

Ashford's Future

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**Ashford Sustainable  
Energy Feasibility  
Study**

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Background to the Study

Document ref  
DOC 6 (of 6)

FINAL ISSUE

Ashford's Future

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Energy Feasibility  
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Background to the Study

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# 1 Introduction

This **document** provides background information to the Ashford Sustainable Energy and Feasibility Study commissioned by Ashford's Future.

This report incorporates the following main elements:

- National Policy for domestic energy consumption
- Local Policy – Adopted Core Strategy
- A comparison of National and Local Policy
- Consumption assessment for Ashford (present and future)
- Overview of Renewable and Sustainable Energy Technologies

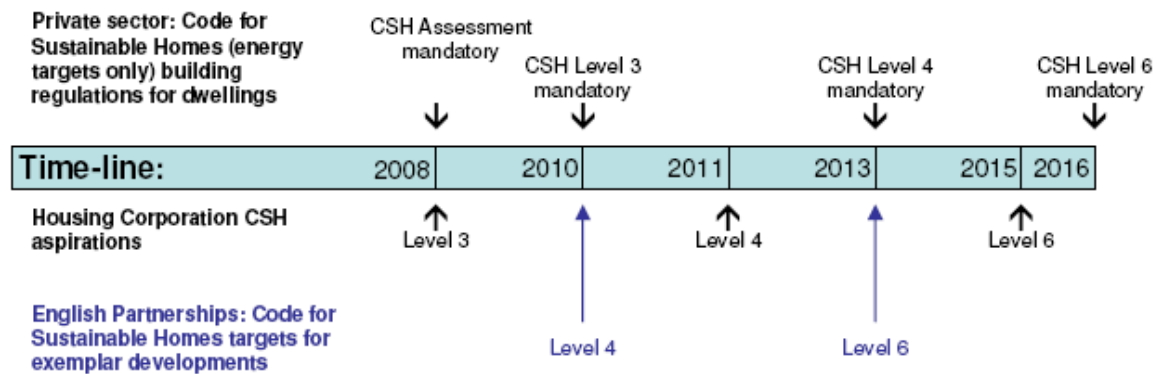
The **Appendices** contain detailed assumption made in the course of the study and Case Studies of a number of renewable energy and zero carbon projects

- Beddington ZED, Surrey (prototype carbon neutral development)
- Cranberry CHP, Newham (community energy scheme)
- Dongtan Eco-city, China (carbon neutral city)
- Barratt Green House (CfSH level 6)
- One Gallions Zero Carbon Development

## 2 National Policy

In 2007 the Government consulted on how the Building Regulations should be enhanced to include aspects of the CfSH and concluded that the energy consumption aspects of the Code should be incorporated into future revisions of the Building Regulations with the intention that from 2016 all new dwellings will be constructed to the Code Level 6 standard.

A staged introduction of the Code is essential to allow the construction industry time to adjust to the requirements of the Code. To this end it is understood that future revisions of the Building Regulations governing energy consumption will require all dwellings to be Code level 3 or better in 2010, Code level 4 or better in 2013 and Code level 6 in 2016. In addition to the above the Government has announced that dwellings funded by certain government institutions will be constructed to standards on an advanced timeline, a step ahead of that applying to private sector funded dwellings. The current CfSH standards aspired to by the Housing Corporation are outlined below in Figure 1 as are those for exemplar English Partnerships developments.



**Figure 1 - Code for Sustainable Homes roll out schedule**

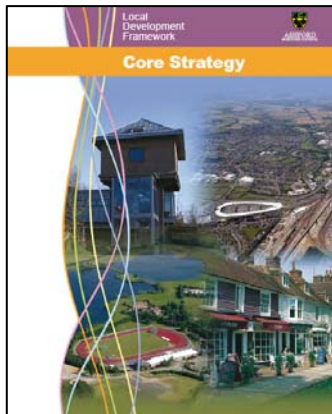
It should be noted that the Code specifies the CO<sub>2</sub> emissions reduction required to achieve each level but does not specify particular proportions of onsite renewable energy or efficiency measures, with the exception of level 6. The designer and developer are thus allowed a degree of flexibility in how the CO<sub>2</sub> emissions reductions are achieved. As of January 2008, the Code only allows offsite renewable energy generation, such as wind turbines, to be used if the generation plant is directly connected to the development by a private wire network.

To achieve Code level 6 a minimum standard of insulation is required and is regulated via a parameter known as the heat loss parameter. To achieve Code level 6 it is required that the dwellings have a maximum heat loss parameter of 0.8W/m<sup>2</sup>K. There is no mandatory heat loss parameter requirement for the lower Code levels.

The reduction in CO<sub>2</sub> emissions required for CfSH levels 1 to 5 relate to the heating and electrical consumption regulated by the Building Regulations. However to achieve Code level 6 requires a 100% reduction in the CO<sub>2</sub> emissions produced by the dwelling as a whole i.e. it is related to both the regulated and the unregulated CO<sub>2</sub> emissions.

The relationship between regulated and total emissions (regulated and non-regulated) CO<sub>2</sub> emissions in dwellings is explained in Section 4 of this report.

### 3 Local Policy – Adopted Core Strategy



The Local Development Framework Core Strategy for Ashford was adopted in July 2008. The Core Strategy sets a target of all development achieving carbon neutral.

Core Strategy 10 (CS10) sets out the 3 step process by which carbon neutrality should be achieved:

- A: Building fabric improvements
- B: On-site Renewables
- C: Contribution to the Ashford Carbon Fund

CS10 sets a minimum CO<sub>2</sub> reduction which needs to be met by 'A' and 'B'. The figure ranges between 10 and 30% of emissions depending on classification of the areas where the development is.

The classifications covered by this study were:

- Town Centre (min 20%),
- Brownfield Urban Sites (min 20%)
- Urban Extensions (min 30%)
- Greenfield Urban Sites (min 30%)

Figure 2 below shows the difference between achieving 100% of reductions by steps A and B and meeting the minimum requirements onsite and offsetting the remainder with contributions to the Ashford Fund.

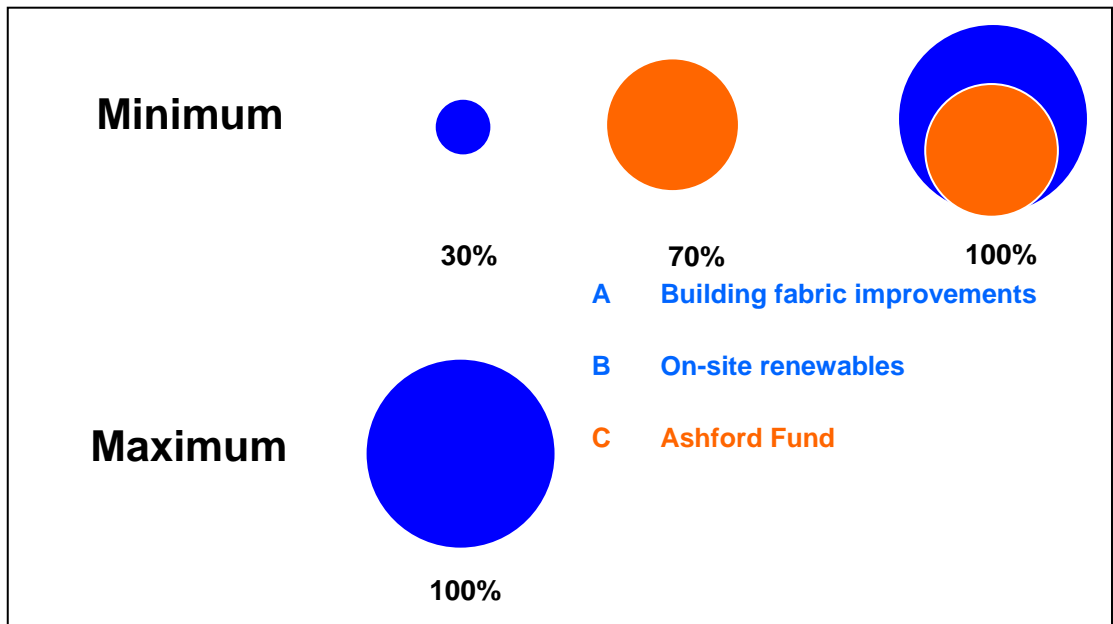
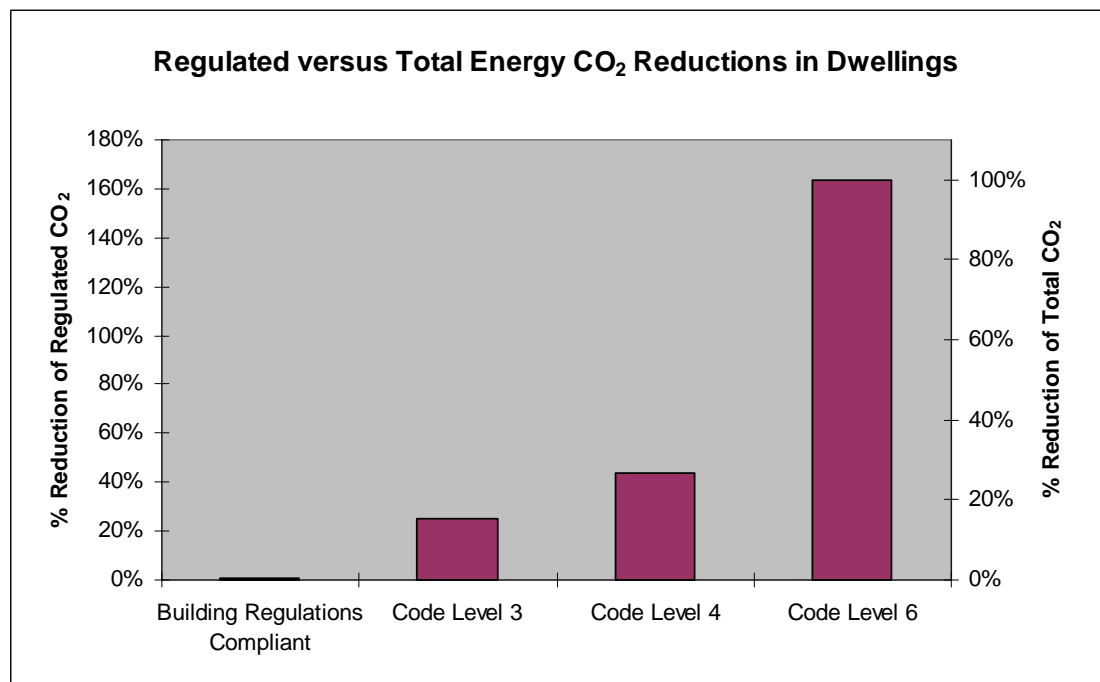


Fig 2 - Comparison of meeting minimum and maximum CO<sub>2</sub> reductions on-site

## 4 Comparison of National and Regional Policy

### 4.1 Regulated and non-regulated CO<sub>2</sub>

Regulated energy describes the portion of energy consumed within dwellings which is subject to the Building Regulations, in particular space heating, hot water and lighting. Unregulated energy encompasses all other energy consumed in a dwelling and is highly subject to behavioural patterns. The relationship between regulated and total emissions (regulated and non-regulated) CO<sub>2</sub> emissions in dwellings is shown in Figure 3 where regulated energy is shown on the left axis and total CO<sub>2</sub> (regulated and non-regulated) is shown on the right axis.



**Figure 3 - Regulated versus total energy CO<sub>2</sub> reductions in dwellings**

### 4.2 Code for Sustainable homes targets

Compliance with CfSH Level 3 requires regulated<sup>1</sup> CO<sub>2</sub> emissions to be reduced by 25%. The minimum levels of CO<sub>2</sub> reduction in CS10 are for both regulated and non-regulated<sup>2</sup> CO<sub>2</sub>. The ratio of regulated to unregulated emissions in dwellings varies according to dwelling size and design. Typically the regulated proportion of the total CO<sub>2</sub> emissions is of the order of 60%. The reduction in CO<sub>2</sub> emissions required, expressed as a percentage of a dwelling's total emissions, is therefore about 15%.

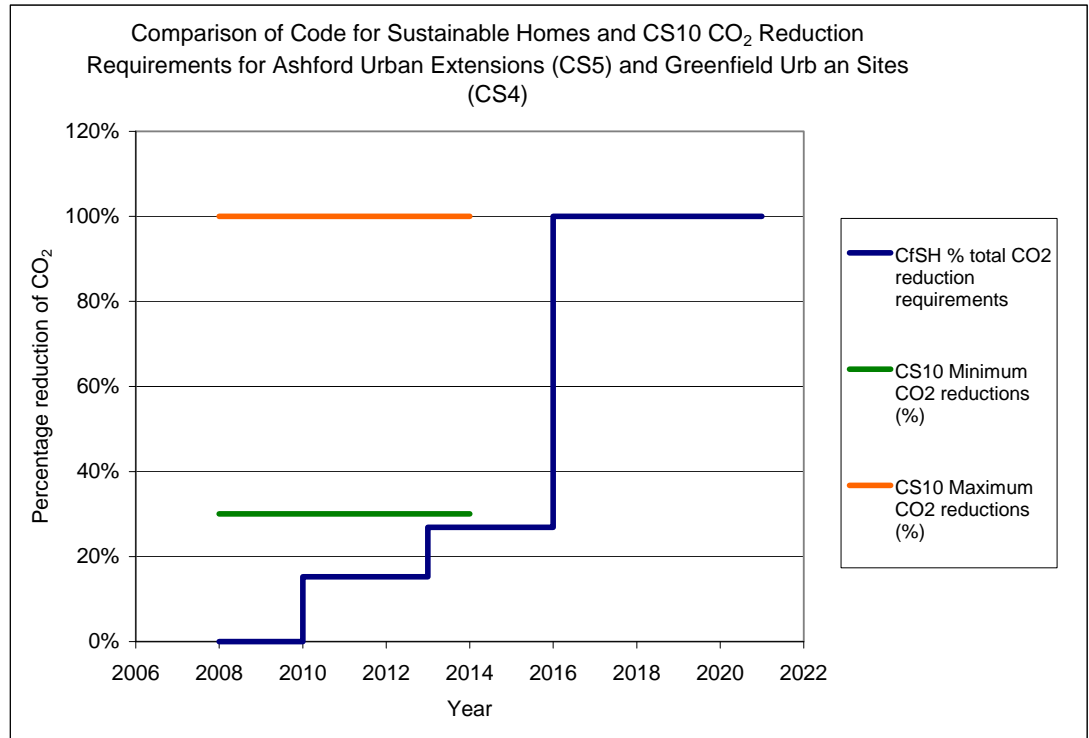
Compliance with CfSH Level 4 requires dwelling regulated CO<sub>2</sub> emissions to be reduced by 44%. The reduction in CO<sub>2</sub> emissions required, expressed as a percentage of a dwelling's total emissions, is therefore about 27%.

<sup>1</sup> Regulated energy describes the portion of energy consumed within dwellings which is subject to the Building Regulations, in particular space heating, hot water and lighting.

<sup>2</sup> Unregulated energy encompasses all other energy

### 4.3 CS10 targets

The minimum CO<sub>2</sub> reductions stipulated in CS10 include both regulated and non-regulated CO<sub>2</sub>. Therefore, the minimum CS10 targets for dwellings are significantly higher than those in the government's suggested timeline of adoption of the Code for Sustainable Homes energy targets. By comparing the green and blue lines in Figure 4, we can see that the 30% minimum target is ahead of national policy until 2013 and the overall target for all development to be carbon neutral is ahead of the national trajectory until 2016 for dwellings.



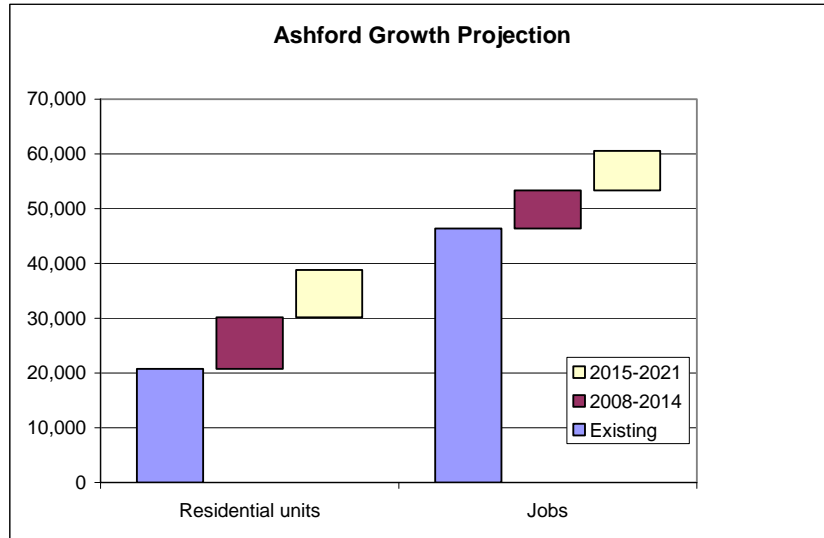
**Figure 4 - Comparison of Code for Sustainable homes and CS10 reduction requirements for Urban extensions and Greenfield Urban Sites**

## 5 Consumption assessment

### 5.1 Existing and Future Development

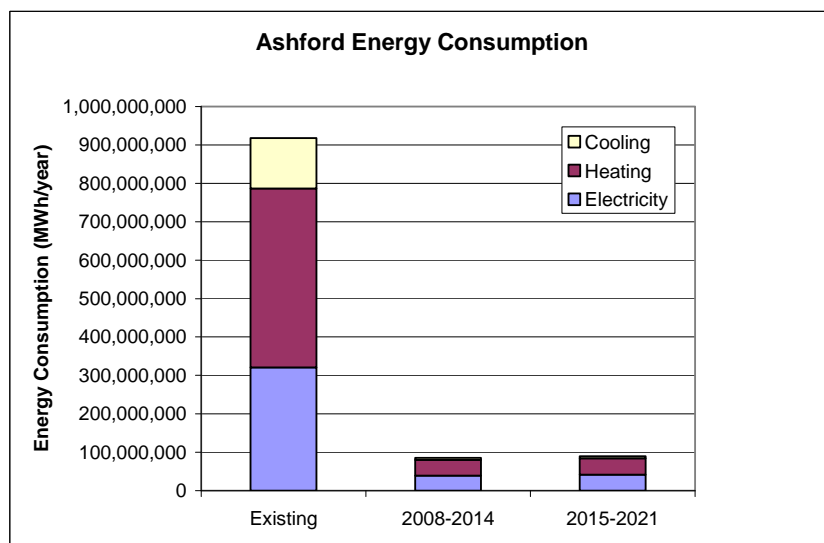
Ashford is a market town of a little over 20,000 households within the Urban Area that is planned to undergo significant expansion. From 2008 to 2021 18,000 new dwellings are planned in developments around the town.

Figure 5 below shows the number of existing dwellings and existing jobs and the numbers planned from 2008 to 2014 and 2015 to 2021. The associated energy consumption of the existing and new build dwellings and non residential buildings are shown in Figure 6 below.



**Figure 5 - Ashford growth projection**

The difference in proportion of the energy consumption of the existing and the new buildings is evidence of the reductions in CO<sub>2</sub> emissions that will be achieved through the construction of better insulated and generally more efficient buildings. Further CO<sub>2</sub> emission reductions will be achieved through the use of renewable and low carbon energy generation technologies.



**Figure 6 - Ashford energy consumption**

## 6 Renewable and Sustainable Energy Technologies

The work conducted for the Sustainable Energy Study (see Document 2: Cluster Studies and Document 3: Pilot Sites Study) looked at 12 key renewable technologies:

1. Gas CHP (connected to heat networks)
2. Individual biomass boilers (not connected to heat networks)
3. Organic Rankine Cycle Biomass CHP (connected to heat networks)
4. Steam Turbine Biomass CHP (connected to heat networks)
5. Gasification Biomass CHP (connected to heat networks)
6. Air Turbine Biomass CHP (connected to heat networks)
7. Photovoltaics
8. Solar hot water panels
9. Small scale roof top wind turbines
10. Large scale wind turbines
11. Ground source heat pumps
12. Air source heat pumps

### 6.1 Biomass

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Biomass is used to describe solid fuel, typically in the form of wood chip or pellets which is typically derived from fast growing woody plants. There is estimated to be in excess of 150,000 tonnes of forestry residues and sawmill co-products plus 85,000 tonnes per year of clean wood waste available in the South East of England for use in bioenergy schemes.

#### 6.1.1 Biomass Boilers

Modern biomass boilers are highly efficient heating units with low or zero carbon emissions depending on the fuel used. Generally speaking biomass boilers come in two different types – wood chip boilers and wood pellet boilers. Both wood chips and wood pellets can be made from a variety of different fuel types. These include waste wood from sawmills and industry offcuts, forestry arisings, and specially grown crops such as coppice willow. Wood chip sizes vary according to the wood chippers used but usually consist of pieces of about 50-100mm in length. In contrast wood pellets are about 6-8mm long and of a uniform size and consistency resulting in a uniform heat output. Wood pellets have a higher energy density than wood chips but are also more expensive and less readily available at this time.

As the production of wood chips and wood pellets is not directly linked to fossil fuel costs, the price of wood chips and pellets is not expected to be as volatile as that of natural gas.

Biomass boilers come in a range of sizes and can be used to heat individual houses or offices or supply many buildings using a district heating network. Wood pellet boilers are available from 10kW to around 110kW. Larger boilers tend to be wood chip boilers.



**Figure 7 - A KWB Easyfire wood pellet boilers**

© Econergy

Suppliers of biomass boilers include Econergy and Wood Energy.

## 6.2 Combined Heat and Power (CHP)

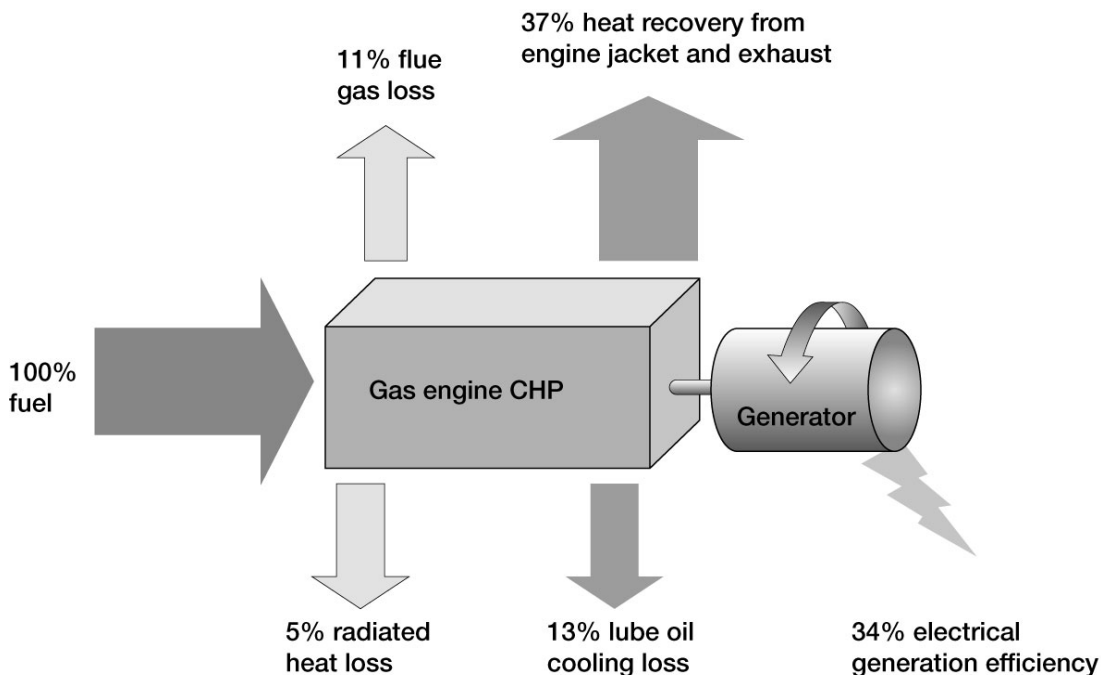
Buildings in Ashford are conventionally provided with heat using local gas boilers and electricity using the national grid. Electricity is supplied to the national grid from large power stations located away from urban areas. The electrical efficiency of these large power stations ranges from 30% for coal fired plant to 55% for new combined cycle gas power stations. The remaining 45 – 70% of the energy is rejected to atmosphere either as low grade waste heat or as distribution losses in the electricity transmission network.

Installations where electricity and useful heat are generated together are known as combined heat and power technologies. CHP plants are generally of a much smaller scale than large power stations and are usually located near to urban areas where the heat can be used in nearby buildings. The heat is transmitted using low pressure hot water at temperatures of 70 – 120°C or steam on flow and return circuits. CHP plants usually achieve overall efficiencies in excess of 80%. The plants can be fuelled using a range of fuels including natural gas and biomass which are explored in this study.

### 6.2.1 Natural Gas CHP

Natural gas fired CHP technology is a mature technology, commonly used all over the world for the provision of heat and power.

Figure 8 below shows the basic principles of CHP with a gas engine as the prime mover. The numbers will vary according to the specific characteristics of the machine. Heat is recovered from the exhaust of the generator by a heat exchanger.



**Figure 8 - The basic principles of gas turbine CHP**

© Arup

Gas engines generally have higher electrical efficiency than gas turbines of a similar capacity and it is possible to recover heat from the jacket of the engine, and the lube oil as well as from the exhaust. The degree to which heat may be recovered from the jacket and the lube oil will depend on the operating temperature of the distribution system.

A typical CHP gas engine (spark ignition or compression) will consist of a gas engine, such as that seen below in Figure 9, a heat recovery boiler, often located beside the engine and a gas booster set. Gas boosters are required to increase the natural gas supply pressure to a pressure suitable for the gas engines where a medium pressure supply is not available. Where noise pollution is a problem, the gas engine and associated plant is located within an acoustic enclosure.



**Figure 9 - A typical natural gas CHP engine**

© Clarke Energy

Suppliers of gas engine CHP packages include Clarke Energy, Rolls Royce, EnerG and Cogenco.

Issues that need to be considered when identifying a suitable location for a large CHP plant are:

- Minimising the length of heat network pipework (installed length per connection)
- Existing infrastructure (electricity and gas networks (for gas CHP))
- Transport links (especially for biomass CHP)
- Visual impact of buildings and flue
- Environmental issues related to flue gas emissions (impact on local NO<sub>x</sub> levels)
- Phasing issues
- Land values

### 6.3 Biomass CHP

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Bioenergy CHP provides heat and power using biomass fuels such as wood chips or liquid biofuels such as biodiesel or bioethanol. Bioenergy CHP may be operated in a number of configurations which include the following:

- Gasification of biomass with spark ignition gas engine/gas turbine
- Direct combustion with steam turbine
- Direct combustion with air turbine.
- Biodiesel/bioethanol engines (compression/spark ignition)

The need for regular fuel deliveries (typically using road transport) needs to be considered when evaluating potential sites.

#### 6.3.1 Biomass Gasification CHP

Gasification is the partial combustion of biomass with a restricted oxygen supply and without a flame to produce a gaseous fuel. After a clean-up process this 'syngas' may then be put through a spark ignition gas engine or turbine to generate electricity (and heat). At this scale gas engines have a higher electrical efficiency than gas turbines. This technology is beginning to be commercialised with several companies in Europe, including one British company, supplying the technology and operating on a number of projects around Europe and the U.K. Gasification CHP plants are currently available from 300kW<sub>e</sub> to 1.5MW<sub>e</sub>. Of the sub 3MW<sub>e</sub> biomass CHP technologies available, gasification CHP has the highest electrical efficiency which results in the greatest level of CO<sub>2</sub> savings due to the low heat to electricity consumption of modern buildings.

### 6.4 Biomass Steam Turbine CHP

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In this process, the feedstock is burnt in a boiler, and the hot exhaust gas is used to raise steam, which is then put through a steam turbine to generate electricity. This is a mature, robust process; however, a steam turbine has a much lower electrical efficiency than a gas engine, and therefore more fuel is required to mitigate the same quantity of carbon dioxide. Steam turbine CHP plants are available from 2.5MW<sub>e</sub> upwards.

### 6.5 Biomass Organic Rankine Cycle (ORC) CHP

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In this process, the feedstock is burnt in a boiler and the hot exhaust gas is used to heat an organic fluid which is then expanded through a turbine to generate electricity in much the same way as in a steam turbine. The organic fluid allows the use of lower temperatures and pressures which together with a higher mass flow rate mean that rankine cycle turbines are available from 200kW<sub>e</sub> to 2MW<sub>e</sub>. This a mature technology however it has a high heat to power ratio so when supplying modern buildings provides a lower level of CO<sub>2</sub> savings compared to other biomass CHP technologies.

## 6.6 Biomass Air Turbine CHP

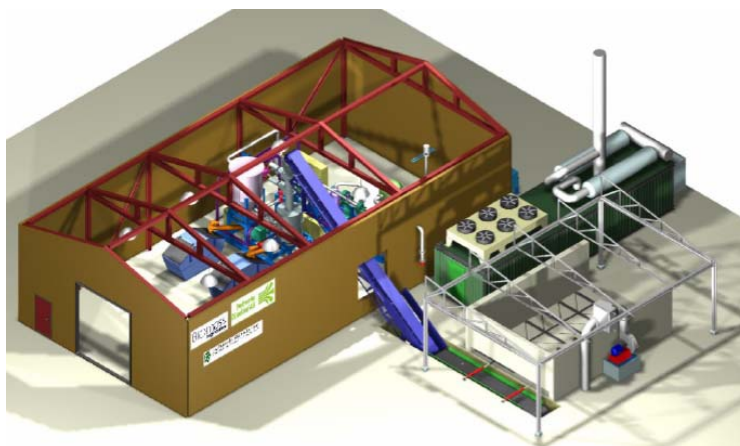
In this process biomass fuel is burned directly in a boiler to generate heat and the exhaust gases passed through an air turbine to generate electricity. This technology is available from one supplier and is currently at the demonstration stage. Direct combustion + air turbine CHP is available in one model which generates 90kW<sub>e</sub>.



© Biomass Engineering

**Figure 10 - A Biomass Gasification CHP Plant in Operation**

Figure 10 above shows a typical gasification CHP setup which consists of a wood store, fuel handling plant, gasification plant, gas cleanup plant, compressors and CHP plant. A typical arrangement of such plant can be seen below in Figure 11.



© Biomass Engineering

**Figure 11: A Typical Gasification CHP Plant Arrangement**

Suppliers of biomass gasification CHP plants include Biomass Engineering Ltd (UK), Xylowatt (Belgium) and CTU (Switzerland).

## 6.7 Wind power

Turbines can broadly be split into two categories: horizontal axis turbines and vertical axis turbines. Most wind turbines currently installed around the world are horizontal axis machines. On a large scale they are well established and well understood, but there is little experience of their use on roof tops in urban areas. There are grounds for believing that vertical axis wind turbines will perform better in the turbulent winds found in cities, and this has led to the development of vertical axis turbines, such as the Quiet Revolution shown in Table 1. Vertical axis turbines will generate power from the wind whichever direction it is coming from, in contrast to horizontal axis turbines which can lose power as they yaw

around to face a changing wind direction. The designers of such machines believe that they will be more effective in an urban environment, but to date there is too little evidence available to reach a conclusion.

The energy generated by wind turbines is highly dependent on the speed of the wind blowing through them, with the energy in the wind varying with the cube of the wind speed. The wind speed increases with height above the ground, so it is important to mount a turbine as high as possible, and on top of as tall a mast as possible. In general, the wind in urban areas is slower than the wind in the open countryside, because of the drag which buildings impose on the wind.

Planning restrictions for wind turbines are mainly based upon the potential effect of the wind turbines on neighbouring properties. The two principle effects are noise and shadow flicker which are discussed below for both building integrated wind turbines and large wind turbines.

#### 6.7.1 Building integrated turbines

An increasing number of different building integrated wind turbine models are appearing on the market and a range of different sizes and different technologies are now available. Table 1 below shows some example turbines.

Turbines for roof top mounting range in size from as little as 1m in diameter, which generates up to 0.4kW, up to 5m in diameter, which generates up to 6kW. It is not currently considered practical to install turbines larger than this on a roof without significant attention to structural design.

The low wind speeds and high turbulence found in urban areas lead to turbines performing less well there than their counterparts do in wind farms in the open country. A recent report<sup>3</sup> suggested that small wind turbines averaged a capacity factor of 7%. This means that on average a small wind turbine will generate power equivalent to 7% of its rated capacity, so a 6kW turbine will have an average output of 400W. In practice the energy generated by a turbine will depend on many details of the installation such as the mean wind speed in the area, proximity to other buildings and the precise location of the turbine on the roof. A well placed turbine might perform better than this and conversely a badly located turbine will have a lower capacity factor.

In order to gain planning permission, wind turbines must be located at such a distance that the noise level at nearby receptors (usually the nearest residence) has dropped to an acceptable level. The level of noise that is acceptable depends on whether the background noise is higher in the day or in the night. The noise level from the wind turbine at the receptor should be no greater than 5 dB(A) above the background level, with a fixed minimum of 35dB(A). If the dominant background noise level is at night time, with allowance of attenuation of an open window a fixed minimum of 43dB(A) is applied to avoid sleep disturbance. For a 6kW turbine in a quiet area a separation distance as large as 50m in a direct line of sight may be required, although manufacturers claim to be reducing the noise generated by turbines, in some cases to 'silent' (which in effect means below background noise level). Background noise generated by, for example, traffic can mask the noise of the turbine and reduce the required separation distance.

Shadow flicker occurs when the moving blades of a wind turbine cast shadows on to an observer, giving a flickering effect. A common guideline in northern Europe is to have a minimum distance of 6 to 8 rotor diameters between the wind turbine and the closest neighbour. For a 6kW turbine this would be between 30m and 40m. However, the problems of shadow flicker can often be avoided by careful location of the turbine or taking other mitigating measures (such as controls to switch off the turbine at critical times).

<sup>3</sup> *Metering and monitoring of domestic embedded generation*, BEAMA, 2007







| Turbine   |                                    | Rating                        | Application   |
|---|------------------------------------|-------------------------------|---|
|    | Proven                             | 0.6kW<br>2.5kW<br>6kW<br>15kW | Proven originally developed turbines to be free standing in remote locations. They are becoming increasingly popular in roof top applications.  |
|    | Renewable Devices<br>Swift         | 1.5kW                         | The Swift was specifically designed for domestic rooftop use. They have been selling well, but recently suffered a mechanical failure and product recall. Renewable Devices say the design flaws have been corrected. |
|   | Windsave WS1000                    | 1kW                           | The Windsave was designed to be a cheap domestic turbine. It is currently being marketed by the B&Q hardware chain.   |
|  | Eclectic Energy<br>Stealthgen D400 | 0.4kW                         | Developed from the design of a turbine for use on yachts, the Stealthgen is a very small domestic turbine.  |
|  | XCO2 Quiet<br>Revolution           | 6kW                           | The Quiet Revolution is a vertical axis turbine designed for use in urban environments. This is a very new turbine and only a small number have currently been installed.   |
|  | Turby                              | 2.5kW                         | The Turby is a vertical axis turbine intended for rooftop use being manufactured in the Netherlands. Very few Turbys have been installed.   |

Table 1 - Example building integrated wind turbines.

### 6.7.2 Large scale turbines

Large scale onshore wind turbines are available up to a capacity of 3MW and can provide significant, relatively low cost CO<sub>2</sub> savings. Large turbines are more cost effective, but they are also visible from a greater distance and produce more noise.



**Figure 12 - Large scale wind turbine**

© Arup

| Turbine          | Rated Power (kW) | Rotor diameter (m) | Hub height (m) |      | Overall height (m) |
|------------------|------------------|--------------------|----------------|------|--------------------|
|                  |                  |                    | Min.           | Max. |                    |
| Fuhrländer 250   | 250              | 30                 | 42             | 50   | 72 – 80            |
| Vestas V52       | 850              | 52                 | 37             | 86   | 89 - 138           |
| RE Power MM70/82 | 2,000            | 70/82              | 55             | 80   | 125 - 162          |
| Vestas V90       | 3,000            | 90                 | 80             | 90   | 170 - 180          |

**Table 2 – Typical dimensions of wind turbines**

The visual impact of a turbine is highly subjective. Community consultation greatly increases the chance of acceptance of a wind turbine installation. There are ways of minimising the visual impact of turbines if necessary, for example through varying the colour of the tower. Shortening the tower will reduce visual impact, but will also reduce energy production.

For a 2MW turbine in an urban residential area with some background noise, an exclusion zone of up to 500m may be required to allow noise to drop to an acceptable level. In sites close to major roads the background noise is likely to be significant, and the size of the exclusion zone may be considerably reduced. In addition, it is possible to reduce the noise generated by a turbine but at a cost of a reduction in its operational efficiency. Conversely in quiet rural areas the area of the exclusion zone may be larger.

For large scale wind turbines shadow flicker also needs to be considered. For an accurate assessment of shadow flicker, fairly complex modelling is required taking into account the turbine's dimensions, the movement of the sun throughout the year and the change in wind turbine orientation with wind speed (yawing). However, a common guideline in northern Europe is to have a minimum distance of 6 to 8 rotor diameters between the wind turbine and the closest neighbour. For a 2MW turbine this would be between 540m and 720m. One additional point worthy of note is that there will be little shadow to the south of a turbine over the year.

In addition to shadow flicker, sunlight may be reflected from turbine blades with glossy surfaces, causing a 'flashing' effect. Flashing can be prevented by the use of non-reflective turbine blades as well as through careful location of the turbines.




The base of a large scale wind turbine will not require a large area of land. Generally a distance of the height of the turbine + around 10% (the fall down distance) is allowed as an exclusion zone for regular activities, although this is not required by the planning regulations. For a 2MWkW turbine this would be around 120m to 170m.

## 6.8 Solar Technologies

### 6.8.1 Solar Photovoltaics

Photovoltaic Systems (PV) convert energy from the sun into electricity using semi conductor cells. These cells produce electrical energy when light shines on the cells. The electricity produced is direct current (dc) and is therefore converted into alternating current, as is required, using an inverter. The PV cells are available in three different types, monocrystalline, polycrystalline and amorphous, each of which has different efficiencies and costs.

Typical module efficiencies are shown below

| Type                   | Monocrystalline silicon   | Polycrystalline silicon  | Amorphous silicon and thin film   |
|------------------------|---|--|---|
| Typical efficiency (%) | 12-16%  | 11-14%   | 5-7%  |
| Visual Appearance      |  |  |  |

**Table 3 - Typical PV efficiency details**

Photovoltaic systems should ideally be located on south facing roofs or facades with a minimum tilt of 15° off the horizontal to allow rain water to wash dirt off the panels. For maximum efficiency the panels should be orientated at 30° - 40° off the horizontal in the UK. Performance is not overly sensitive to its orientation – a change of 30° from the optimum may affect energy output by only 10%.



**Figure 13 - Photovoltaic Systems on The Hub, Newham, London**

© Arup

Potential shading should be carefully considered as even a small amount of shading will dramatically reduce the output of the panels.

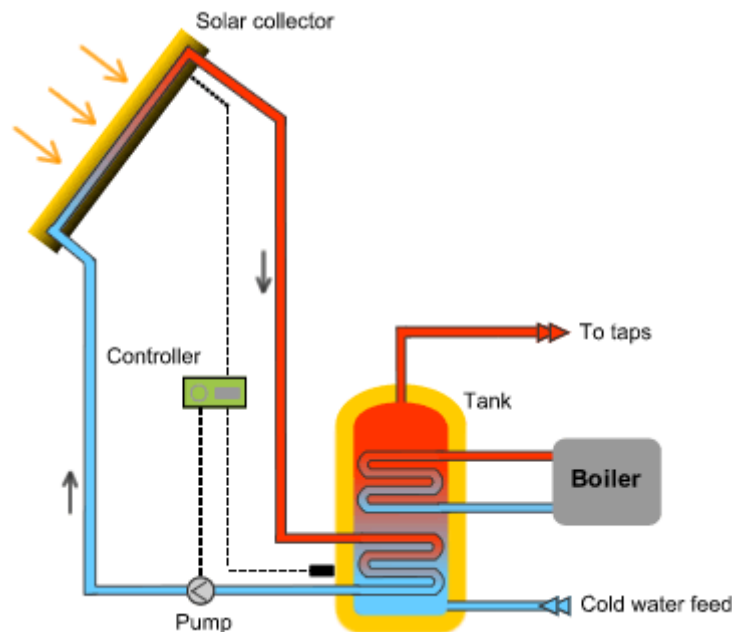
Energy generation will vary considerably throughout the year.

Suppliers of PV in the UK include Solar Century, PV Systems, Genasys Power Systems and Dulas Ltd.

6.8.2 Solar Thermal

Solar hot water systems use a heat collector which is usually mounted on a roof to heat a fluid such as glycol using the sun's energy. This fluid is then usually used to heat up a hot water supply by circulating it through a coil in a hot water cylinder.

A typical solar hot water schematic is shown below in Figure 14.



**Figure 14 - Typical Solar Hot Water Schematic**

© Arup

Contrary to popular opinion, solar water heating systems can provide a significant contribution towards domestic hot water requirements in Northern European locations. During the summer months solar hot water systems can provide 80-100% of domestic hot water requirements. Over the course of a year this can amount to 50% of a household's domestic hot water requirements. Solar hot water systems also require relatively little maintenance.

It should be noted that where solar hot water systems are used space heating and supplementary domestic hot water heating would still be required.

Solar hot water collectors should be located ideally on unshaded south facing, pitched roofs.

Suppliers of solar hot water systems in the UK include Vaillant, Veissmann and Solartwin.

## 6.9 Heat Pumps

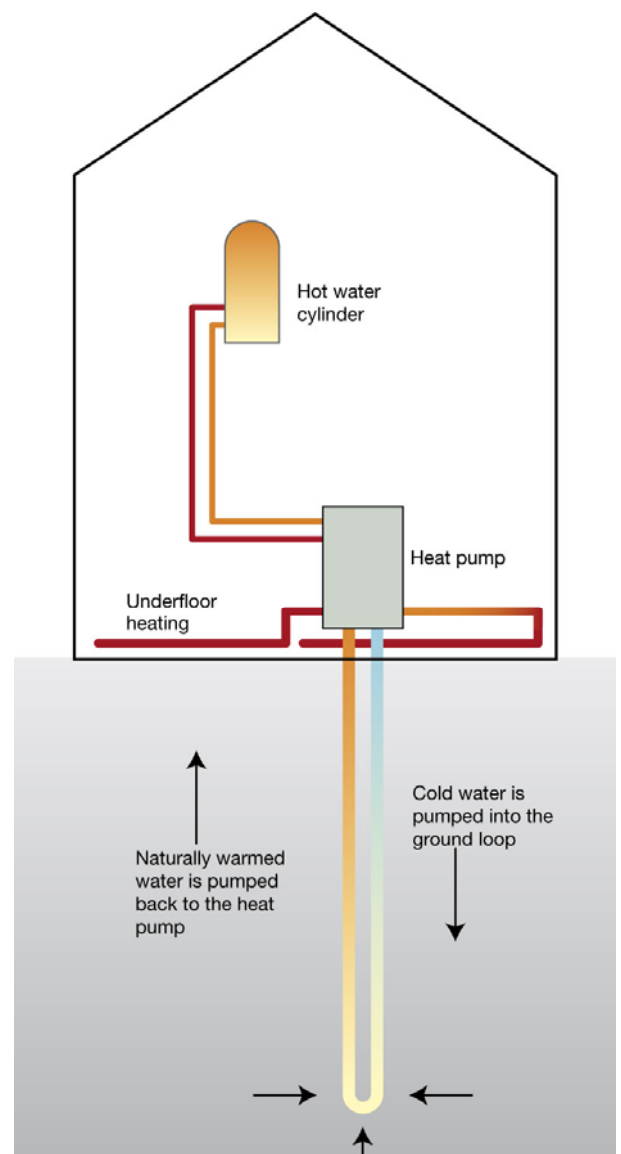
### 6.9.1 Ground Source Heat pumps

Ground source heat pumps (GSHP) are low energy systems that use the near constant temperature of the soil and/or ground water together with an electric heat pump to provide space heating, cooling and domestic hot water.

Around the world, particularly in the USA and parts of Europe, the use of GSHP systems is common. It is not new a technology. The ground source heat pump was actually invented more than 50 years ago, and continuous development has greatly improved its efficiency and reliability. It is now a proven, cost-effective, safe and environmentally friendly technology.

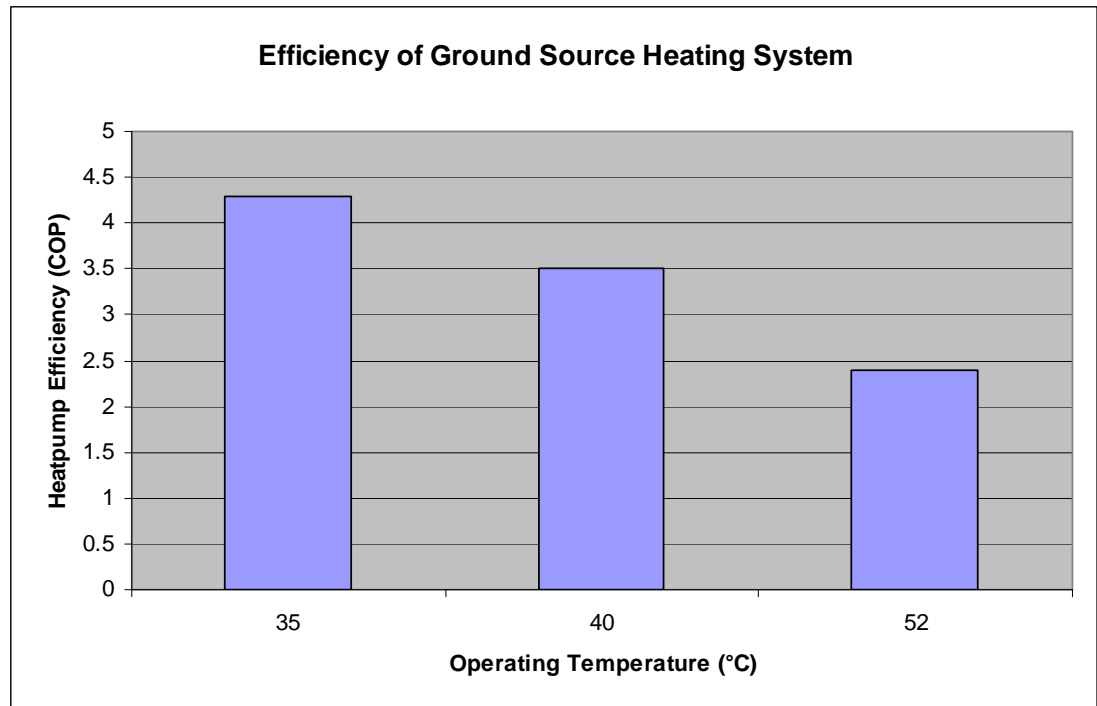
The ground heat exchanger can either be located in a trench or where less space is available it can be located in a borehole.

Trench heat exchangers are generally cheaper than borehole heat exchangers but their performance is also lower because being close to the surface the earth temperature is not quite as constant as that deeper down. Boreholes can be expected to provide energy at the rate of 35-70 W/m of buried pipework, and have a lifetime of 50 years.



**Figure 15 - Domestic Ground Source Heating Schematic** © Arup

Both underfloor heating systems and radiator heating systems can be used with ground source heating. Underfloor heating is ideally suited for use with ground source heating as underfloor heating has lower temperature requirements than other systems, such as wall hung radiator systems. The lower the flow temperature, the greater the efficiency of the heat pump and therefore the lower the operating costs. An example of the variation in efficiencies can be seen in Figure 16. The difference in efficiency will be proportional to the difference in running cost and carbon emissions for space heating on an annual basis.



**Figure 16 - Efficiency Variation of Ground Source Systems with Operating Temperature**

For much of the year a ground source underfloor system will operate at between 35°C and 40°C whereas a ground source radiator system would require 45-50°C. Radiator systems using ground source are therefore generally not only less efficient than an underfloor system but the radiators would be much larger than radiators connected to a conventional boiler circuit which operate at 71-82°C, reducing the usable space within the rooms. In contrast an underfloor system will increase the usable space within the rooms when compared to a conventional radiator system.

A typical heat pump unit for a domestic dwelling is about the same size as a large fridge and can be installed externally or in garages or basements if there is not sufficient space within the building being served.

Heat pumps can also extract energy from water or air. An 'open loop' heat pump would take water from the surface or from below ground and remove heat from it. This is a cheap system, but there must be a plentiful supply of water it to be practicable. A 'closed loop' heat pump would have boreholes reaching down into the ground water. These take heat from the ground water, but leave it otherwise unaffected. This is usually more efficient than running the ground loop through ground above the water table.

Suppliers of ground source heat pumps include Ice Energy, Geothermal International, Viessmann, Mitsubishi and Worcester-Bosch.

### 6.9.2 Air Source Heat Pumps

Air source heat pumps use an electric heat pump to extract energy from the air to heat a building. While the installation costs of air source heat pumps are generally lower than those of ground source heat pumps, as boreholes are not required, in the UK the operational costs are higher. This is due to the fact that air source heat pumps are generally less efficient than ground source heat pumps due to the tendency of the exterior coils to freeze up in winter due to the high moisture content of the air. Direct electrical heating is then required to thaw them out, at regular intervals on cold days. Where a ground source heat pump system will have a coefficient of performance (COP) of 3.5 – 5, the seasonal COP of an air heat pump system is usually limited to about 2. This means that they are not a desirable source of heat where others are available.



© Heat King

**Figure 17 - An air source heat pump**



Appendix A

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**Analysis Assumptions**

## A1 Energy Consumption and Building Fabric Assumptions

### Existing Buildings

The following assumptions have been made to allow estimates of energy consumption and renewable energy generation to be calculated:

- The population of the Ashford Urban Area is 66,200.
- The existing stock in the Urban Area is 20,736.
- According to the Employment Land Review, 2006, Ashford Borough contained some 47,000 employee jobs (Source: Annual Business Inquiry).
- 60% of the dwellings are assumed to have cavity walls, 40% are assumed to have solid walls.
- The heating consumption of the existing dwellings is taken from the Energy Savings Trust document, Central Heating System Specifications 2005 (reference: <http://www.energysavingtrust.org.uk/uploads/documents/housingbuildings/CE51%20Final.pdf> ).
- The electricity consumption of the dwellings has been estimated using the formula used in the Code for Sustainable Homes with an allowance made for the fact that all cooking is assumed to be gas fuelled rather than electric.

The heating, electricity and cooling consumption of the Type 3 office is assumed to be as per the typical consumption of a type 3 office, as outlined in Energy Consumption Guide 19 Energy Use in Offices.

### New Developments

- The new development has been considered in two main phases – 2007-2014 and 2015-2021
- There will be 8,220 new dwellings constructed in the period 2007-2014 and 8,655 new dwellings in the period 2015-2021.
- The average dwelling size is 85m<sup>2</sup>
- Domestic heat and electricity consumption was based upon equal numbers of 2 bed flats and 4 bed terraced houses with heat loss parameters of 0.8 and 1.0 respectively. There is assumed to be no domestic cooling required.
- The non residential building floor plan area is equal to 10m<sup>2</sup> / job.
- The energy consumption of non residential buildings is assumed to be equivalent to that of a Type 3 (standard air conditioned) office that is 20% better in CO<sub>2</sub> emission terms than a Type 3 office compliant with the 2006 Building Regulations.

## A2 Cluster Studies

The principal assumptions made during the Cluster Analysis and agreed with the client and steering groups are outlined below. Those which are likely to have a more significant impact on the outcome of the analysis are highlighted in bold.

- There will be a primary school for every 250 dwellings.
- There will be a secondary school for every 5000 dwellings.
- There will be a GP's surgery for every 400 dwellings.
- Cluster of over 400 dwellings will include some retail, equivalent to approximately 1.5% of the residential floor area in that cluster.
- Clusters of over 500 dwellings will include some commercial space, equivalent to approximately 7% of the residential floor area in that cluster.
- The assumed average net to gross floor area ratio for all building types is 85%.
- The assumed average number of storeys across all the clusters is two storeys.
- Average dwelling has a net floor area of 80m<sup>2</sup>.
- It is assumed that all electricity generated onsite in the clusters is assigned the full carbon credit of 0.146kg/kWh of electricity generated as specified in Part L of the Building Regulations 2006.
- 10 and 30 dwelling clusters are assumed to consist of detached dwellings with the potential for a single 1.5kW wind turbine mounted on each dwelling. Clusters of 100+ dwellings are assumed to be mainly semi detached and terraced dwellings with one 1.5kW wind turbine per two dwellings. For the clusters of 100+ dwellings one wind turbine of 6kW rated power output is added per 1000 m<sup>2</sup> of non residential area.
- For the cluster of 1,000 dwellings one large wind turbine of 500 kW capacity has been assigned, while for the 6,500 dwellings cluster two wind turbines of 500kW capacity have been assigned. For the cluster of 18,000 dwellings it has been assumed that one wind turbine of 2 MW capacity could be accommodated. These assumptions are based on Arup's experience of similar projects and actual installations.
- Retail is assumed to be 50% non food stores and 50% small food stores.
- Healthcare is assumed to be mainly doctor's surgeries which are assumed to have an energy consumption which is similar to that of a prestige (type 4) office.
- Conventional cooling is assumed to be via air cooled chillers with a COP of 3.
- It is assumed that on average 25% of a building's roof space is available for the location of photovoltaic or solar hot water panels.
- Where renewable energy solutions will require more space than a conventional solution using gas boilers, such as biomass boilers, it is assumed that for comparison with other solutions, the cost of this extra space will be the construction cost of the space only (ie excluding land price).
- Small scale biomass boilers are assumed to be wood pellet boilers while those connected to district heating schemes are assumed to be wood chip boilers.
- Conventional heating is assumed to be via a single gas boiler in each dwelling. Where the viability of biomass heating using local boilers has been considered it has been assumed that each dwelling would have an individual wood pellet boiler for all clusters.
- Where ground source heating is considered 2 x 100m deep vertical boreholes are assumed



Appendix B

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**Renewable Energy and  
Zero Carbon Case  
Studies**

## B1 Case Study 1: Beddington Zero Energy Development, Surrey

### **Client:**

Peabody Trust with the BioRegional Development Group

### **Architect**

Bill Dunster Architects

### **Awards**

Building Energy Globe Award for Sustainable Energy - First Prize for Buildings and Houses

The H & V Awards 2002 - Air Movement

Product of the Year



BedZED is a zero energy development designed to produce at least as much energy as it consumes. This urban village on a brownfield wasteland site consists of 100 flats, maisonettes, and townhouses; approximately 2500m<sup>2</sup> of work/office space; and community accommodation including a health centre, nursery, organic café/shop, and a sports clubhouse. The village incorporates sustainable material sourcing, a renewable energy supply, a total water strategy, and an integrated transport system.

This is one of the first developments in the United Kingdom to demonstrate how low planning gain can fund environmental impact infrastructure. Workspace in the shade zone of housing provides additional revenue to fund an ultra low energy specification, whilst 'skygardens' on the workspace roof surfaces give flats access to green open space. Integral conservatories harvest winter sunlight and become open balconies in the summer.

All buildings have a high thermal mass, reducing the need for central heating, and all dwellings face south to maximize opportunity for passive solar gain. The development is powered by a combined heat and power plant (110kWe) running on tree surgery waste to give overall net zero CO<sub>2</sub> emissions. Willow coppicing on the adjacent landfill site will

eventually provide fuel for the CHP plant. The village's water consumption is reduced by the use of low flush WCs and spray taps. Rainwater is collected from the uppermost parts of roofs and stored in tanks below ground for non-potable use in dwellings and for irrigating the landscape and willow coppice.

**Project scope**

- Mixed development
- Housing

**Arup scope**

- MEP engineering
- Building physics



## B2 Case Study 2: Cranberry CHP, Newham

### Client

New Deals for Communities



Arup were commissioned by New Deals for Communities, Newham to assess the feasibility of a Community Energy scheme to supply heat and power to the dwellings on the Cranberry estate and to Eastlea Community School and Star School, which are heated using gas boilers. The majority of these boilers are old and in need of replacement. The Cranberry estate was constructed in the mid 1980s and consists of a mixture of social housing and private dwellings. The social housing is all electrically heated while the private housing has a mixture of electric and gas heating. The study was based upon a Community Energy system sized to provide 100% of the heat load within the estate and that of the two schools.



Electricity and gas prices in the UK are currently extremely volatile and are rising at above inflation rates. As a result of this the number of people who are classed as being in fuel poverty is increasing. Fuel poverty is defined as being when a household has to spend more than 10% of its income keeping the house at a reasonable temperature. The cost of heating using electricity is currently about 1.5 times that of heating using gas. Fuel poverty is therefore more likely for residents living in electrically heated homes. Community energy can help take households out of fuel poverty, through the provision more efficient heat and power.

There were three main project drivers behind this project:

- Reduction of heating and electricity costs to tenants
- Reduction of heating and electricity costs to the schools

- Reduction of CO2 emissions from the housing and the schools

The report demonstrated that a gas CHP scheme could provide energy cost savings to the residents and the schools connected to the scheme of 25% and 10% respectively, provided 35% of the scheme's capital cost was grant funded.

The client required the scheme to give an IRR of at least 5% for it to proceed and it was shown that with 35% grant funding an IRR of 5.1% could be achieved.

The study indicated that the CHP scheme could save the development up to 830 tonnes of CO2 a year and significantly reduce the number of homes suffering fuel poverty.

Careful consideration was given to the location of the Energy Centre, maximizing distribution efficiency and flexibility for future expansion.

**Key Features:**

- Significant energy savings to tenants
- Up to 830 tonnes of CO2 saved a year
- Economics shown to match clients' desired return

**Arup services:**

- CHP/district heating pre-feasibility study
- Full feasibility study
- Related Arup projects:
  - Croydon Gateway
  - St Christopher's School

## B3 Case Study 3: Dongtan Eco-city, China

### Client

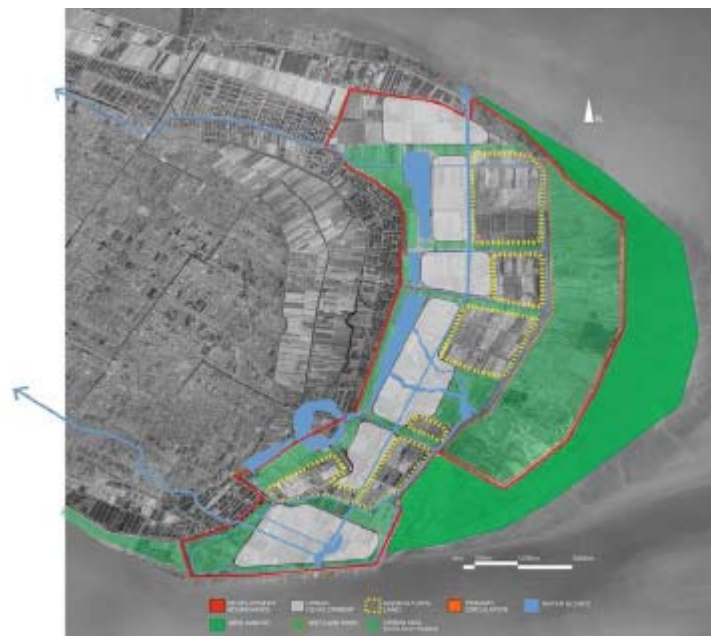
SIIC



Dongtan Eco City is a 'speculative' developer led project to develop an Ecocity for 0.5 m people. The first stage is to produce a masterplan for three villages of 650 ha for 80,000 people by 2020. It is to be carbon neutral from 2010 and to have one planet 'eco footprint'. It is government backed.

We have provided a control plan and detailed sustainability design guidelines, which include the energy standards as well as renewable and low carbon building and system specification advice. We submitted funding applications to Energy Saving Trust and for EC Concerto funding application.

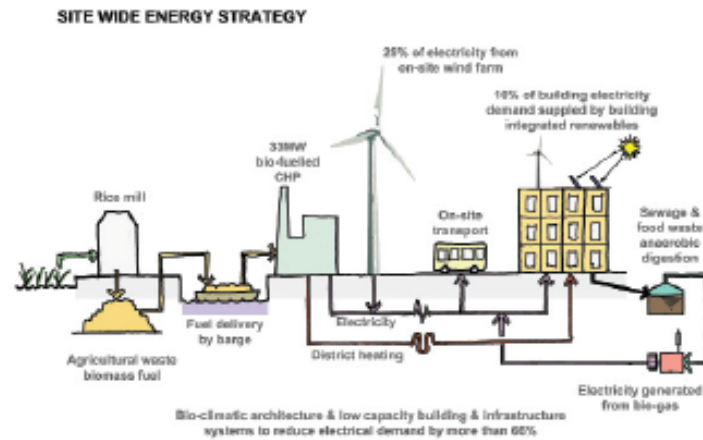
The overarching vision for Dongtan is to create a world class sustainable city that responds to the needs of accommodating economic growth and demographic trends and, at the same time, places environmental and social sustainability at the core of the developments' objectives.



### Energy Strategy

- To provide carbon neutral energy supply to all on-site sectors
- Reduce overall electrical and transport energy demand by more than 2/3rds, shared across all energy consuming sectors compared with a defined "baseline"
- Provide nett 100% of energy demand from renewable sources

- To limit on-site operational energy demand levels to a level representing a fair “Earth Share” as assessed using the Eco Footprint methodology



#### Key Features:

- 86 km<sup>2</sup> development
- Carbon neutral city
- 75% reduction in electricity demand
- Zero tailpipe emissions
- 200 000 tonnes CO<sub>2</sub>/yr saved

#### Arup services:

- Masterplan for buildings and landscape
- Infrastructure and engineering masterplan
- Financial model for buildings and infrastructure
- Phasing strategy
- Resource targets
- Supply chain recommendations
- Design manual for plot developers
- Formulating planning conditions
- Transport assessment
- Infrastructure design
- Efficient water use and re-use
- Logistics
- Waste management

## B4 Barratt Green House

### Client

Barratt

### Architect

Gaunt Francis



### Project

The Barratt Green House is the first house from a major house builder to achieve the highest level of the Code for Sustainable Homes, 6\*. As such, it is a carbon neutral house, as it produces all of its energy from on site renewable sources. Based on the winning Gaunt Francis design for the “Home for the Future” competition hosted by the Mail on Sunday, and located at the BRE as an exhibition house, it aims to demonstrate that high levels of sustainability can be integrated and be appealing to the broad housing market.

### Design

With three bedrooms, a study room, a play room and two bathrooms, the Green House is a large terraced property designed to maximise its energy performance. Of heavyweight construction (Aircrete concrete wall panels and pre-cast concrete floor slabs), the house has very air tight envelope, thanks to both the walling system and a very controlled construction process. Combined with triple glazing and whole house mechanical ventilation with heat recovery, the house comfortably meets the required heat loss parameter of 0.8 W/m<sup>2</sup>K. The high levels of thermal mass also help to mitigate peaks and troughs of temperature change within the house, reducing the risk of summer overheating.

### Renewable energy

With almost 100% of the lighting being of an energy efficient nature, the Green House features an air source heat pump which takes energy from the outdoor air and converts it to

heat to supplement the solar thermal heating system to provide space heating and hot water.

A large PV array of 7.2kWp, a proportion of which is in a structure adjacent to the building, meets all the required electrical needs from the house.



### **Water**

Water efficient appliances and fittings combined with a rainwater collection system, which collects water from the roof and permeable paving and is used for toilet flushing, the washing machine and external irrigation, will allow potable water consumption to be limited to 80l/person/day, around 50% reduction on a typical UK household.

### **Key features**

- First Code for Sustainable Homes Level 6 from a volume house builder
- Net zero carbon
- Air to air source heatpump
- Solar thermal panels
- Photovoltaic panels
- Rainwater harvesting
- Energy monitoring
- Landmark scheme

### **Project scope**

- Exhibition house, 132m<sup>2</sup>

### **Arup services**

- Sustainability strategy
- Mechanical, electrical, structural and public health building engineering
- Ecology strategy
- Waste strategy

## B5 One Gallions Zero Carbon Development

**Client:** Crest Nicholson Bioregional Quintain

**Architect:** Feilden Clegg Bradley



© Crest Nicholson BioRegional Quintain LLP, Feilden Clegg Bradley and Studio Toni Yli-Suanto

### Project

One Gallions will be the first zero carbon development since BedZED. It will produce all onsite energy from renewable sources. The objective of the landowner, the London Development Authority, was to set a precedent for highly energy efficient developments in an area of major strategic importance. It is envisioned that Gallions Park will act as a benchmark for sustainable development, not only during construction but also for energy use into the future. It will also show how carbon neutral housing can be financially viable and built by commercial developers.

### Energy production

- Biomass combined heat and power (CHP) with wood pellets
- Talbott air turbine: 100 kW electricity, 175 kW heat
- Gas boilers for peak lopping and back-up
- Community ESCo (Energy services company) being set up to run energy plant

### Energy conservation

- Good insulation: walls to have Ziegel block plus 100 mm wood wool insulation,  $U = 0.2 \text{ W/m}^2\text{K}$
- Double glazing with low emissivity coating
- Building fabric heat loss parameter (HLP)  $\leq 0.8 \text{ W/m}^2 \text{ K}$
- HLP meets "True Zero Carbon Dwelling" building fabric requirement for Code for Sustainable Homes level 6

- HLP meets same requirement for zero carbon stamp duty exemption
- External shading
- 100% low energy lighting technology
- A++ electrical goods

#### **Water conservation**

- Very efficient water fittings
- A++ water appliances
- EcoHomes Excellent water standard, 32 m<sup>3</sup>/bedspace/yr
- Waterbutts for roof gardens
- Some water recycling

#### **Achieving zero carbon**

The scheme will be net zero carbon on an annual basis using the renewables electricity carbon credit. Biomass CHP will export some electricity to the grid. It will offset carbon associated with growth, production and delivery of the biomass and the gas used for peak heating.

#### **Project scope**

- Residential development, 260 homes
- 1.24 hectare site
- Public space
- One Planet Living centre

#### **Key features**

- Net zero carbon
- Biomass CHP
- Community ESCo
- Landmark scheme
- Public space
- Minimal parking

#### **Arup services**

- Mechanical, electrical and public health building engineering concept design
- Sustainability strategy
- Environmental consultancy
- Geotechnical engineering