# Barry Waterfront

# Low Carbon Strategy

## August 2009

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# GLOSSARY OF TERMS

| ***Term*** | ***Meaning / Definition*** |
|---|---|
| ABP | Associated British Ports |
| ADL1A | Building Regulations Approved Document Part L1A |
| ASHP | Air Source Heat Pump |
| BREEAM | Building Research Establishment Environmental Assessment Method |
| CHP | Combined Heat and Power |
| CIBSE | Chartered Institute of Building Services Engineers |
| DBFO | Design Build Finance Operate |
| DER | Dwelling Emission Rate |
| DHW | Domestic Hot Water |
| DNO | Distribution Network Operator |
| EA | Environment Agency |
| ESCO | Energy Services Company |
| GHG | Greenhouse Gas |
| GSHP | Ground Source Heat Pump |
| LZC | Low and Zero Carbon |
| ORC | Organic Rankine Cycle |
| TER | Target Emission Rate |
| WAG | Welsh Assembly Government |
| WSHP | Water Source Heat Pump |

# 1 Introduction

Atkins have been appointed as Sustainability Consultant to the Barry Waterfront development, which is being developed by a tri-partite consortium of Persimmon Homes, Taylor Wimpey and Barratt.

The development comprises some 2000 dwellings, plus a commercial/retail quarter, and land safeguarded for new primary school. Some of the commercial development may be ultimately undertaken by other parties, but they are part of the overall redevelopment of the former docks, and hence form a part of its overall energy strategy.

This document provides a low carbon strategy for the development. It considers the context to low carbon, and appraises the various technologies available and looks at their appropriateness to the Barry Waterfront Development. It makes recommendations for the current standards and considers how the anticipated improvements in carbon targets could be met.

A particular emphasis is placed upon the dwellings as these form the bulk of the development and are anticipated to be constructed by the consortium directly.

# 2 Low Carbon Context

## 2.1 Governmental Targets

Both the UK national and Welsh Assembly Governments have taken the threat posed by anthropic climate change seriously. They have made a number of strategic commitments to reducing carbon emissions, and have also focused upon the emissions from new buildings for stringent 'targets'.

The UK government's climate change panel originally recommended that greenhouse gas emissions should be cut by some 60% from 1990 levels by 2050. Following recent reviews on the rate of climate change the panel has recommended an increase of this cut to 80% from 1990 levels; and this has been adopted as a target by the UK government in October 2008.

Buildings form a substantial part of the UK's current carbon emissions, and limiting the emissions of new buildings is a key component of meeting this target. The buildings constructed in Barry Waterfront will be standing and forming a part of UK's carbon footprint in 2050 and beyond.

England has set a target of achieving Code for Sustainable homes level 4 by 2013 and level 6 by 2016. The carbon implications of these are discussed in 2.3 below.

Wales devolved government has set an 'aspiration' to achieve level 6 by 2011, and in addition carbon neutrality on all other new build. The Welsh Assembly Government (WAG) has sought to devolve Building Regulations to Wales; one of the principal driving forces behind this move is the desire to improve Part L of the Building Regulations to enable this 'aspiration' to be delivered in Wales.

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## 2.2 EcoHomes

The Barry Waterfront development is currently contracted to attain EcoHomes 'excellent'. This is an overall assessment of Environmental impact of which energy forms a part. Achieving a low carbon solution gains additional credits to the overall score, of which 70% must be attained to achieve an 'excellent' rating.

EcoHomes itself had no mandatory carbon targets, but the site constraints at Barry add additional value to obtaining good energy scores. To enable 'excellent' to be achieved the EcoHomes assessor has advised that the dwellings need to achieve on average at target of $\leq$22 kg/m²/yr CO2,

## 2.3 Code for Sustainable Homes

The Code for Sustainable Homes has a number of levels which have increasingly onerous requirements. Unlike ECOhomes, the Code for Sustainable Homes requires minimum scores to be attained in various categories, ensuring that a fully balanced approach has to be taken to sustainability. The Code for Sustainable Homes will not apply to the Barry Waterfront scheme, at least in the initial phases, as this outline application is submitted in advance of the 1st September 2009 introduction date in Wales.

In respect of energy the code sets the following requirements for the Dwelling Emission Rate (DER) compared to the Target Emission Rate (TER) set down under Building Regulations Approved Document L1A. These are:

| | |
|---|---|
| Level 3 | DER 25% below TER |
| Level 4 | DER 44% below TER |
| Level 5 | DER 100% below TER |
| Level 6 | 'Zero Carbon' |

The DER encompasses energy used in lighting, heating and domestic hot water (DHW), termed regulated energy. This is effectively summed to zero at level 5.

At level 6, the energy used in operating and living in the building (such as small power and cooking) must also be included, and the building must attain 'Carbon Neutral' on all energy.

## 2.4 The National Home Energy Rating

The National Home Energy Rating is based on a scale of 0-20. It varies from the other metrics in that although aiming to give benchmark on efficiency, it is a measure of fuel cost rather than Carbon emissions. As such it is not a useful metric to establish the environmental performance of an option. Its existence though is forcing change in a similar direction

NHER 20 is equivalent to zero fuel costs and is in fact beyond both carbon neutrality and zero carbon. To attain NHER 20, the dwelling will be exporting energy (essentially from PV) to pay for any inbound fuel (such as gas or biomass). At this level the Dwelling Emission Rate (DER) is highly negative – DER zero

NHER information paper 07/02 gives a table of typical equivalence between NHER and other standards. The figure in this can be related to mandatory levels of carbon performance in the Code, and clearly illustrate the difference between the cost and carbon based metrics.

| Dwelling Energy Standard | Code Equivalent | NHER Rating |
|---|---|---|
| Building Regulations 2006 | N/A | 9.8 |
| 25% Improvement | 3 | 10.9 |
| 44% Improvement | 4 | 11.8 |
| 100% Improvement (Regulated) | 5 | 13.6 |
| Carbon Neutral (biomass boiler) | 6 | 15.0 |

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# 3 Recommendations for Barry Waterfront

## 3.1 Demand Reduction

### 3.1.1 Introduction

The sustainable approach to energy is to first concentrate on demand reduction, once this is at a minimum, then to look at applying low or zero carbon sources as required for delivering the remainder. This is the approach that has been adopted at Barry Waterfront

There are several reasons behind this approach:

1. The buildings constructed will be around in 50 years time, when fuel prices will be much higher and carbon footprint will be an even more serious issue. Improving them after construction is disproportionately costly. The low energy requirement is locked in now.

2. There is only a finite amount of renewable resource for ultimate development in the whole of UK. By managing load down now, the long term pressure on this is eased.

3. Renewable energy sources are generally more expensive than conventional plant. Reducing the energy demand will reduce the capital costs of renewable sources proportionately more.

### 3.1.2 Passive Design and Orientation

Passive design of buildings to maximise the opportunity of solar gains in the winter period, yet without overheating in summer is a key facet of low carbon design.

This technique has been exploited at Barry as far as possible and the main grain of the development in the major West Pond area has a southerly elevation which will both allow winter solar gain to living spaces, and also provide an optimum south facing roof elevation for the potential application of solar technologies such as solar thermal and photovoltaics (PV).

The adoption of this orientation was only possible in the South Quay area on the units facing the dock. However, this is not a serious issue, as it is the units lying closest to the escarpment that are affected, and these will be in shadow from the escarpment at lower solar angles in winter and would not have had the same potential passive gain.

### 3.1.3 Thermal Properties and Airtightness

High qualities of materials and construction shall be used to minimise the heating energy requirements of the building. The pre-assessment conducted by the EcoHomes assessor has indicated a number of key points of higher performance.

Improvements over the maximum U values permitted in Building Regulations will reduce the energy lost by direct transmission. There is a law on diminishing returns, but values of 1.5 $W/m^2K$ for doors and windows and 0.14 $W/m^2K$ for roofs are achievable.

The dwellings shall be constructed to attain a high standard of airtightness. Best practice can achieve an air permeability figure of <5 $m^3/m^2hr$ when tested at an overpressure of 50Pa. This is half of the implied target of 10 $m^3/m^2hr$ in the current building regulations.

Good design of details and selection of materials will minimise the losses arising from thermal bridging of the structure, and the associated heat loss.

### 3.1.4 Electrical Energy

Lighting is the single biggest consumer of electrical energy in the home. In order to limit the energy used by the dwellings at Barry Waterfront, the fittings used throughout the dwelling shall be designed only to use low energy light sources.

Any white goods supplied with the dwellings shall be A rated for energy and water efficiency.

The waste of energy in tumble driers shall be discouraged. All the dwellings shall have provision for clothes to be dried naturally. The houses shall be provided with rotary dryers, and the flats with tidy-drys.

## 3.2 Low and Zero Carbon Technologies

### 3.2.1 Technologies Appropriate to Barry Waterfront Dwellings

The available technologies for Low and Zero Carbon (LZC) provision of heat and electrical energy to the Barry Waterfront development are discussed in detail in sections that follow in this report. The reader is referred to the individual sections for full information:

Section 4 – Heat Pumps

Section 5 – Wind Power

Section 6 – Solar Power

Section 7 – Community Heating

Section 8 – Micro CHP

From the assessment of suitability conducted in these sections the following were identified with potential to form a part of the energy strategy at Barry Waterfront. These have the potential to be developed as the application and construction knowledge mature and provide improved performance to dwellings at later stages of the development:

Solar Thermal

Photovoltaic

Community Heating (Thermal only or CHP)

### 3.2.2 Technologies Appropriate to Barry Waterfront Commercial Quarter

The larger scale of the commercial buildings opens up other technologies that are not appropriate to the individual dwellings. They are not all necessarily suitable for each and every commercial development.

From Sections 4 to 8 the following were identified:

- Water Source Heat Pump
- Small Scale Wind
- Solar Thermal
- Photovoltaic
- Community Heating (Thermal only or CHP)

With the exception of the connection to a community heating system, all the above technologies would be developed within the local boundary of the unit. The selection and application of technology to an individual development will depend upon the business use, and particular environmental profile of the occupant. This would be assessed and appropriate selection made at the point of detail application for the particular unit occupier.

### 3.2.3 Developing and Emergent Technology

The development shall take place over a prolonged period, during which existing LZC technologies are expected to develop and improve their energy yield, their constructability and reduce in cost. In addition new technologies could emerge that may be applicable and appropriate to Barry waterfront.

Prior to the start of any phase the designers would review the low/zero carbon approach taken to revalidate it and adopt, if appropriate, better solutions that have become available.

## 3.3 Low Carbon Strategy

### 3.3.1 EcoHomes excellent

The current contract requires the development to reach EcoHomes excellent. Although there are no mandatory carbon targets, the development shall be achieving a low average carbon target of 22kg/m$^2$/year as calculated using SAP 2005.

To attain this, the dwellings shall be incorporating good demand side measures including:

- High levels of insulation
- Good Airtightness
- Robust Thermal bridging details and materials choice
- Low energy lighting
- ‘A’ rated white goods

Heat will be generated by an ‘A’ rated high efficiency low NOx condensing boiler in each house to maximise the efficient use of fuel.

### 3.3.2 Developing Carbon Performance

Over the life of the development, the carbon performance will be improved as techniques and construction experience is gained, and targets are raised. There are a number of industry wide steps that are anticipated in the future, and consideration has been given into the strategy of the development to meet these.

**a. DER to be 25% less than 2006 Building Regulations**

It is anticipated that this level could be met by further improvements to the Building Fabric in terms of both its thermal performance and its airtightness, together with additional sophistication in the heating controls for the building.

For houses, solar thermal hot water would be installed to provide carbon free hot water during the summer months, and some pre-heating of water in the spring and autumn periods.

For apartment blocks, the connection of multiple units to solar hot water can prove complex. To attain this level of performance in apartments, photovoltaics would be provided to supply electricity to the communal areas. This would be an effective solution because electricity has a high carbon loading.

**b. DER to be 44% less than 2006 Building Regulations**

For both apartments and housing, solar thermal hot water would be required, together with a larger area of photovoltaics. The combined impact of these should permit the 44% reduction step to be met whilst still retaining the traditional local high efficiency boiler plant.

**c. DER to be 100% less than 2006 Building Regulations – Carbon Neutral on regulated energy**

To attain carbon neutrality of regulated energy using on site renewables will require the heat and electricity to be considered separately. Demand reduction will be crucial to limiting the cost of renewable installation and should be driven to the utmost.

A large PV array will be required to generate sufficient power to enable the regulated electrical consumption across the year at each dwelling to be matched by electricity generated from the array. Although power will be drawn in from the grid at times (such as overnight), this will be balanced by surplus power exported from the array when generating. The net balance will be zero giving a 'Carbon Neutral' solution.

For effectively a zero carbon heating option, some form of biomass combustion to generate heat and distributed in a district heating system would be required. If the aspirational development wide district heating network had been fundable, then connection to this with the additional boiler plant for this phase being biomass would meet the requirement. Alternatively a smaller localised system could be used to serve the phase concerned.

### 3.3.3 District Heating

District Heating provides a significant opportunity to improve the carbon performance of the development. A system of this size serving a residential and mixed use development would be a pioneering approach for UK.

It would allow for long term flexibility of the energy source. The carbon performance for heating of all the connected properties can be improved by changing the fuel mix of the heat source and between fossil fuels and biomass.

The consortium aspires to District Heating for Barry Waterfront, should adequate funding be available to implement such a solution.

# 4 Heat Pumps

## 4.1 Ground Source

### 4.1.1 Description

Ground Source Heat Pumps (GSHP) are a low carbon technique, and based on well proven technology. The system comprises a refrigerant circuit, which is used to pump heat between the ground and the building. Although generally used for heating (especially in housing), there are units that will pump heat both ways allowing cooling in the summer.

For the unit to function efficiently, the heat produced is a low grade i.e. not very hot. This is used in conjunction with underfloor heating which can operate with temperatures in the mid 30 degrees Celsius. If the output temperature of the unit is raised its efficiency falls quickly.

This can pose problems for the production of DHW, and must have some form of temperature top up.

The ground connection of the system is made either via vertical boreholes, or use of a shallow loops laid in trenches and sometimes known as a ‘slinky’.

Although the heat pump uses electricity as a fuel source, it does this in an efficient way, generating typically 4 to 5 units of heat for each unit of electricity consumed. The overall effect on Carbon footprint is to reduce this to about half the value of a conventional condensing boiler plant.

### 4.1.2 Evaluation for Barry Waterfront

The ground connection will make GSHP impractical at Barry. The area required for the shallow loop for each building is too large to allow this to work within each plot, with the exception of the school where the playing fields could be used. In the commercial area, such loops could be laid under the car park, but these would cool the surface of the car park, causing it to freeze earlier with consequent hazard.

Boreholes also provide a difficulty. The ground on which the development takes place is reclaimed industrial land, with contamination. This will be capped when the general level of the land is raised for flood purposes. Boreholes would penetrate this layer and it would compromise its effectiveness. Additionally, the density of housing means that there is insufficient space for all houses to have boreholes within their plots without them affecting each other.

## 4.2 Water Source

### 4.2.1 Description

The Water Source Heat Pump (WSHP) works in exactly the same manner as the GSHP at 4.1 above, by pumping heat between the source and the building. As before, the low grade of heat required to make this efficient requires the use of underfloor heating and DHW temperature top up. This time the process exchanges heat with a large body of water via a heat exchanger; the technique has been used at the new National Waterfront Museum in Swansea.

Where the water abstracted will be (as at Barry) seawater, then materials in contact with it must be correctly specified, such as titanium plates in the heat exchanger. Filtration and maintenance of the filters will also need to be considered.

The return water will also be at a different temperature to the dock, higher in summer and lower in winter. This will lead to variations in water temperature and an ecological microclimate around the return. The impact of this will need to be considered as some warm seawater returns have had problems with biological or crustacean growth.

To gain the maximum benefit at Barry, it is envisaged that a centrally run condenser water system would be installed connected to the docks via a heat exchanger. The commercial units and any housing would connect their individual heat pumps to this network. As with any district based solution it would require co-ordination of the various commercial units within the development.

### 4.2.2 Evaluation for Barry Waterfront

With the large surface area of the dock nearby, WSHP is a viable option for a proportion of the development. As this technique can be used to pump heat both ways, it provides a particularly useful opportunity for the commercial quarter at the head of the docks.

A particular issue is the prevention of recirculation of water between inlet and outlet positions from the heat exchanger. This can be avoided by allowing the water to be drawn from on side of the mole and returned to the other. The abstraction and return will need the agreement of relevant bodies such as ABP and the Environment Agency (EA).

The experience at Swansea is understood to have been mixed.

As with GSHP, the scheme uses electricity very efficiently as a low carbon solution. It could also be expected to generate about 4 to 5 units of heat from each unit of electricity, with a carbon footprint about half that of gas.

The central plant would have the potential to be developed by an Energy Services Company (ESCO).

## 4.3 Air Source

### 4.3.1 Description

In response to the changes in Part L1A, which has made direct electric heating in apartments unattractive, attention has turned to the new Air Source Heat Pumps being produced by the air conditioning industry. These use a unit similar to a conventional small outdoor unit to heat water from air, the water being used with underfloor heating as with other heat pump solutions.

The presence of the outdoor unit introduces both aesthetic and noise considerations, although as the unit will generally be working in winter when people are generally indoors, this will not be the same problem in a practical sense as with an air conditioning outdoor unit.

Pumping heat from air is less efficient than from the water or ground, so although much more efficient than electrical heating, it would not be expected in a practice to have a carbon loading much better than a conventional condensing boiler solution. For this reason it does not attract the enhanced capital allowances and Low Carbon building programme support that other heat pumps do.

### 4.3.2 Evaluation for Barry Waterfront

ASHP would not be expected to generally deliver the carbon reduction benefit required for Ecohomes 'Excellent' and is not recommended as a first option for technology.

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# 5 Wind Power

## 5.1 Micro Wind

### 5.1.1 Description

In recent times a number of small scale wind turbines have been produced that can be fitted to individual properties, or in small open areas. In general with wind power, the effectiveness and efficiency are related to the size of turbine; small units are notoriously inefficient. The overall efficiency can be enhanced by coupling the micro-turbine with an immersion heater allowing the householder to benefit from overnight generation, where Renewable Obligations Certificates payments (ROCs) cannot be obtained and the tariff for export is inadequate. This adds complexity and cost to the application.

The Mid Wales Energy Agency published a report on two micro turbines being developed for household deployment and concluded ‘On the basis of the information currently supplied and the current costs, neither product could be recommended in terms of cost-effectiveness. There are clearly alternatives which offer a more attractive investment. This would not be the case were the turbines available at their target price.’

The report investigated two larger units with good potential. Ultimately these are hoped to be installed at £1500/unit, but the current costs are several times this.

It terms of yield it noted that the expected power output would be less than half the headline figure quoted by the manufacturers. This is due to the selected windspeed for quoting output. Micro-turbines are quoted at 7m/s, but the typical urban windspeed is around 4.5-5.5m/s. As power is related to the cube of windspeed, a small reduction in windspeed gives a huge reduction in delivered energy.

### 5.1.2 Evaluation for Barry Waterfront

With indifferent output and high costs for units, these units do not deliver an economic carbon reduction. In addition with a low output, their potential to significantly reduce carbon is quite limited. They are not recommended for Barry Waterfront.

## 5.2 Small Scale Wind

### 5.2.1 Description

The effectiveness of small to mid range wind power serving larger buildings is better than micro power. As with all wind power, they work best with clear uninterrupted airstreams. The turbines are typically mast mounted and range in the high singles to tens of kWs. There is a degree of activity in this market with supermarkets and small commercial organisations installing them as a highly visible statement, in car parks and fields on their land.

They can also be fitted to buildings, but this requires a detail assessment to enable the reactionary forces to be carried.

Most of the installations of these do not achieve their best effectiveness as they are placed in turbulent airstreams in the vicinity of buildings or trees.

### 5.2.2 Evaluation for Barry Waterfront

The distances between buildings and the planting involved in green spaces to create the quality of environment in the Barry Waterfront development does not lend itself to the best deployment of small scale wind power in general.

It is recommended that this is left to the development of the larger commercial buildings with which it would be associated. This allows them to make the economic and marketing judgement applicable to that development achieving the BREEAM Excellent score.

## 5.3 Large Scale Wind

### 5.3.1 Description

At large scales these units become most effective. In addition to the increasing efficiency with size, they can be operated by ESCOs or power producers, who will be able to enhance the economics by obtaining payment for the ROCs.

The size of such units would be similar to that installed at Green Park near Reading, achieving a significant contribution to power. Whilst such units will also have output compromised when placed in turbulent airstreams in the vicinity of buildings or trees, the size makes them less prone to the consequent effects.

### 5.3.2 Evaluation for Barry Waterfront

Large scale wind will require adequate space and will be more difficult to obtain planning consent. There will be issues of perceived aesthetics and acoustics to resolve. In addition, the escarpment and the causeway would both form local constraints on airflow which could impede performance.

Given the constraints of the overall site, the best location for large scale wind turbines would be on the mole. These could be co-ordinated and incorporated into the plans for a marina in this location. By placing them away from the residential areas this would alleviate acoustic issues and would allow a better airflow and performance. The housing and associated free spaces do not leave any clear locations for large scale wind turbine in the residential area.

# 6 Solar Power

## 6.1 Solar Thermal

### 6.1.1 Description

Solar Thermal is a well proven technique, using heat from solar collectors to produce Domestic Hot Water (DHW). Flat collectors have been available for many years, but more recently evacuated tube collectors have become available which are more efficient collectors of solar radiation, and extend the time of the year through which some heat can be recovered.

The technology is virtually carbon free in running, with only a small pump being required to circulate water between the collection array and the storage tank, consuming a small amount of electricity. This pump would be required with a conventional boiler plant in any case.

The typical solar thermal array for a house is 3-4$m^2$, and is usually sized to provide all the domestic hot water in the summer, with some preheat at other times of the year. Provision of larger arrays will enable hot water to be produced at other periods of the year with a greater carbon saving, but the system will then need to be matched to a heat dump to prevent overheating of the water storage.

The cost of installing an array would be in the region of £4000-£7000 per dwelling.

A variation is the 'Sunwarm' unit marketed by NuAire. This uses a combined array to produce domestic hot water in the summer, and to pre-warm ventilation air used by the Positive input ventilation unit in the winter. If both whole house ventilation and solar thermal heating are used, this unit should be considered.

### 6.1.2 Evaluation for Barry Waterfront

Solar thermal has a useful contribution to make towards achieving a low carbon footprint and sustainable development at Barry Waterfront. This is particularly so in the West Pond Area with its essentially south facing roofs, and in Arno Quay with the south facing elevation.

In South Quay, the houses lie in an east/west orientation, solar thermal will therefore be less effective in this location. During the detail design of the solar collectors, it will be possible to design a larger array to offset to some extent the poorer orientation. There may also be some overshading at low solar angles from the escarpment to the units placed closer to it. However, these low angles occur in the winter period when solar heat would not normally expect to be recovered and this should not be a serious constraint.

The selection of Solar Thermal will depend upon the other renewable techniques in use. If other low or zero carbon technologies such as biomass district heating are to be used to generate DHW in the winter, the carbon benefit of solar thermal collectors is much reduced.

## 6.2 Photovoltaics

### 6.2.1 Description

The generation of electricity by photovoltaics (PV) has been around for many years, and extensive use is made of the technology on the continent, particularly in Germany, where a preferential feed in tariff has encouraged take up in the residential market.

Photovoltaics generate DC electricity directly from sunlight, which is converted to power suitable for connection to the 230V AC house system by an inverter. The power is used first in any loads within the house; any surplus is then exported, with the householder receiving income from the exported energy. There are three types of silicon array used: polycrystalline, monocrystalline, and amorphous. Monocrystalline has the highest efficiency, but is the most expensive. Amorphous cells are less efficient in conversion of light to electricity, but respond to scattered light more efficiently and will not lose so much output in non-ideal orientations. Research work is looking at other materials, but current PV is essentially silicon based.

Because PV will only work during the day, it cannot generate all the power needed in a house all of the time without storage. However, a sufficiently large array will allow the dwelling to become carbon neutral in regulated energy, with the exported zero carbon energy in periods of excess (which is used by others and displaces carbon elsewhere) balancing the imported carbon based energy overnight. This approach to carbon neutrality will work effectively on the macro scale to a considerable penetration of PV in the overall UK energy balance.

Current costs for PV are relatively high making the simple payback quite long. They are carbon negative (they save more carbon in their life than is spent in making them). As efficiency of the PV cells rises and production costs fall, they will become increasingly cost effective in the future.

### 6.2.2 Evaluation for Barry Waterfront

At this stage PV is an expensive option for obtaining low carbon performance. At the immediate future levels of dwelling carbon performance, its use would be recommended only where a particularly beneficial application is available. An example of this is in apartment blocks, where the use of PVs to power communal areas lighting is often more cost effective as a carbon reduction measure than the complex application of solar water heating to a multi-occupied building.

However, costs will fall in the future and locally harvested energy will become increasingly important in the overall UK energy mix.

PV would be required to meet the higher levels of carbon reduction that are expected to be attained as the development progresses. The on-site generation of substantial amounts of electricity give the potential to meet ‘Carbon Neutral’ scenarios in regulated energy. The cost would be likely to be around £20,000 per dwelling at current costs for this level of PV.

With an even larger array, it would offer the prospect of giving a dwelling full carbon neutrality on the operating energy of small power and consumables as well as regulated energy and the offsetting of any residual gas used for cooking

Should PV be installed then solutions are available that are fitted like conventional tiles/slates on a roof and will give an integrated aesthetic, compared to a separately fixed array. This does allow the offset of some roofing materials and fixings, but these PV cost more than a conventional array and the overall cost is higher.

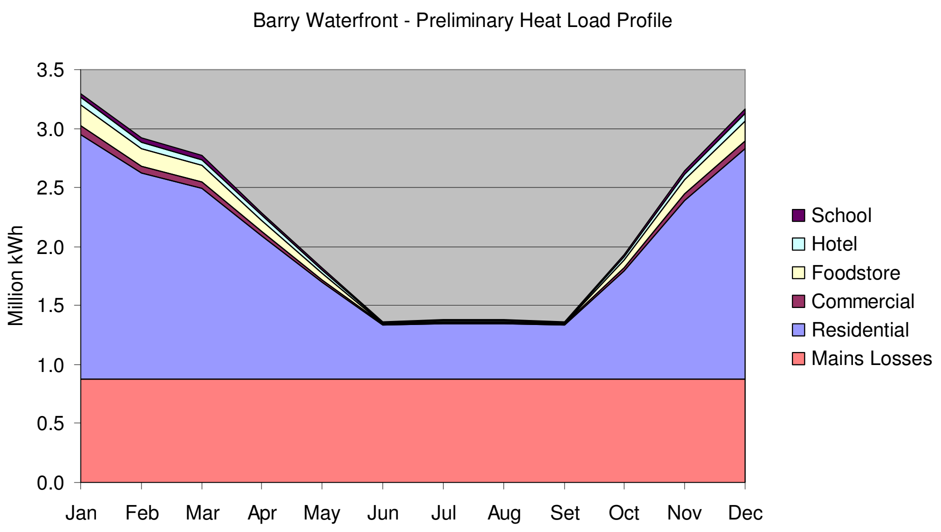
# 7 Community Heating

## 7.1 Outline Load Profile

Community Heating, and in particular Combined Heat and Power solutions rely on and understanding of the thermal profiles available for the heat produced. At Barry Waterfront, an outline load profile has been produced using CIBSE data for weather and DHW consumption for the building categories anticipated in the overall development.

Full load heating requirements have been taken as 4kW/unit from dwellings and at 40W/m$^2$ for commercial and other units. The mains losses have been averaged at 30W/m run.

This yields the graph below, shown in stacked format:




Points to note are:

1. The relatively high proportion of mains losses, due to the efficiency of the loads and the length of distribution to them, even in a compact urban environment.
2. The base load in the summer, which defines the maximum economic size of CHP – 1.38 million kWh/month.
3. The dominance of the residential load.

## 7.2 Thermal Only

### 7.2.1 Description

Community heating would be provided from a central boilerhouse or energy centre to serve the buildings in the development. The heat would be distributed in buried pipework, following the line of the roads from the boilerhouse to local heating substations serving an area for the residential and heating substations located in the buildings for the larger commercial units

At the substations buried pipework would serve the individual house where it would connect to a package substation unit which would replace the boiler in the building.

A location for the boilerhouse and its associated fuel store would need to be found within the development, reducing the available land, or acquired off-site resulting in additional costs.

By centralising the boiler plant, better control is retained over the combustion process, and the part load performance of the boilers with economisers will be improved compared to individual boiler plant. However, there will be additional losses resulting from the heating mains which will more than offset this.

Operation of the community heating system can be undertaken by an ESCO, who recover the costs by recharging for heat used against meters in each property. (See section 7.4 – Assets).

One prime advantage of the community heating is the ability to design the plant for any fuel. This could be gas, biomass, or liquid biofuel, or a combination, allowing the carbon profile to be improved over time after the installation of the system.

### 7.2.2 Evaluation for Barry Waterfront

The development of a community heating system would be seen as a positive move in terms of sustainability, but would need to be counterbalanced against the potential effect on sales as this arrangement is very uncommon in the UK, where individual boilers and gas connections are the cultural norm. The ‘novelty’ of having a tied heat supplier may affect the marketability.

Community Heating has the ability to flexibly adapt the fuel source and allows the development to attain at a cost even lower carbon footprints. This flexibility can be invoked up to a late point in the design process. The fuel solution can be varied between the stages of the development by installing the appropriate boiler type for each stage of housing.

The optimal location for the boiler plant would be near the centre of load, towards the centre or south end of west pond. It is envisaged that a significant proportion of biomass fuel would be used, and the storage and road transport of this needs to be considered. This would point to a location close to the main road with easy HGV manoeuvring.

It is assumed in this scenario that Arno and East Quays would be provided with local plant, although a value engineering exercise could be conducted during stage C/D to evaluate whether an extension of the community heating from West Pond to serve these would be more economic. If low carbon community heating was installed at east quay, then the council offices could be invited to join the network, improving their carbon footprint.

The largest obstacle to community heating is the initial cost. Although this would be phased as the development proceeds, there will be a slight forward weighting as a certain degree of resilience must be set up and the boilerhouse constructed (in a means that can be expanded) from the start. The rough order of cost of the network and heating substations to connect all 2000 dwellings and the commercial quarter would be around £12,500,000. A single boilerhouse using about half biomass fuel to supply this would be another £4,500,000.

## 7.3 Centralised CHP Component

### 7.3.1 Description

Large scale CHP plant produces electricity as its main product. In order to qualify for ROC payments which improve the economics, the plant needs to be classified as of 'good' quality. This is a measure of the overall efficiency of the plant, and to attain this standard it is essential that there is a maximum recovery of the heat produced by the engines. Where electricity is produced, but the heat from the engines has to be dumped, both the economic and carbon performance of the CHP collapse.

This means that CHP must be used as a base load energy source for the maximum economic return. It is therefore sized based upon the minimum thermal load available, with the generation selected to produce the maximum amount of electricity for this thermal sink size, bearing in mind the overall economics of maintenance and reliability between differing plant types.

Alternative approaches of larger size CHP plants following the thermal load down in the summer and producing less power, or being turned off completely in summer have been tried, but reduce the revenue earned by the plant and are generally much less favourably economically.

Most CHP is still based upon fossil fuel fired reciprocating engines as a prime mover, gaining its lower carbon footprint from the efficient conversion it gives. Development is also ongoing into biomass or biofuel fuelled CHP, which is seen as a talisman of sustainability. There are viable plants in operation on the continent, but little uptake in the UK yet.

### 7.3.2 Evaluation for Barry Waterfront

A centralised CHP component to the Barry Waterfront development is a viable option with good potential for carbon savings. By use of thermal storage to even out diurnal variations in the summer, a constant thermal base load of 1.38 $MW_{th}$ can be achieved. This would imply a CHP unit of between $250kW_e$ and $350kW_e$. A unit of this size would be the annual electricity consumed by about 750 electrically efficient homes, although there would be periods of overall import and export.

The CHP unit would be connected to the local grid, which would allow the maximum value of ROCs to be obtained by sale of electricity to the general pool. However, if the plant is 'allocated' to the low carbon of Barry Waterfront, attaining ROCs for its output would lead to double counting of its carbon saving, and government may act to close the loophole.

If such CHP was biofuel based, or was converted to biofuel at a later date (there are land implications of this), it could provide a significant proportion of the zero carbon electricity required to meet an imposed 'zero' carbon requirement.

Once the base load has been taken by CHP, the wintertime thermal peaks can be met by supplementary boiler plant, fuelled as required to meet the carbon target. With a large diurnal store provided for the CHP and careful design, short cycling of biomass fuelled plant which can cause problems should be avoidable.

One issue to be resolved in the design and economics of a CHP plant will be the gradually ramp up of the available thermal load over ten years. This will constrain the selection of plant, as the economic optimum would be a single plant running at full capacity. It may be that the CHP unit can only be installed once the development reaches a certain size.

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## 7.4 Biomass Power Station

### 7.4.1 Description

There are proposals to build a biomass power station on the nearby Barry No 2 dock. This would use imported stock and generate power using either a conventional Rankine cycle steam plant or engines depending upon the final design of the station. The distance is around a kilometre and a half from the entrance to the greater part of the development. This is close enough to allow for the connection of district heating to the power station.

The power station would have interest only in providing heat. The electricity is more valuable to them sold directly to the grid allowing the ROCs to be paid, rather than distributing to the households over a private wire network.

The heat itself will come at a price in thermodynamic efficiency of the power station, and this, together with the capital cost of the distribution must be balanced against the benefit in revenue from the value of heat sold.

The proposal would be to run district heating mains from the power station along Millennium Way to serve first the East Quay, then Arno Quay, before entering the main development site at the North West corner of No 1 dock by the proposed commercial quarter. From here it would serve West Pond and South Quay via distribution pipework as described in 7.1 above. There would be an additional cost in the large mains connecting the development to the power station.

Should it be possible this would be a first class piece of integrated design and sustainability.

### 7.4.2 Evaluation for Barry Waterfront

There are numerous difficulties is making the schemes work together, including approvals, planning, financial, programming and market considerations. In the light of this, the development must continue to pursue the options for meeting their energy requirements without the power station. Reliance on a third party project for the heating source is a huge project risk which would need to be mitigated and managed. This would only be mostly eliminated once both projects had received all approvals and funding and their programmes interlocked.

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# 8 Micro CHP

## 8.1 Micro CHP

### 8.1.1 Description

Micro Combined Heat and Power is a recent technology, aiming to get the best use out of gas consumed in a house. It uses the CHP principle of generating power and using the associated heat. Unlike large scale CHP, the unit is looking to replace a domestic boiler, and so it operates on a thermally led basis.

This means that the unit looks to meet the thermal load being imposed upon it, and generates this much heat. The fact that it produces electricity as well is incidental and the quantity is governed by the efficiency of the engine driving the generator, and the design of the micro CHP unit. The more heat is required, the more electricity is produced, and any excess over the requirement of the house is exported to the grid.

One of the macro benefits of micro CHP is that it is producing the most power in the winter when heat demand is high; this is also when power demand is higher.

There are three technologies in the micro CHP units either available or coming to market. The first units used a Stirling engine to drive the generator, with a heat exchanger to recover the heat after the engine. The electricity to heat ratio is about 1:8 which is low.

A second technology is the Organic Rankine Cycle (ORC). This works in the same manner as a water based steam cycle, but uses a more volatile fluid to operate at lower temperatures. The working fluid is usually a refrigerant and uses a screw expander (a screw compressor in reverse).

The third technology from Honda uses the world's smallest gas internal combustion engine. This has a much better electrical energy ratio than the others about 1:3.5, but is much noisier – being equivalent to a domestic air conditioning outdoor unit. This would be too much for a UK kitchen, but would be satisfactory in a garage.

The technology was primarily aimed at existing property boiler replacement, but field trials, by one company at least, has involved a new property. Newer units are looking towards the lower thermal requirements of new build.

Claims made by companies vary, but e.on have published some details of their trials conducted under the Carbon Trust's evaluation of micro CHP technology. This shows a range of 11% to 14% savings in $CO_2$ compared to a basic Building Regulations compliant boiler. As with conventional boilers the units tend to become less efficient on part load.

Costs of the units are around £3000 to £5600 per dwelling. They replace the conventional boiler.

### 8.1.2 Evaluation for Barry Waterfront

Many of the micro CHP units have a thermal capacity too high for the most effective operation in a new build, even though some models turn down to between 5 and 7.5kW. The Honda unit has a heat output of 3.5kW is more suited for a new build.

Combined with large DHW storage for a family home or a thermal buffer this would make a low output unit a possible option for reducing the carbon footprint of some larger houses in Barry Waterfront, but it would not be a first choice.