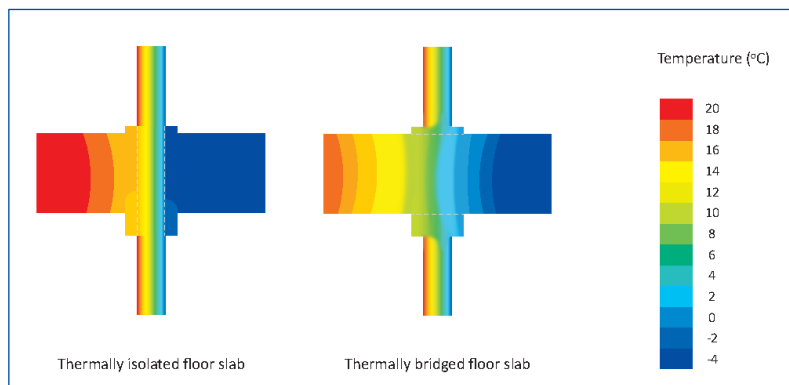


Diagram 3 - Thermal Bridging

Space Heating and Hot Water

5.7 The space heating requirement of the proposed development will be reduced by the fabric, air tightness and ventilation measures detailed above.

5.8 Furthermore, high efficiency SEDBUK 'A' rated gas boilers will be installed in each of the dwellings to efficiently generate heat.

5.9 Time and Temperature Zone (illustrated in Diagram 4) will be provided in all homes as the most effective control strategy to reduce energy use.

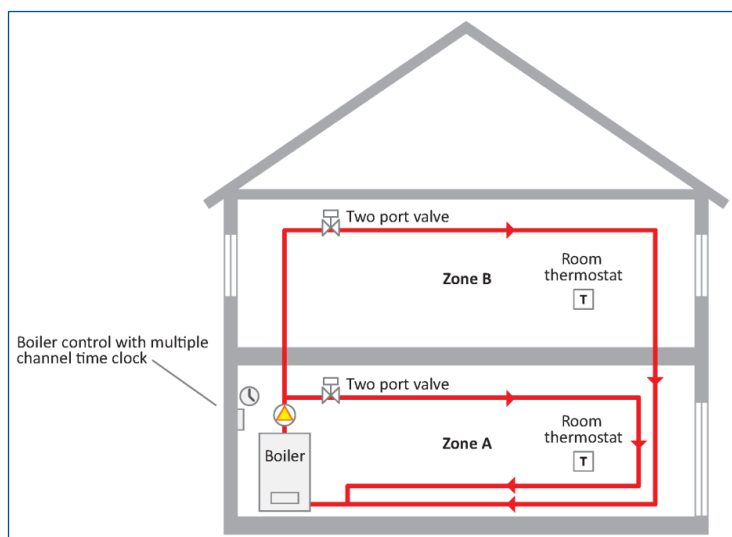


Diagram 4 - Time & Temperature Zone Control

¹ <http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/bcassociateddocuments9/acd>

- 5.10** It is intended to take advantage of winter solar gain to reduce the space heating demands of the dwellings. The benefits of this will be carefully balanced with the need to reduce the risk of excessive summer solar gains (discussed below).

Limiting the Risk of Summer Overheating

- 5.11** Minimising the risk of summer overheating is important so as to ensure that dwellings are adapted to climate change and remain comfortable to occupy in the future.
- 5.12** This will be done through the specification of non-mechanical measures such as good thermal insulation and air tightness. Furthermore the presence of deciduous trees will provide an element of summer shading. The trees and substantial green areas that are provided as part of the development will facilitate evapotranspiration: energy which would otherwise heat the local environment is used evaporating water, thus maintaining a cooler environment. It is estimated that a single mature tree has the same cooling effect as ten room-sized air conditioners.
- 5.13** Open-able windows will be used across the development and will enable cross-ventilation, convective-ventilation and night purging (illustrated in Diagram 5). These factors will reduce the build-up of heat within dwellings. The SAP overheating assessments that have been undertaken on the sample dwelling types show that there is not expected to be a high risk of summer overheating.

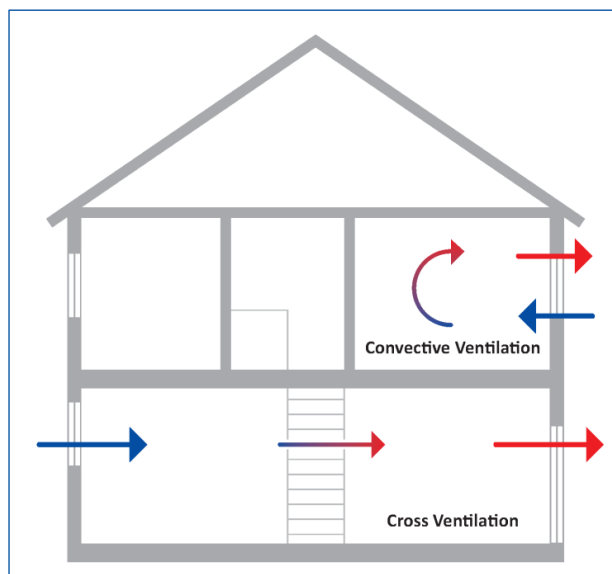


Diagram 5 - Natural Ventilation

Lighting and Appliances

- 5.14** Energy efficient lighting will be installed in 100% of internal fittings in the dwellings. External lighting will also be low energy lighting and controlled through PIR sensors, or daylight cut-off devices. Kitchen and other pre-installed appliances will be A or A+ rated for energy efficiency.
- 5.15** It is very difficult to design and construct dwellings to reduce the unregulated electricity demands, because this is almost entirely dependent on the occupant of a dwelling and can vary substantially. However, the Applicant is committed to ensuring that all efforts are made to enable the residents to minimise their unregulated electricity consumption. Advice will be provided to all occupants in the form of a Home User Guide on how to minimise electricity consumption. This includes advice on purchasing low-energy devices as well as ensuring that they are used efficiently. It has been shown that the provision of such information can significantly reduce energy use.

Impact of Energy Efficiency Measures

- 5.16** The impact of the above measures on the site-wide Regulated CO₂ emissions and total energy demand of the proposed development is shown in Table 2, below. It is evident that the measures detailed above enable Building Regulations (2010) and the mandatory energy requirements of Code for Sustainable Homes Level 3 to be achieved through energy efficiency measures alone.

Table 2: Energy Efficiency Measures

	Regulated CO₂ (kg/yr)	Total Energy (kWh/yr)
Building Regulations (2010) Baseline	454,500	2,510,400
Energy Efficiency measures	442,000	2,437,300
Reduction Achieved	2.8%	2.9%

6. LOW CARBON & RENEWABLE ENERGY TECHNOLOGIES

Having met the Building Regulations (2010) baseline through energy efficiency alone, the next step in a sustainable energy strategy is the consideration of low carbon or renewable energy technologies. There is no specific policy target for the amount of renewables that are sought.

Further details on the renewable energy technologies discussed in this section can be found in Appendix A. Appendix C provides a feasibility study table of the available technologies.

Combined Heat and Power (CHP)

- 6.1** The inclusion of decentralised heating has been investigated in terms of appropriateness to the proposed development, and, to be in line with our priorities for this energy strategy, whether decentralised heating is the best technology to provide the greatest reductions in CO₂ emissions and minimisation of pollutants with an affordable and deliverable strategy.
- 6.2** Whilst CHP would enable reductions in CO₂ emissions, there are a number of reasons why it is not considered appropriate for this development.
- 6.3** Firstly, CHP is most suited to developments where there is a diversity of high density energy uses which produce a continuous heat demand, thus allowing electricity to be generated for extended periods. This is not the case for this relatively low density solely residential scheme, where the space heating demands have been significantly reduced with high levels of energy efficiency. The result is that as the engine would not be required for extended periods it would not be producing the expected levels of electricity.
- 6.4** Secondly, the provision of a CHP engine, plant room and heat distribution network is a highly capital intensive strategy, particularly for a small development of predominantly housing. Furthermore, CHP has considerable long-term running costs and could increase the energy bills of the occupants over what they would pay with energy from the grid.
- 6.5** Thirdly, CHP engines have high emissions of oxides of nitrogen (NO_x). These are around 700mg/kWh, even with a catalyst to reduce emissions. NO_x is associated with damage to lung

function and acidification/eutrophication of habitats. As such, CHP has a harmful effect on the local environment and air quality and should therefore be avoided.

- 6.6** It has therefore been concluded that a CHP engine is not a viable strategy for this development and will therefore not be specified.

Biomass Boiler

- 6.7** Biomass boilers generate heat on a renewable basis as they are run on biomass fuel which is carbon neutral. A biomass boiler would require a central Energy Centre and heat distribution network and would therefore be liable to the same high capital and running costs noted for CHP.
- 6.8** Whilst technically feasible, a biomass boiler is not appropriate for this development for the same reasons as a CHP engine is not.

Ground and Air Source Heat Pumps (ASHPs and GSHPs)

- 6.9** Heat Pumps upgrade energy from the ground or air and utilise it for space heating and hot water.
- 6.10** Heat Pumps are able to provide substantial reductions in energy. However, GSHPs require costly ground excavation works to bury the coils – boreholes would be required for the proposed development due to the high space requirements of ground coils. Air Source Heat Pumps are a more economic alternative to GSHPs as they do not require ground works. However, the performance of ASHPs is substantially lower than for GSHPs and therefore the reductions in CO₂ are correspondingly low. Whilst reducing energy significantly, heat pumps replace gas as the heating fuel with electricity, which is more carbon intensive. Electricity is also substantially more expensive than gas, so fuel bills are not reduced by heat pumps as much as by other technologies. Whilst ASHPs are cheaper to install than GSHPs they have a lower performance and provide only limited reductions in total CO₂ emissions.
- 6.11** It has therefore been concluded that heat pumps are not the most appropriate technology for the proposed development.

Wind Turbines

- 6.12** Small scale roof-top wind turbines are unlikely to be a viable technology for this development due to its urban location where wind speeds are low and conditions are turbulent. These conditions reduce the generating potential of wind turbines to levels which are not viable. Detailed assessment of wind conditions at the development site over the course of a year would be required to determine the technical viability of wind turbines.
- 6.13** It has therefore been concluded that PV panels represent a more appropriate technology for the proposed development.

Photovoltaic (PV) Panels

- 6.14** All houses and blocks of flats have suitably oriented roofs for the installation of PV panels. PV panels could technically therefore be installed on the roofs of the houses and blocks of flats to generate renewable electricity and reduce CO₂ emissions.
- 6.15** Due to the high carbon intensity of grid displaced electricity, PV panels are good at reducing CO₂ emissions, but less good at generating energy.
- 6.16** Whilst technically viable, it has therefore been concluded that as this development is subject to a renewable energy (as opposed to CO₂) policy, that solar thermal panels represent a more appropriate technology in this instance.

Proposed Technology: Solar Thermal Panels

- 6.17** Solar Thermal Heating Systems contribute to the hot water demand of a dwelling or building. Due to the seasonal variability of heat, solar thermal panels should be scaled to provide no more than 1/2 of the annual hot water load. Solar thermal panels are illustrated in Diagram 6.

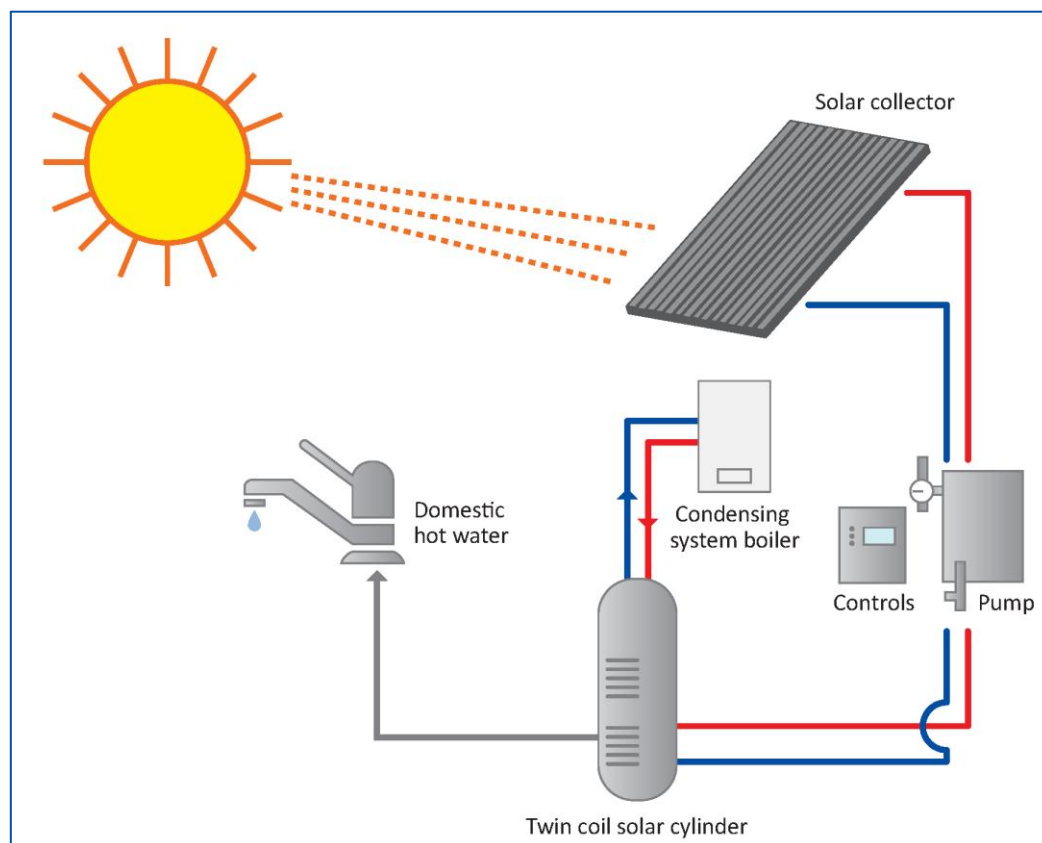


Diagram 6 - Solar Thermal System

- 6.18** All houses and blocks of flats have suitably oriented roofs for the installation of solar panels. Solar thermal panels could technically therefore be installed on the roofs of the houses and blocks of flats to generate renewable energy and reduce CO₂ emissions.
- 6.19** Solar thermal panels are equally good at generating renewable energy as well as reducing CO₂ emissions. For this reason it is considered that they are a more appropriate technology than PV panels in this instance.
- 6.20** Installation of solar thermal panels for the flats is complicated by the difficulty of accommodating the pipe-runs between the roof and the lower storey dwellings.
- 6.21** The applicant is keen to focus the specification of renewable energy technologies on the affordable dwellings in the first instance. This will have the effect of helping to reduce energy bills for those that would benefit most from this.

- 6.22** Consequently it is intended that solar thermal panel systems will be installed for each of the 59 affordable houses. Further provision on the private dwellings would compromise the economic viability of the proposed development.
- 6.23** Panels will be installed on the most southerly facing roofs of the subject dwellings in order to maximise efficiency. An average orientation of SE/SW has been assumed. Each house will also have a twin-coil solar hot water cylinder.
- 6.24** In order to avoid an overgeneration of heat it is considered that a single-panel ($\sim 2\text{m}^2$) system is appropriate for the 2-bed houses; with 2-panel ($\sim 4\text{m}^2$) systems for the 3 and 4-bed houses.
- 6.25** The solar thermal calculation is shown in Appendix D.

Renewable Energy Generation

- 6.26** Table 3, below, shows that the proposed solar thermal panels will generate 3% of the total energy demand of the proposed development. This responds positively to the requirement for major development to incorporate renewable energy technologies and does so without affecting the economic viability of development.

Table 3: Renewable Energy Generation	
	Total Energy (kWh/yr)
Proposed Energy Efficiency Specification	2,437,300
Proposed Renewable Energy Generation	2,366,600
Reduction Achieved	3%

- 6.27** These results are shown in greater detail in Appendix D.

7. SUMMARY

- 7.1** The proposed energy efficiency measures will enable all dwellings to meet the Building Regulations (2010) baseline and the Code Level 3 energy requirements through energy efficiency measures alone. This represents a very high level of sustainable design and construction and prioritises the reduction in energy demand over the generation of renewable energy.
- 7.2** The full spectrum of low carbon and renewable energy technologies has been assessed. It has been concluded that solar thermal panels are the most appropriate technology for the proposed development. The 59 affordable houses (out of a total of 89 affordable homes) have been prioritised for the specification of solar thermal panels. Further provision of renewable energy technologies for the private homes would compromise the economic viability of the proposed development.
- 7.3** It is estimated that the specification of solar thermal panels will enable 3% of the development's total energy demand to be generated from renewable energy technologies. This responds positively and meets the policy requirement that renewable energy technologies should be provided for major development.
- 7.4** The Summary Table, below, shows the overall reductions expected from the combination of energy efficiency measures and renewable energy technologies.

Summary Table		
	Regulated CO ₂ (kg/yr)	Total Energy (kWh/yr)
Building Regulations (2010) Baseline	454,500	2,510,400
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Proposed Renewable Energy Generation	428,008	2,366,600
Total Reduction over Baseline	5.8%	5.7%

- 7.5** It can be seen that a reduction of 5.8% in Regulated CO₂ emissions and 5.7% reduction in Total energy demand is expected through a combination of energy efficiency and renewable energy generation. This represents a high level of sustainable design and construction, which substantially exceeds the mandatory energy requirements of Level 3 of the Code for Sustainable Homes.

APPENDICES

- A) Low Carbon & Renewable Energy Technologies
- B) Summary of SAP Energy Calculations
- C) Feasibility Table of Low Carbon & Renewable Energy Technologies
- D) Solar Thermal Panel Calculation

Appendix A: Low Carbon and Renewable Energy Technologies

1. INTRODUCTION

- > This Appendix is intended to provide the background information for the low carbon and renewable energy technologies that have been considered in the formulation of this Energy Statement.
- > The information provided here forms the basis for the project specific technical selection of low carbon/renewable energy technologies contained in the main section of this Energy Statement.

2. COMBINED HEAT AND POWER (CHP)

> CHP is a form of decentralised energy generation that generally uses gas to generate electricity for local consumption, reducing the need for grid electricity and its associated high CO₂ emissions. As the CHP system is close to the point of energy demand, it is possible to use the heat that is generated during the electricity generation process. As both the electricity and heat from the generator is used, the efficiency of the system is increased above that of a conventional power plant where the heat is not utilised.

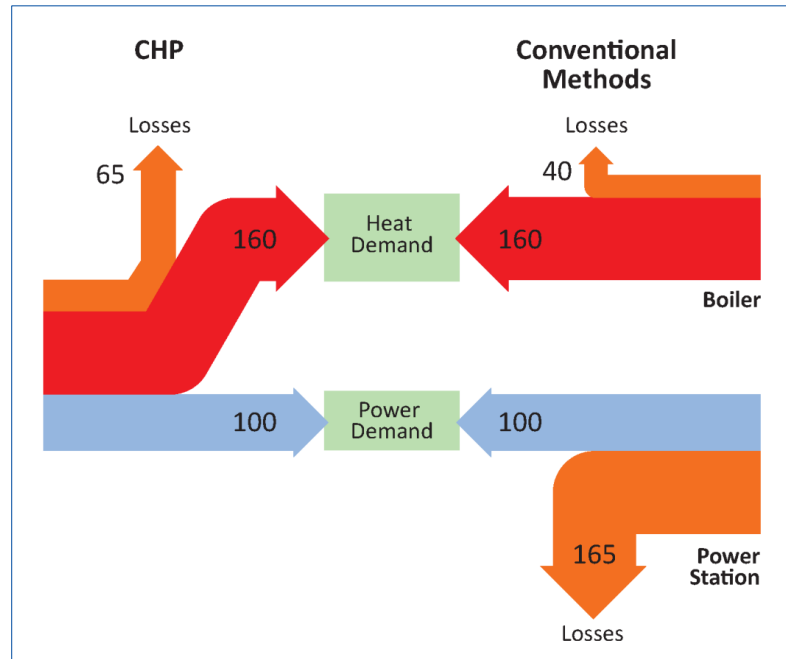


Diagram 1 - CHP Sankey Diagram

- > However, the overall efficiency of ~80% is still lower than the ~90% efficiency of a heat only gas boiler.
- > Where there are high thermal loads, CHP can be used within district heating networks to supply the required heat.
- > **Performance and Calculation Methodology:** -
 - > Most commonly sized on the heat load of a development, not the electrical load. This prevents an over-generation of heat.
 - > Require a high and relatively constant heat demand to be viable.
 - > CHP engines are best suited to providing the base heating load of a development (~year round hot water demand) with conventional gas boilers responding to the peak heating demand (~winter space heating). CHP engines are not able to effectively respond to peaks in demand.
 - > In general, CHP engines have an electrical efficiency of ~30% and a thermal efficiency of ~45%.
 - > Electricity produced by the CHP engine displaces grid electricity which is given a carbon intensity of 0.529 kg per kWh.

> **Capital Cost:** -

- > High in comparison to biomass boilers.
- > Relative cost reduces as the size of engine increases.

> **Running Costs/Savings:** -

- > CHP engines often struggle to provide cost-effective energy to dwellings on residential schemes.
- > Running costs and maintenance are higher than for domestic gas boilers.
- > Needs Private Wire supply for economic case to be positive.

> **Land Use Issues and Space Required:** -

- > CHP engines require a plant room, and possibly an energy centre for large residential developments.
- > CHP engines require a flue to effectively disperse pollutants. The height of the chimney required is dependent on the size of the engine installed.
- > Heat network issues.

> **Operational Impacts/Issues:** -

- > Often run by Energy Services Company (ESCo) who are unenthusiastic about getting involved in small – medium scale schemes.
- > Issues with rights to dig up roads for district heating networks.
- > Emissions of oxides of nitrogen – ~500mg/kWh – 10 times higher than for a gas boiler.

> **Embodied Energy:** - Comparable to that of a conventional gas boiler.

> **Funding Opportunities:** - Tax relief for businesses under the Enhanced Capital Allowances scheme.

> **Reductions in Energy Achievable:** - Can provide some reductions in effective primary energy, but when distribution losses and other local losses are included more fuel is required.

> **Reductions in CO₂ Achievable:** - Can provide greater reductions in CO₂ than energy, aided by the emissions factor of grid displaced electricity of 0.529 kg CO₂/kWh.

> **Advantages:** - Good reductions in overall primary energy and CO₂ emissions.

> **Disadvantages:** -

- > More expensive and greater NOx emissions than a biomass boiler.
- > Often do not supply energy cost-effectively in comparison to the market.
- > Requires Private Wire network to maximise cost effectiveness.

3. COMBINED COOLING HEAT AND POWER (CCHP)

- > CCHP is a CHP system which additionally has the facility to transform heat into energy for cooling. This is done with an absorption chiller which utilises a heat source to provide the energy needed to drive a cooling system. As absorption chillers are far less efficient than conventional coolers (CoP of 0.7 compared to >4) they are generally only used where there is a current excess generation of heat. New CHP systems are generally sized to provide the year round base heating load only.
- > For this reason it is generally not suitable for new CHP systems to include cooling.
- > Where there are high thermal loads, CCHP can be used within district heating and cooling networks to supply the required heat and coolth.
- > **Performance and Calculation Methodology:** -
 - > Most commonly sized on the heat load of a development, not the electrical load. This prevents an over-generation of heat.
 - > Require a high and relatively constant heat and cooling demand to be viable.
 - > CCHP systems are best suited to providing the base loads of a development with conventional gas boilers and chillers responding to the peak demands. CCHP systems are not able to effectively respond to peaks in demand.
 - > In general, CHP engines have an electrical efficiency of ~30% and a thermal efficiency of ~45%.
 - > Absorption chillers have a CoP of ~0.7.
 - > Electricity produced by the CHP engine displaces grid electricity which is given a carbon intensity of 0.529 kg per kWh.
- > **Capital Cost:** -
 - > High in comparison to biomass boilers and increased further by inclusion of absorption chiller.
 - > Relative cost reduces as the size of engine increases.
- > **Running Costs/Savings:** -
 - > CHP engines often struggle to provide cost-effective energy to dwellings on residential schemes.
 - > Running costs and maintenance are higher than for domestic gas boilers.
 - > Needs Private Wire supply for economic case to be positive.

> **Land Use Issues and Space Required: -**

- > CHP engines require a plant room, and possibly an energy centre for large residential developments.
- > CHP engines require a flue to effectively disperse pollutants. The height of the chimney required is dependent on the size of the engine installed. Additionally the absorption chiller requires either a cooling tower or dry cooler bed for heat rejection purposes.
- > Heat network issues.

> **Operational Impacts/Issues: -**

- > Often run by an ESCo who are unenthusiastic about getting involved in small – medium scale schemes.
- > Issues with rights to dig up roads for heat networks.
- > Emissions of oxides of nitrogen– ~500mg/kWh – 10 times higher than for gas boilers.

> **Embodied Energy: -** Comparable to conventional gas boilers.

> **Funding Opportunities: -** Tax relief for businesses under Enhanced Capital Allowance scheme.

> **Reductions in Energy Achievable: -** Can provide some reductions in effective primary energy, but when distribution and other local losses are included, more fuel is required.

> **Reductions in CO₂ Achievable: -** Can provide greater reductions in CO₂ than energy, aided by the emissions factor of grid displaced electricity of 0.529 kg CO₂/kWh.

> **Advantages: -** Good reductions in overall primary energy and CO₂ emissions.

> **Disadvantages: -** More expensive and greater emissions of NO_x than biomass.

- > Often do not supply energy cost-effectively in comparison to the market.
- > Requires Private Wire network to maximise cost effectiveness.

4. BIOMASS BOILERS

- > Biomass boilers generate heat on a renewable basis as they are run on biomass fuel which is carbon neutral. Fuel is generally wood chip or wood pellets. Wood pellets are slightly more expensive than wood chips but have a significantly higher calorific value and enable greater automation of the system.
- > Can be used with district heating networks or as individual boilers on a house-by-house basis.
- > **Performance and Calculation Methodology: -**
 - > Biomass boilers are best suited to providing the base heating load of a development (~year round hot water demand) with conventional gas boilers responding to the peak heating demand (~winter space heating).
 - > Operate with an efficiency of 87-91%.
 - > Small models available.
 - > Conflicts with CHP they are both best suited to providing the base heating load of a development. As such they should not be installed in tandem unless surplus hot water capacity is available. Special control measures would be required in this case.
- > **Capital Cost: -**
 - > Low in comparison to CHP.
 - > More suitable to smaller developments than CHP as installed cost is lower.
- > **Running Costs/Savings: -**
 - > Biomass fuel is more expensive than gas and as such heat being provided to dwellings is generally more expensive than the market.
- > **Land Use Issues and Space Required: -**
 - > Biomass boilers require a plant room and possibly separate energy centre for large residential developments.
 - > Require a flue to effectively disperse pollutants. The height of the chimney required is dependent on the size of the boiler installed.
 - > Fuel store will be required. This should be maximised to reduce fuel delivery frequency.
 - > Space must be available for delivery vehicle to park close to plant room.
 - > Heat network issues.

> **Operational Impacts/Issues:** -

- > Normally run on biomass, but can also work with biogas.
- > Require some operational support and maintenance.
- > Fuel deliveries required.
- > Boiler and fuel store must be sited in proximity to space for delivery vehicle to park.
- > Issues with rights to dig up roads, etc (for heat networks).
- > Emissions of oxides of nitrogen – ~80-100mg/kWh.

> **Embodied Energy:** - Comparable to conventional gas boiler.

> **Funding Opportunities:** - The Bio-energy Capital Grants Scheme offers grants of up to 40% of the difference between the installed cost of biomass boiler and the cost of the fossil fuel alternative to the industrial, commercial and community sectors.

> **Reductions in Energy Achievable:** - No reduction in energy demand, but energy generated from a renewable fuel. Significant long term running costs (fuel).

> **Reductions in CO₂ Achievable:** - Can provide significant reductions in CO₂, but generally limited by the hot water load (base heating load).

> **Advantages:** - Reductions in CO₂ at low installed cost.

> **Disadvantages:** -

- > High long-term running costs.
- > Often do not supply energy cost-effectively in comparison to gas boilers.

5. SOLAR THERMAL PANELS

- > Solar Thermal Heating Systems contribute to the hot water demand of a dwelling or building. Water or glycol (heat transfer fluid) is circulated to roof level where it is heated using solar energy before being returned to a thermal store in the plant room where heat is exchanged with water from the conventional system. Due to the seasonal availability of heat, solar thermal panels should be scaled to provide no more than 1/2 of the hot water load.

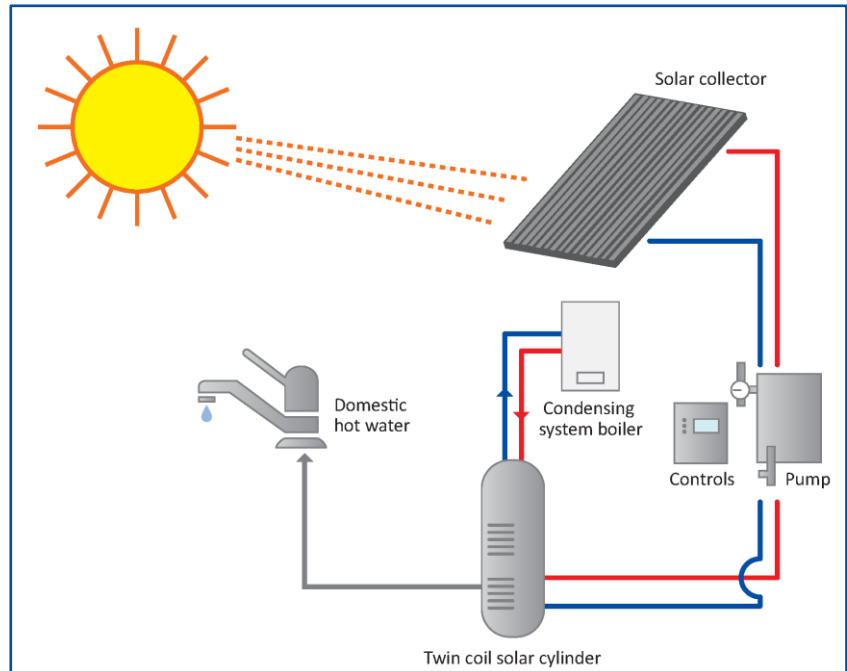


Diagram 2 - Solar Thermal System

- > Can also be used to provide energy for space heating in highly insulated dwellings.
- > There are two types of solar thermal panel: evacuated tube collectors and flat plate collectors.
- > **Performance and Calculation Methodology:** -
 - > Evacuated Tube Collectors: ~60% efficiency.
 - > Flat Plate Collectors: ~50% efficiency.
 - > SAP Table H2 used for solar irradiation at different angles.
 - > Operate best on south facing roofs angled at 30-45° and free of shading, or on flat roofs on frames. East/West facing panels suffer a loss in performance of 15-20% depending on the angle of installation.
 - > Flat plate collectors cannot be installed horizontally as this would prevent operation of the water pump. Must therefore be angled and separated to avoid overshadowing each other.
 - > SAP limits benefit to a ~12-14% reduction in regulated CO₂ over baseline.

- > **Capital Cost:** - Typically £2,500 per 4m² plus installation. Costs higher for evacuated tubes than flat plate collectors.
- > **Running Costs/Savings:** -
 - > Reduce reliance on gas and therefore reduce costs.
 - > Payback period of ~20 years per dwelling.
- > **Land Use Issues and Space Required:** -
 - > Installed on roof so no impact on land use.
 - > Due to amount of roof space required and distance from tank to panels, less suitable for dense developments of relatively high rise flats.
 - > Within permitted development rights unless in a conservation area where they must not be visible from the public highways.
 - > Dormer and Velux windows may conflict if energy/CO₂ reduction required is large.
- > **Operational Impacts/Issues:** - Biggest reductions achieved by people who operate their hot water system with consideration of the panels.
- > **Embodied Energy:** - Carbon payback is ~2 years.
- > **Funding Opportunities:** - none
- > **Reductions in Energy Achievable:** - Reduce primary energy demand by more per standard panel area than solar PV panels.
- > **Reductions in CO₂ Achievable:** - Comparable to solar PV per m².
- > **Advantages:** - Virtually free fuel, low maintenance and reductions in energy/CO₂.
- > **Disadvantages:** - Benefits limited to maximum ~50% of hot water load.

6. SOLAR PHOTOVOLTAIC (PV) PANELS

- > Solar PV panels generate electricity by harnessing the power of the sun. They convert solar radiation into electricity which can be used on site or exported to the grid in times of excess generation.
- > **Performance and Calculation Methodology: -**
 - > The best PV panels operate with an efficiency approaching 20%. $\sim 7\text{m}^2$ of these high performance panels will produce 1kWp of electricity.
 - > Operate best on south facing roofs angled at $30\text{-}45^\circ$ or on flat roofs on frames. Panels orientated east/west suffer from a loss in performance of 15-20% depending on the angle of installation.
 - > Must be free of any potential shading.
 - > Cannot be installed horizontally as would prevent self-cleaning. Must therefore be angled and separated to avoid overshadowing each other.
 - > Electricity produced displaces grid electricity which has a carbon intensity of 0.529 kg CO₂ per kWh.
- > **Capital Cost: -** $\sim$ £2,500 per kWp.
- > **Running Costs/Savings: -**
 - > Reduce reliance on grid electricity and therefore reduce running costs.
 - > At current electricity prices, payback period of $\sim$ 60-70 years per dwelling.
 - > Feed-in tariff and Renewables Obligation Certificates (ROCs) payments required for maximum financial benefit.
- > **Land Use Issues and Space Required: -**
 - > Installed on roof so no impact on land use.
 - > Due to amount of roof space required are less suitable for dense developments of relatively high rise flats.
 - > Within permitted development rights unless in a conservation area where they must not be visible from the public highways.
 - > Dormer and Velux windows may conflict if energy/CO₂ reduction required is large.
- > **Operational Impacts/Issues: -**
 - > Proportionately large arrays may need electrical infrastructure upgrade.
 - > Virtually maintenance free and panels are self-cleaning at angles in excess of 10 degrees.

- > **Embodied Energy:** - Carbon payback of 2-5 years.
- > **Funding Opportunities:** - Financier utilising Feed-in-Tariffs.
- > **Reductions in Energy Achievable:** - Reduce energy demand by less per m² than solar thermal panels.
- > **Reductions in CO₂ Achievable:** - Provide greater percentage reductions in CO₂ than energy. Comparable to solar thermal per square metre.
- > **Advantages:** - Virtually free fuel, very low maintenance and good reductions in CO₂.
- > **Disadvantages:** -
 - > More expensive than solar thermal.
 - > Slightly greater loss in performance than solar thermal panels when orientated away from south.

7. GROUND SOURCE HEAT PUMPS (GSHPs)

- > Ground Source Heat Pumps work in much the same way as a refrigerator, converting low grade heat from a large 'reservoir' into higher temperature heat for input in a smaller space. Electricity drives the pump which circulates a fluid (water/antifreeze mix or refrigerant) through a closed loop of underground pipe. This

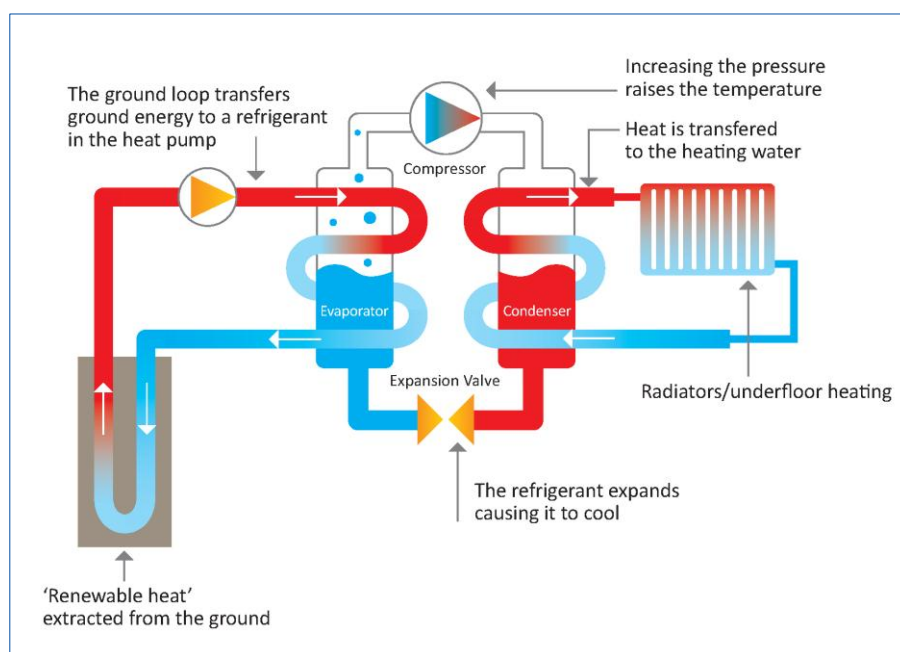


Diagram 3 - Ground Source Heat Pump

fluid absorbs the solar energy that is stored in the earth (which in the UK remains at a near constant temperature of 12°C throughout the year) and carries it to a pump. A compressor in the heat pump upgrades the temperature of the fluid which can then be used for space heating and hot water.

> **Performance and Calculation Methodology:** -

- > System requires electricity to drive the pump. Therefore displaces gas heating with electric, which has a higher carbon intensity (gas: 0.198; electricity: 0.517).
- > As they are upgrading heat energy from the earth, GSHPs operate at 'efficiencies' in excess of 350%. This is limited in SAP unless Appendix Q rated model used.
- > Due to the lower temperature of the output of GSHPs compared to traditional gas boilers, GSHPs work best in well insulated buildings and with underfloor heating. They can, however, also be installed with oversized radiators, albeit with a consequent reduction in performance

> **Capital Cost:** - ~£7,500 per house. Additional costs if underfloor heating is to be installed.

> **Running Costs/Savings:** -

- > Electricity more expensive than gas, thus fuel costs not reduced as much as energy is reduced.
- > Payback period of ~20 years per dwelling.

> **Land Use Issues and Space Required:** -

- > Require extensive ground works to bury the coils that extract the low grade heat from the earth. They therefore require a large area for horizontal burial (40-100m long trench) or a vertical bore (50-100m) which is considerably more expensive but can be used where space is limited.
- > Must be sized correctly to prevent freezing of the ground during winter and consequent shutdown of the system.
- > May require planning permission for engineering works. Once buried, there is no external evidence of the GSHPs.

> **Operational Impacts/Issues:** -

- > Work best in well insulated houses.
- > Need immersion for hot water.
- > Highly reliable and require virtually no maintenance.
- > Problems if ground bore fails.

> **Embodied Energy:** - Low, but as gas is being replaced with the more carbon intensive electricity, carbon payback is slowed. Carbon payback depends on CoP.

> **Funding Opportunities:** - none.

> **Reductions in Energy Achievable:** - Reduce energy demand by less per m² than solar thermal panels.

- > **Reductions in CO₂ Achievable:** - Provide greater %age reductions in CO₂ than energy. Comparable to solar thermal (esp. in SAP).
- > **Advantages:** - Large reductions in Energy. Currently receives benefit from SAP of an electrical baseline rather than gas.
- > **Disadvantages:** - Small reduction in CO₂. CoP limited in SAP. Only small cost savings.

8. AIR SOURCE HEAT PUMPS (ASHPS)

- > Air Source Heat Pumps work in much the same way as a refrigerator, converting low grade heat from a large 'reservoir' into higher temperature heat for input into a smaller space. Electricity drives the pump which extracts heat from the air as it flows over the coils in the heat pump unit. A compressor in the heat pump upgrades the temperature of the extracted energy which can then be used for space heating and hot water.

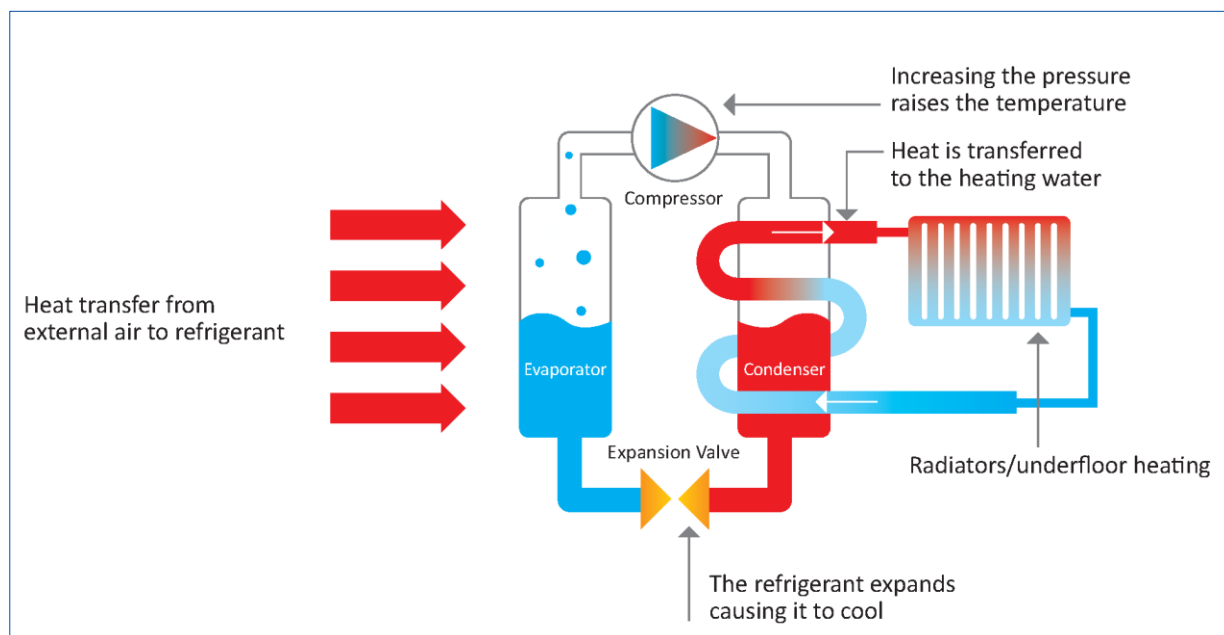


Diagram 4: Air Source Heat Pump System

- > Generally ASHPs are air-to-water devices but can also be air-to-air.

> **Performance and Calculation Methodology: -**

- > System requires electricity to drive the pump. Therefore displaces gas heating with electric, which has a higher carbon intensity (gas: 0.198; electricity: 0.517).
- > Performance defined by the Coefficient of Performance (CoP) which is a measure of electricity input to heat output. However, the concept of a CoP must be treated with caution as it is an instantaneous measurement and does not take account of varying external conditions throughout the year.
- > As they are upgrading heat energy from the air, ASHPs operate at 'efficiencies' in excess of 250%. This is limited in SAP unless an Appendix Q rated model is used.
- > British winter conditions (low temperatures and high humidity) lead to freezing of external unit. Reverse cycling defrosts the ASHP, but can substantially reduce performance when it is most needed. Performance under these conditions varies considerably between models. Vital that ASHP that has been proven in British winter conditions is installed.
- > Due to the lower temperature of the output of ASHPs compared to traditional gas boilers, ASHPs work best in well insulated buildings and with underfloor heating. They can, however, also be installed with oversized radiators, albeit with a consequent reduction in performance.

> **Capital Cost: -** ~£2,000 per house.

> **Running Costs/Savings: -**

- > Electricity more expensive than gas, thus fuel costs not reduced as much as energy is reduced.
- > Payback period of ~10 years per dwelling.

> **Land Use Issues and Space Required: -**

- > No need for external ground works, only a heat pump unit for the air to pass through.
- > Minimal external visual evidence.

> **Operational Impacts/Issues: -**

- > Work best in well insulated houses.
- > Unit must be sized correctly for each dwelling.
- > Vital that ASHP model selected has been proven to maintain performance at the low temperature and high humidity conditions of the British winter.
- > May need immersion for hot water.
- > Highly reliable and require virtually no maintenance.

- > **Embodied Energy:** - Low. Carbon payback longer than for GSHPs as the CoP is lower.
- > **Funding Opportunities:** - none
- > **Reductions in Energy Achievable:** - Large reductions in energy demand. Less so than GSHPs.
- > **Reductions in CO₂ Achievable:** - Provide smaller percentage reductions in CO₂ than energy. Less than GSHPs.
- > **Advantages:** - Large reductions in Energy. Currently receives benefit from SAP of an electrical fuel factor rather than a gas baseline.
- > **Disadvantages:** - Small reduction in CO₂. CoP limited in SAP. Only small cost savings.

9. WIND POWER

- > Wind energy installations can range from small domestic turbines (1kW) to large commercial turbines (140m tall, 2MW). There are also different designs and styles (horizontal or vertical axis; 1 blade to multiple blades) to suit the location. They generate clean electricity that can be provided for use on-site, or sold directly to the local electricity network
- > **Performance and Calculation Methodology:** -
 - > Power generated is proportional to the cube of the wind speed. Therefore, wind speed is critical.
 - > Horizontal axis turbines require >~6m/s to operate effectively and vertical axis turbines require >~4.5m/s. The rated power of a turbine is often for wind speeds double these figures.
 - > Wind speeds for area from BERR's Wind Speed Database.
 - > Electricity produced displaces grid electricity which has a carbon intensity of 0.568 kg/kWh.
- > **Capital Cost:** -
 - > ~£1,000 per kW. Smaller models are more expensive per kW.
 - > Vertical axis turbines more expensive than horizontal.
- > **Running Costs/Savings:** -
 - > Reduce reliance on grid electricity and therefore reduce costs.
 - > Payback period of ~15-20 years per dwelling.
 - > Feed-in tariff and ROC payments required for maximum financial benefit.
- > **Land Use Issues and Space Required:** -
 - > Smaller models (<6kW) can be roof mounted.

- > Must be higher than surrounding structures/trees.
- > Planning permission required.
- > **Operational Impacts/Issues:** -
 - > Urban environments generally have low wind speeds and high turbulence which reduce the effectiveness of turbines.
 - > Vertical axis turbines have a lower performance than horizontal axis turbines but work better in urban environments.
 - > Annual services required.
 - > Turbines rated in excess of 5kW may require the network to be strengthened and arrangements to be made with the local Distribution Network Operator and electricity supplier.
 - > Noise.
- > **Embodied Energy:** - Carbon payback is ~1 year for most turbines.
- > **Funding Opportunities:** - Financier utilising Feed-in-Tariffs.
- > **Reductions in Energy Achievable:** - Significant reduction in reliance on grid electricity.
- > **Reductions in CO₂ Achievable:** - Good. Greater reduction in CO₂ than PV for same investment.
- > **Advantages:** - Virtually free fuel; reductions in CO₂.
- > **Disadvantages:** -
 - > Expensive, although cheaper than PV for same return.
 - > Lack of suitable sites.
 - > Maintenance costs.
 - > Often not building integrated.

10. HYDRO POWER

- > Hydro power harnesses the energy of falling water, converting the potential or kinetic energy of water into electricity through use of a hydro turbine. Micro hydro schemes (<100kW) tend to be 'run-of-river' developments, taking the flow of the river that is available at any given time and not relying on a reservoir of stored water. They generate clean electricity that can be provided for use on-site, or sold directly to the local electricity network.

> **Performance and Calculation Methodology:** -

- > Flow rates at particular sites from National River Flow Archive held by Centre for Ecology and Hydrology.
- > Electricity produced displaces grid electricity which has a carbon intensity of 0.568 kg/kWh.

> **Capital Cost:** -

- > £3,000 - £5,000 per kW.
- > Particularly cost effective on sites of old water mills where much of the infrastructure is in place.

> **Running Costs/Savings:** -

- > Reduce reliance on grid electricity and therefore reduce costs.
- > Payback period of ~10-15 years per dwelling
- > Feed-in tariff and ROC payments required for maximum financial benefit.

> **Land Use Issues and Space Required:** -

- > Require suitable water resource.
- > Visual intrusion of scheme.
- > Special requirements where river populated by migrating species of fish.
- > Planning permission will require various consents and licences including an Environmental Statement and Abstraction Licence.

> **Operational Impacts/Issues:** -

- > Routine inspections and annual service required.
- > Automatic cleaners should be installed to prevent intake of rubbish.

> **Embodied Energy:** - Carbon payback for small schemes of ~1 year.

> **Funding Opportunities:** - Financier utilising Feed-in-Tariffs.

> **Reductions in Energy Achievable:** - significant reduction in reliance on grid electricity.

> **Reductions in CO₂ Achievable:** - High.

> **Advantages:** - Virtually free fuel, reductions in CO₂.

> **Disadvantages:** -

- > Expensive, but good payback period.
- > Lack of suitable sites.
- > Planning obstructions.

Appendix B: Summary of SAP Energy Calculations

Summary of SAP Calculations on Representative Units												
Tenure	Type	Average Area (m2)		Sample SAP Calculation Type	Energy (kWh/yr)				CO2 (kg/m2/yr)		Reduction	Fabric Energy Efficiency Credits
					Space Heating	Hot Water	Lights, Fans & Pumps	Unregulated Appliances & Cooking	TER	DER		
Private	Flats	63		Mid Floor Corner	1,624	2,219	522	1,386	16.48	16.36	0.7%	8.2
	2 Bed House	63		Mid-Terrace	2,572	2,193	461	1,386	18.77	18.75	0.1%	4.1
	3 Bed House	94		Semi-Detached	4,383	2,614	563	1,692	18.41	17.84	3.1%	4.4
	4 Bed House	126		Detached	6,373	2,736	637	2,016	17.98	16.93	5.8%	3.6
Affordable	Flats	67		Mid Floor Corner	1,759	2,265	241	1,407	16.11	16.07	0.2%	8.2
	2 Bed House	75		Mid-Terrace	3,042	2,322	507	1,500	17.91	17.65	1.5%	3.9
	3 Bed House	85		Semi-Detached	3,961	2,562	537	1,615	18.88	18.46	2.2%	4.3
	4 Bed House	100		Detached	4,975	2,683	579	1,700	18.73	18.15	3.1%	3.8
Total											2.8%	

Total Energy Demands & Associated CO2 Emissions											
Tenure	Type	Average Area (m2)	Number of Units	Sample SAP Calculation Type	Energy (kWh/yr)				CO2 (kg/m2/yr)		Reduction
					Space Heating	Hot Water	Lights, Fans & Pumps	Unregulated Appliances & Cooking	TER	DER	
Private	Flats	63	30	Mid Floor Corner	48,719	66,561	15,648	41,580	31,147	30,920	0.7%
	2 Bed House	63	32	Mid-Terrace	82,288	70,161	14,736	44,352	37,840	37,800	0.1%
	3 Bed House	94	106	Semi-Detached	464,599	277,036	59,709	179,352	183,437	177,758	3.1%
	4 Bed House	126	36	Detached	229,421	98,496	22,914	72,576	81,557	76,794	5.8%
Affordable	Flats	67	30	Mid Floor Corner	52,772	67,936	7,242	42,210	32,381	32,301	0.2%
	2 Bed House	75	29	Mid-Terrace	88,206	67,338	14,694	43,500	38,954	38,389	1.5%
	3 Bed House	85	26	Semi-Detached	102,981	66,610	13,952	41,990	41,725	40,797	2.2%
	4 Bed House	100	4	Detached	19,901	10,732	2,314	6,800	7,492	7,260	3.1%
Sub-Total					1,088,886	724,872	151,209	472,360			
Total			293				2,437,327		454,534	442,019	2.8%

Appendix C: Feasibility Table of Low Carbon Renewable Energy Technologies

Feasibility Study Table									
Technology	Sufficient Energy Generated?	Payback	Land Use Issues	Local Planning Requirements	Noise	Carbon Payback	Available Grants	Feasible?	Reason not Feasible or Selected
Combined Heat & Power (CHP)	Yes	Medium	Air quality in residential area	Encouraged for large scale developments	In Plant Room	Yes	Tax Relief - ECA	No	Not appropriate for low density development
Biomass	Yes	None	Air quality in residential area	Encouraged for large scale developments	In Plant Room	Yes	Bio-energy Capital Grants Scheme	No	Not appropriate for low density development
Solar Thermal	Yes	High	Sufficient roof space required	Encouraged	None	~2 years	None	Yes	Selected for affordable houses
Solar Photovoltaic (PV)	No	Very High	Sufficient roof space required	Encouraged	None	2-5 years	None	Yes	Solar thermal a more appropriate alternative
Ground Source Heat Pumps (GSHPs)	Yes	High	Requires large area for coils or borehole	Encouraged	None	Low	None	Yes	Unviable due to cost
Air Source Heat Pumps (ASHPs)	Yes	Very High	Visual intrusion of external units	None	Low	Low	None	Yes	Solar thermal a more appropriate alternative
Wind Power	No	Low	Urban Area - low and turbulent wind; Visual impact	Encouraged for large scale developments	Yes	~1 year	None	No	Monitoring needed to assess wind speeds. Expensive
Hydro Power	No	Medium	Requires suitable water resource; Visual impact	None	Low	~1 year	None	No	-

Appendix D: Solar Thermal Calculations

2 Bed Affordable House	
TFA	75
Occupancy	2.36
Hot Water (L/day)	90.28
Hot Water (kWh/yr)	2,322
Panel Orientation	Southwest
Panel Angle	45

3 Bed Affordable House	
TFA	85
Occupancy	2.55
Hot Water (L/day)	94.78
Hot Water (kWh/yr)	2,562
Panel Orientation	Southwest
Panel Angle	45

4 Bed Affordable House	
TFA	100
Occupancy	2.74
Hot Water (L/day)	99.26
Hot Water (kWh/yr)	2,683
Panel Orientation	Southwest
Panel Angle	45

SAP Box Number		
Aperture Area	2.0	H1
Zero loss collector efficiency	0.78	H2
heat loss coefficient	4.0	H3
performance ratio a1/n0	5.03	H4
annual solar radiation	997	H5
overshading factor	1	H6
solar energy available	1603	H7
solar to load ratio	0.691	H8
utilisation factor	0.765	H9
collector performance factor	0.800	H10
dedicated solar storage volume	80	H11
if combined cylinder: total volume	210	H12
effective solar volume	119	H13
daily hot water demand	90.3	H14
volume ratio	1.318	H15
solar storage volume factor	1.055	H16
Solar Input	981.9	H17

SAP Box Number		
Aperture Area	4.0	H1
Zero loss collector efficiency	0.78	H2
heat loss coefficient	4.0	H3
performance ratio a1/n0	5.03	H4
annual solar radiation	997	H5
overshading factor	1	H6
solar energy available	3169	H7
solar to load ratio	1.237	H8
utilisation factor	0.555	H9
collector performance factor	0.800	H10
dedicated solar storage volume	95	H11
if combined cylinder: total volume	250	H12
effective solar volume	141.5	H13
daily hot water demand	94.8	H14
volume ratio	1.493	H15
solar storage volume factor	1.080	H16
Solar Input	1406.4	H17

SAP Box Number		
Aperture Area	4.0	H1
Zero loss collector efficiency	0.78	H2
heat loss coefficient	4.0	H3
performance ratio a1/n0	5.03	H4
annual solar radiation	997	H5
overshading factor	1	H6
solar energy available	3169	H7
solar to load ratio	#REF!	H8
utilisation factor	0.555	H9
collector performance factor	0.800	H10
dedicated solar storage volume	95	H11
if combined cylinder: total volume	250	H12
effective solar volume	141.5	H13
daily hot water demand	#REF!	H14
volume ratio	#REF!	H15
solar storage volume factor	#REF!	H16
Solar Input	1406.4	H17

Renewable Energy Generation			
Dwelling Type	Solar Thermal Generation per Dwelling (kWh/yr)	No. Dwellings with Solar Thermal Panels	Total Renewable Energy Generation (kWh/yr)
2 Bed Affordable House	982	29	28,474
3 Bed Affordable House	1,406	26	36,566
4 Bed Affordable House	1,406	4	5,625
Total		59	70,665
Renewable Energy Proportion			2.9%