elementenergy

Shakespeare Terrace Energy Assessment

FINAL REPORT

For

Planning Potential Ltd

07/01/2010

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1 EXECUTIVE SUMMARY

There Richmond Upon Thames Core Strategy contains two policies that are relevant to the energy system employed at Shakespeare's Terrace:

(i) New housing developments should meet Code Level 3 of the Code for Sustainable Homes – to achieve this standard requires a reduction of regulated CO_2 emissions (i.e. those related to heating, ventilation and fixed lighting) of 25% compared to Part L 2006 standards.

(ii) A 20% reduction of CO_2 emissions through onsite generation of renewable energy – it is assumed that this policy will be applied in line with the London Plan energy hierarchy, i.e. that the 20% reduction is to be applied to a baseline of the dwelling's total emissions, once energy efficiency measures and clean energy supply technologies (such as CHP and connection to district heating networks) have been taken into account.

In order to achieve this, a package of energy efficiency and low carbon and renewable measures has been investigated.

1.1 Energy efficiency

The energy demands and CO_2 emissions expected from the Shakespeare Terrace development have been calculated, assuming that the development is designed to meet Part L 2006 of the Building Regulations. A set of basic building fabric energy efficiency improvements have subsequently been recommended. These energy efficiency improvements have been shown to deliver a 10.8% improvement on the Dwelling Emission Rate (DER)[1]. The Part L 2006 compliant and improved fabric efficiency packages are illustrated in Table 1 (green shading highlights where standards are improved over the Part L compliant case).

Table 1 – Improvements from energy efficiency measures

Efficiency parameters	Part L 2006	Improved
Wall U-value (W/m^2K)	0.3	0.25
Windows, roof lights and door U-value (W/m^2K)	2.0	1.5
Ground floor U-value (W/m^2K)	0.22	0.22
Roof U-value (W/m^2K)	0.16	0.16
Air tightness ($m^3/m^2/hr$)	9	7
Thermal bridging value (W/m^2K)	0.09	0.08
Lighting	75% efficient lighting fittings	75% efficient lighting fittings
Heating system	Boiler with insulated primary pipe-work and with cylinder thermostat	Boiler with insulated primary pipe-work and with cylinder thermostat
Heating efficiency	91%	91%
Ventilation	Naturally ventilated	Naturally ventilated
Total regulated CO_2 emissions (kg/yr)	15,120	13,485
Improvement over Part L 2006	-	10.8%

The total energy consumption and CO_2 emissions from the proposed development, following the implementation of these energy efficiency improvements, are illustrated in Table 2.

[1] The DER is a measure of the dwelling's regulated emissions, measured in $kgCO_2/m^2/yr$.

Table 2 – Improved energy consumption and CO_2 emissions

Source	Energy use (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	10,216
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
Electricity for appliances	21,217	8,953
Total regulated emissions		13,485
Total non-regulated emissions		8,953
Total emissions		22,439

1.2 Low carbon technology options for meeting the CO_2 reduction target

An extensive range of options to provide the remaining CO_2 reduction has been assessed. Three preferred options have been identified, as follows:

1. **Biomass boiler.** A centralised biomass boiler would reduce site CO_2 emissions by 34.6% relative to Part L 2006, which comfortably achieves the requirements of both Code Level 3 and the 20% CO_2 reduction through renewables target. This can be achieved at a relatively low additional cost (compared to conventional gas condensing boilers in each unit). However, this solution raises a number of other issues that must be addressed. For example, space must be allocated for a central plant room to house the boiler and biomass fuel store. A reliable and preferably local fuel supply would be required and provision must be made for the management of the system, including maintenance, fuel supply and billing residents for the heat they consume.

2. **Gas-fired CHP.** This option, combined with the energy efficiency improvements, could also meet the CO_2 reduction standard required by Code Level 3, however, further renewable energy generation would need to be installed to meet the 20% renewables policy. This would make this a significantly more expensive option than the biomass boiler solution. The centralised CHP plant would present the same issues as the biomass boiler system in terms of requirement for central plant space and need for a management organisation to oversee maintenance and provide a billing service.

3. **Solar PV array.** A 76m^2 PV array could generate enough electricity to meet both the Code Level 3 and 20% CO_2 reduction through renewables policies. While this is a higher capital cost option, it has the advantages of low ongoing maintenance requirements and can be incorporated relatively easily into the existing building design without loss of space for plant.

   The PV array should be installed on the flat roofs of units 7 and 9, where the potential for overshadowing is minimised. Based on a typical power density of 125 W/m^2, the 76m2 array area should be accommodated on these roofs with allowance for access and placement to avoid shading by the parapet. Careful selection of modules will be required to ensure that the potential for installing generating capacity in the available area is maximised. There is some potential for overshadowing of an array on these roofs, from the fire tower and potentially from a new five-storey development to the south (which may overshadow the south roof of the Shakespeare Terrace at times of low sun). A shading analysis should be undertaken during detailed design of the system, to ensure that the impact of shading is acceptable and to inform the physical layout and electrical configuration of the array to minimise loss of output due to shadowing. .

1.3 Recommendation

Photovoltaics provide the simplest option for meeting the requirements of Richmond's energy and sustainable building policies. The incorporation of PV can provide the necessary CO_2 reduction with limited implications for the design of the building. The costs associated with this size of PV array are relatively high, estimated at approaching £43k.

Installation of centralised biomass boiler plant could provide the necessary CO_2 reduction at lower plant costs, however, this would require a partial redesign of the building in order to provide a central plant room for the biomass and gas peak-load boilers. The biomass plant would also present greater ongoing operation and maintenance issues, requiring management of the fuel supply and an arrangement for billing of tenants for their heat consumption.

In light of the design and operational issues surrounding centralised biomass plant, it is anticipated that the PV option will be preferred for Shakespeare's Terrace. Emissions from the site after the application of the recommended solar PV system are illustrated in Table 3.

Table 3 – Development CO_2 emissions with a roof-mounted PV array installed

Source	Energy demand / generation (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	10,216
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
System capacity ($kW_{electrical}$)	9.5	
Electricity from PV	7,600	-4,491
Total regulated emissions	8993	
Unregulated emissions	8954	
Total emissions	**17,947**	
CO_2 saved relative to Part L 06 due to Energy Efficiency	10.8%	
CO_2 saved relative to Part L 06 due to PV	29.7% - exceeding Code Level 3 requirement	
Total CO_2 saved relative to Part L 06 (PV and energy efficiency measures)	40.5%	
Reduction of overall emissions compared to energy efficient baseline	20% - in line with the 20% renewables policy	
Total marginal capital cost	£42,750	
Capital cost per tonne of CO_2 saved annually	£9,903	

The impact of the energy efficiency improvements and incorporation of PV on the development's CO_2 emissions are summarised in the chart below. It is clear that the 20% reduction of CO_2 through renewables policy requires a significantly large PV array than would be required to meet the requirements of Code Level 3.

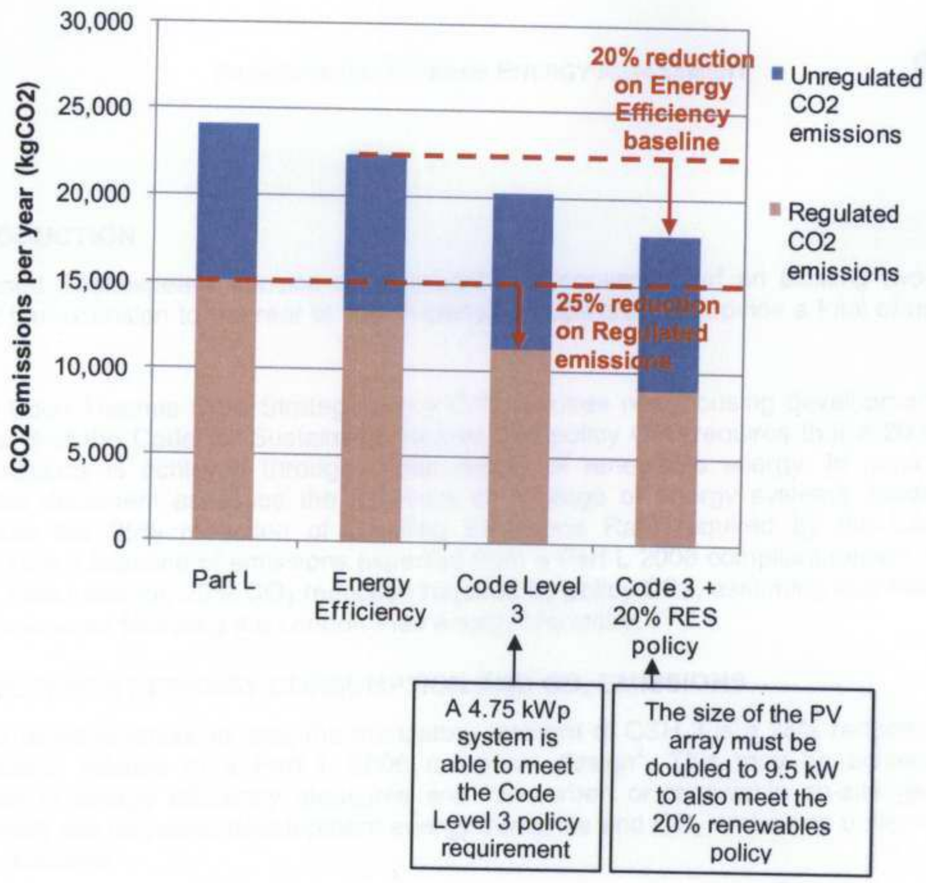
30,000
25,000
20,000
15,000
10,000
5,000
0
CO2 emissions per year (kgCO2)
Part L
Energy Efficiency
Code Level 3
Code 3 + 20% RES policy
20% reduction on Energy Efficiency baseline
25% reduction on Regulated emissions
Unregulated CO2 emissions
Regulated CO2 emissions
A 4.75 kWp system is able to meet the Code Level 3 policy requirement
The size of the PV array must be doubled to 9.5 kW to also meet the 20% renewables policy

Table 7 – Development CO_2 emissions with gas-fired CHP installed

Source	Energy demands / generation (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	14,834
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
Electricity from CHP	12,975	-7,370
Total regulated emissions		10,732
CO_2 saved relative to Part L 06 due to CHP		18.2%
Total CO_2 saved relative to Part L 06 (including fabric improvement)		29.0%
Total marginal capital cost		£10,500
Capital cost per tonne of CO_2 saved annually		£3,815

While sufficient to meet the CO_2 reduction required by the Code for Sustainable Homes Level 3, gas-fired CHP clearly does not make a contribution to reduction of CO2 emissions by onsite renewable energy generation. Assuming that the requirement for renewables is applied following the London Plan hierarchy, a further CO_2 reduction of 3,940kg/yr would need to be delivered through renewable energy generation. If this were to be provided by photovoltaics, for example, a system of around 8.3kWp capacity would be required, at an additional capital cost of £37,500.

5.2.3 Site-specific issues

The CHP unit would require a significant amount of space which would need to be incorporated into the development design – most conveniently for access and maintenance on the ground floor, although this may require a redesign of the development, or a loss of space in the courtyard. An alternative would be to situate the unit on the roof of the building, although this might have visual impact and access implications.

There would also be a need for a backup conventional heating system to provide the extra peak loads to the development. This could be in the form of individual boilers in each flat, or a larger, centralised boiler (although this would have the same space availability issues as the CHP plant).

Additionally, recent Carbon Trust CHP field trials highlight that appropriate expertise is vital to avoid unnecessary downtime or poor performance – it may be necessary to train an on-site facilities manager in how to optimise the performance of the CHP system.

5.2.4 Recommendations

Including a centralised CHP plant in the development to meet base heating loads could reduce overall CO_2 emissions by 18.2% (and 29.0% overall including the energy efficiency improvements), thereby exceeding the overall 25% reduction required by CSH 3 at a marginal capital cost of £10,500. However, to also meet the renewable energy policy would require additional plant and incur substantial additional cost. If the requirement for renewable energy generation were to be met by installation of PV, then an additional on-cost of £37.5k would be incurred.

There are some practical issues associated with the inclusion of a centralised CHP plant in this development, most notably the lack of available space to house the unit, as discussed above.

Table 8 – Development CO_2 emissions with a centralised GSHP installed

Source	Energy demands (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	7,120
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
System capacity ($kW_{thermal}$)	22.5	
Total regulated emissions	10,388	
CO_2 saved relative to Part L 06 due to GSHP	20.5%	
Total CO_2 saved relative to Part L 06 (including fabric improvement)	31.3%	
Total marginal capital cost	£36,000	
Capital cost per tonne of CO_2 saved annually	£11,629	

The renewable energy supplied by the ground source heat pump in meeting the thermal load exceeds the CO_2 reduction required by Code Level 3, but falls short of the reduction required by Richmond's renewable energy policy. Therefore, to comply with both policies, additional renewable electricity generation would be required on the site. A 3kWp photovoltaic array would provide sufficient renewable energy generation, at an additional capital cost of approx. £13,250.

6.1.3 Site-specific issues

Because of the lack of available land for digging heat-exchange loop trenches or boreholes, the only viable option for the use of a GSHP would be the relatively untested 'energy pile' technology. 'Energy piles' are heat-exchange loops which are inserted into the ground at the same time as piles are dug for the building foundation. A number of issues would be associated with this technology, most notably the lack of access to the ground loops for maintenance, but also the fact that the boreholes would not be dug to the same depth as would normally be the case for a borehole system, thereby reducing their thermal output. Taking this and the site area into account, it would however be possible to use an 'energy pile' system on this site, utilising a total of nine piles.[10]

The GSHP unit would require a significant amount of space which would need to be incorporated into the development design – most conveniently for access and maintenance on the ground floor, although this may require a redesign of the development, or a loss of space in the courtyard.

Heat pumps are most efficient and effective when used in conjunction with low temperature heating systems, such as under floor central heating. As this is a new development, this should not however prove to be a problem to incorporate into the design.

The applicability of a GSHP system to this site, utilising energy pile technology, would need to be confirmed by a ground survey and by structural engineers designing the building's foundations.

6.1.4 Recommendations

Including a centralised GSHP unit in the development could reduce overall CO_2 emissions by 20.5% (and 31.3% overall including the energy efficiency improvements), thereby exceeding the overall 25% reduction target, at a capital cost per tonne of CO_2 saved annually of £11,629. However, further renewable energy generation would be required to meet the 20% renewables target, which, if supplied by photovoltaics, would add a further £13,250 to the capital on-cost. This represents a high capital cost solution overall.

Taking this into account as well as the issues surrounding the 'energy pile' technology, we would not recommend a GSHP as a viable solution.

[10] Assuming a minimum separation of 7 metres and a thermal output of 2.5$kW_{thermal}$ per pile.

6.2 Air source heat pumps (ASHP)

6.2.1 Introduction

ASHPs work on a similar principle to ground source heat pumps and air conditioners. Domestic ASHPs meet heating and hot water demands by transferring heat from air (outside) to water (inside). Heat is extracted from the air via heat exchanger coils, often with a fan for improved heat exchange (see Figure 1).

Well designed and installed systems can extract up to three or four units of heat from the outside air for every unit of electricity used, thereby obtaining renewable heat for 'free'. However, efficiency varies over the year and, for the purpose of this evaluation, a Seasonal Performance Factor of 2.5 is assumed.

Figure 1 – External ASHP heat exchanger unit

6.2.2 Potential performance in proposed development

Domestic ASHP units tend to be sized for individual homes. The smallest units currently commercially available are around 5kW, which would provide all the heating requirements of the Shakespeare Terrace units. The inclusion of a 5kW ASHP unit in each of the nine flats could reduce overall CO_2 emissions by an estimated 11.1%[11] at a total capital cost of £13,500 and a capital cost per tonne of CO_2 saved annually of £8,077[12], as shown in Table 9.

Table 9 – Development CO_2 emissions with 9 ASHP units installed

Source	Energy demands (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	8,544
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
System capacity ($kW_{thermal}$)	45	
Total emissions	11,812	
CO_2 saved relative to Part L 06 due to ASHP	11.1%	
Total CO_2 saved relative to Part L 06 (including fabric improvement)	21.9%	
Total marginal capital cost	£13,500	
Capital cost per tonne of CO_2 saved annually	£8,077	

[11] Assuming a conservative COP of 2.5 (the standard value used in SAP 2005) and a load factor of 25%.
[12] Assuming a marginal cost of £1,500 per $kW_{thermal}$.

The ASHP strategy falls slightly short of the emissions reduction required by Level 3 of the Code for Sustainable Homes and significantly short of the requirement of the 20% renewables policy. In order to provide the shortfall (a reduction of CO_2 emissions of 2,815 kgCO2/year) would require a PV array of 7 kWP, at an additional capital cost of £31,300.

6.2.3 Site-specific issues

One of the main advantages of installing individual ASHP units is that they do not require a centralised heating system to be installed and therefore do not require a central 'boiler room'. This reduces the system design complexity, or the need to redesign parts of the development. Furthermore, there is no requirement for additional plumbing between the flats and the boiler. The internal ASHP heat exchangers can be housed in the space that would otherwise have been used to house a gas boiler.

There is however still a requirement to house the external heat exchangers. These units are no larger than a typical air conditioning heat exchanger and could be housed either on the roof of the building, or on the balconies, assuming there is enough space to allow for sufficient air flow through the device.

Heat pumps are most efficient when used in conjunction with low temperature heating systems, such as under floor central heating. As this is a new development, this should not however prove to be a problem to incorporate into the design.

6.2.4 Recommendations

Including ASHP units in every flat could reduce overall CO_2 emissions by 11.1% (and 21.9% overall including the energy efficiency improvements), at a capital cost per tonne of CO_2 saved annually of £8,077. This solution falls slightly short of the 25% reduction target, which suggests that additional CO_2 saving measures would be required in order to meet Code Level 3 and the 20% renewables policy. To comply with both policies, a 7 kWp PV array would be required, at an additional capital cost of £31,300.

6.3 Biomass boiler(s)

6.3.1 Introduction

Typically in the UK biomass heating involves combustion of woody biomass in either pellet (see Figure 1) or chip form. A typical biomass installation involves a biomass store, some form of pellet/chip transport system and the boiler itself.

Biomass fuel is currently more expensive than gas, particularly when delivered in pelletised form. However, the government has recently announced a Renewable Heat Incentive scheme to incentivise the installation of renewable heat generators. This will provide a premium tariff to the operators of renewable heating plant for every unit of heat produced. This subsidy will significantly improve the economic case for installing biomass-fired heating systems.

Thermal efficiencies of biomass boilers are generally comparable to condensing gas boilers, although the units tend not to operate as well at lower outputs or when rapid cycling is required.

Figure 2 – A biomass boiler and wood pellets

6.3.2 Potential performance in proposed development

A correctly sized, centralised biomass unit could provide all the base-load heating requirements for the proposed development, with the shortfall made up by conventional gas boiler(s). A 12.5 $kW_{thermal}$ biomass unit[13] would reduce overall CO_2 emissions by 34.6%[14] at an additional capital cost of £25,000 and a capital cost per tonne of CO_2 saved annually of £4,774[15], as shown in Table 10. Note that these are the marginal costs of installed plant, but do not account for the costs of plant room space required for centralised plant.

Table 10 – Development CO_2 emissions with a centralised biomass boiler installed

Source	Energy demands (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	4,980[16]
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
System capacity ($kW_{thermal}$)	12.5	
Total regulated emissions	8,248	
CO_2 saved relative to Part L 06 due to biomass boiler	34.6%	
Total CO_2 saved relative to Part L 06 (including fabric improvement)	45.4%	
Total marginal capital cost	£25,000	
Capital cost per tonne of CO_2 saved annually	£4,774	

Due to the very low carbon heat provided, the biomass boiler system is able to provide the required CO_2 reduction of both Code Level 3 and the 20% renewables policy. This avoids the need for any further renewable energy generating technology and, as a result, provides significantly the lowest cost solution in terms of capital costs.

6.3.3 Site-specific issues

The biomass boiler and fuel store would require a significant amount of space which would need to be incorporated into the development design – most conveniently for access and maintenance on the ground floor, although this may require a redesign of the development, or a loss of space in the courtyard.

[13] Assuming a total of 2,430 full-load run hours and 60% of heat load met by the biomass boiler (with remainder met by heat only gas boilers).
[14] Assuming an efficiency of 85%.
[15] Assuming a marginal cost of £25,000.
[16] Assuming a wood pellet CO_2 intensity of 0.025 kg/kWh.

Biomass resource is a key issue to be taken into account when assessing the viability of biomass heating systems. The environmental benefits of a biomass heating system are maximised when fuel is locally sourced (as the CO_2 impact of fuel transportation is minimised).

An organisation would be required to take on management of a centralised biomass boiler plant. This organisation would be responsible for operation and maintenance of the plant, including fuel supply, and also billing residents for the heat consumed.

6.3.4 Recommendations

Including a centralised biomass boiler in the development could reduce regulated CO_2 emissions by 34.6% (and 45.4% overall including the energy efficiency improvements), which exceeds the requirement of Code Level 3 and is, in fact, sufficient to meet the CO2 reduction standard required at Code Level 4. The reduction in overall emissions provided by renewable energy is 23%, in excess of the requirement of the 20% policy.

There are some issues with use of a centralised biomass boiler system that would need to be resolved. These include finding a reliable and, ideally local, supply of biomass fuel, incorporating space into the design for central boiler plant and fuel storage and developing a mechanism for the ongoing O&M of the plant and billing of heat customers. Additionally, the Borough of Richmond-Upon-Thames is Smoke Control Area, which limits the choice of boilers that could be used on site to approved appliances only.

6.4 Solar photovoltaic (PV) panels

6.4.1 Introduction

Solar Photovoltaic (PV) systems generate electricity via the interaction of sunlight with a semiconductor layer. The semiconductor is typically housed within a glass plastic sandwich to make a solar module. These modules are then connected together to form an array which can be mounted on the roof of a building (see Figure 3), or even built into the building's skin. Electricity from the array must first be fed through an inverter to provide AC power at the correct voltage before it can be fed into the building's electrical system or exported to the local grid.

Figure 3 – A large PV array on a sloping roof

6.4.2 Potential performance in proposed development

A PV array sized to meet a 14.2% CO_2 reduction target (totalling a 25% overall reduction by including the energy efficiency savings of 10.8%) would need to provide 4.75 kW of power (peak output) and would require 39m^2 of roof space[17].

In order to comply with the 20% renewable energy policy will require the PV array to be approximately doubled. The required reduction on the energy efficient baseline could be supplied by a PV array of 9.5 kWp, requiring a roof area of 76m^2. The capital cost of a system of this size is estimated to be approximately £42,750.

The emissions reductions delivered by this system are shown in Table 11.

Table 11 – Development CO_2 emissions with a roof-mounted PV array installed

Source	Energy demand / generation (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	10,216
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
System capacity ($kW_{electrical}$)	9.5	
Electricity from PV	7,600	-4,491
Total regulated emissions	8993	
Unregulated emissions	8954	
Total emissions	**17,947**	
CO_2 saved relative to Part L 06 due to Energy Efficiency	10.8%	
CO_2 saved relative to Part L 06 due to PV	29.7%	
Total CO_2 saved relative to Part L 06 (PV and energy efficiency measures)	40.5%	
Reduction of overall emissions compared to energy efficient baseline	20%	
Total marginal capital cost	£42,750	
Capital cost per tonne of CO_2 saved annually	£9,500	

6.4.3 Site-specific issues

It is important that PV arrays are installed in non-shaded areas for optimal performance. To the south of the site is a four-storey office block, although this is expected to be demolished as there is a planning permission for a three to five-storey development of residential units and office space on this site (see Figure 4). If this building were to be constructed to five-storeys and extended to the line of the pavement on the south side of Garden Road, then it could cause some over-shadowing of the southern roof of Shakespeare Terrace (i.e. the roof on unit 7).

The north roof of Shakespeare Terrace (roof of unit 9) is one storey higher and further from the possible five-storey building to the south, so would not be overshadowed by this development. However, the fire tower to the south-east of this roof (as indicated in Figure 4) will cause some overshadowing in the morning.

The PV area required to deliver the required emissions reduction is 76m^2 (assuming a typical power density of 0.125 kW/m^2) of the 120 m^2 of roof area provided by the roofs of units 7 and 9. In calculating the total roof area that can be used for installation of PV, an allowance must be made for access around the modules for maintenance and cleaning. The Shakespeare's Terrace roof also has a parapet, which needs to be taken into account when positioning the modules to ensure it does not cause overshadowing. Taking these factors into account, it should be just possible to accommodate

[17] Assuming an output per unit area of 96 kWh/m^2/year and a power density of 0.12 kWp/m^2.

the 76m^2 array if the useable area of the roofs of unit 7 and 9 is maximised. Careful selection of PV modules and consideration of the optimum layout will be required to ensure the potential for installed capacity in the available roof area is maximised. A detailed shading analysis is recommended to ensure that a system of this size can be accommodated, without unacceptable over-shading by the neighbouring buildings or the parapet.

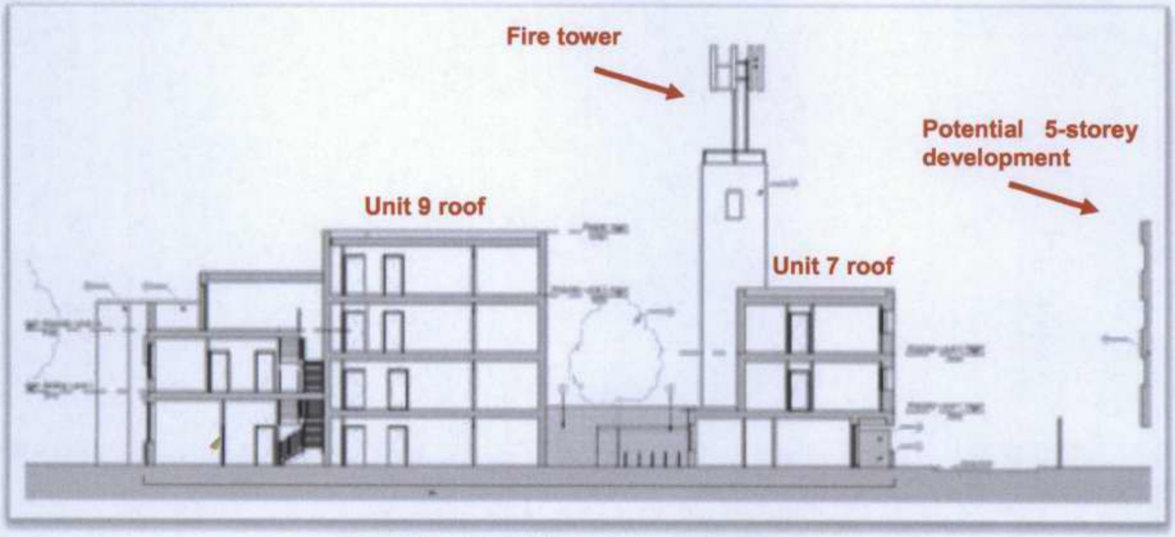

Figure 4 – Suitable locations for PV array

6.4.4 Recommendations

Combined with the energy efficiency improvements, a 76m^2 array (approx 9.5 kWp) on the roof of units 7 and 9 could reduce overall CO_2 emissions the required amount to meet each of Richmond's policies.

Although this is one of the higher cost technologies, it does not have any of the space-requirement drawbacks of the other technologies. Installation would be a relatively simple process and would use otherwise-unused space. The high capital costs are mitigated to some extent by low running costs.

6.5 Solar thermal

6.5.1 Introduction

Solar thermal systems extract heat from sunlight for use in the home for hot water provision and in some cases for space heating. A range of technologies exists for collecting heat, though all involve a circulating fluid passing through roof based solar collectors (often a simple flat plate with a glass cover, or an evacuated glass tube with a water pipe in the centre).

Solar thermal systems cannot viably provide the entire hot water heating demand for a home, nor can they provide enough heat for central heating. They are therefore usually incorporated into a conventional heating system (see Figure 5) and sized to provide between 50% and 60% of the hot water demands.

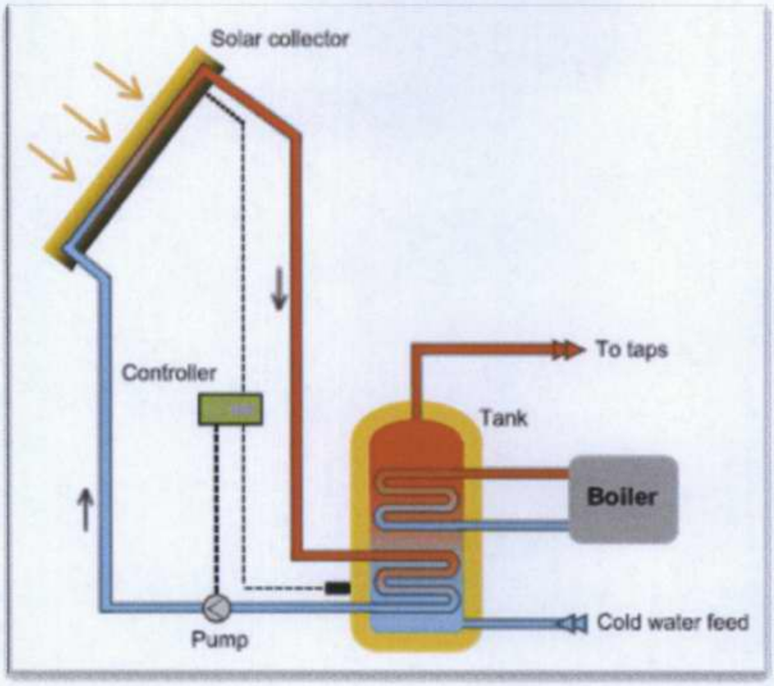

Figure 5 – A solar thermal array connected to a conventional heating system

6.5.2 Potential performance in proposed development

A solar thermal array sized to meet 60% of the development's hot water demands would require 28m^2 of roof space[18], from a total useful roof area of roughly 111m^2. An array of this size would reduce overall CO_2 emissions by 20.0%[19] at a total capital cost of £34,059 and a capital cost per tonne of CO_2 saved annually of £11,258[20], as shown in Table 12.

Table 12 – Development CO_2 emissions with a roof-mounted solar thermal array installed

Source	Energy use (kWh/yr)	CO_2 emissions (kg/yr)
Space heating	26,967	7,191
Domestic hot water	23,652	
Electricity for heating, pumps, fans, lighting	7,746	3,269
System capacity ($kW_{thermal}$)	17.0	
Total regulated emissions	10,459	
CO_2 saved relative to Part L 06 due to solar thermal system	20.0%	
Total CO_2 saved relative to Part L 06 (including fabric improvement)	30.8%	
Total marginal capital cost	£34,059	
Capital cost per tonne of CO_2 saved annually	£11,258	

6.5.3 Site-specific issues

It is important that solar arrays are installed in non-shaded areas for optimal performance. The presence of a four-storey office block to the South of the proposed development may provide shade to the roof area above Unit 7 at certain times of the day.

We would therefore recommend that any solar array be installed on the roof area above Unit 9 (which is one storey higher and further away from the four-storey block). The presence of the fire station

[18] Assuming an output per unit area of 500 kWh/m^2/year and peak output per unit area of 600W/m^2.
[19] Assuming a gas CO_2 displacement intensity of 0.194 kg/kWh.
[20] Assuming a cost of £2,000/kW.

training tower to the South East of these roof areas may however provide some shading at certain times of the day and a more detailed analysis would need to be undertaken at the design stage.

6.5.4 Recommendations

Including a solar thermal array on the roof of Unit 9 could reduce overall CO_2 emissions by 20.0% (and 30.8% overall including the energy efficiency improvements), thereby exceeding the 25% reduction on regulated emissions required by Code Level 3. To also comply with the 20% renewables target will require further renewable energy generation. If the additional renewable generation is provided by photovoltaics, an array of 3.1kWp would be required at an additional capital cost of £13,900, resulting in an overall on-cost of nearly £48k.

6.6 Mini-wind

6.6.1 Introduction

Wind turbines extract energy from the wind, operating like a fan in reverse, and the energy extracted depends strongly on the wind speed. Wind speeds vary around the country and also according local topography (hills, obstacles etc.) and hence siting of the turbine is a very important consideration.

Figure 6 – A mini-wind turbine

6.6.2 Potential performance in proposed development

The average wind speed at 10m above the ground, at the proposed location is 4.8m/s[21], which is towards the lower threshold of wind turbine viability. Once the turbulence from surrounding buildings has been taken into account, the average wind speed would be significantly reduced and the output from a small building mounted wind turbine would be expected to be poor in this location.

6.6.3 Recommendations

Mini-wind turbines do not provide an attractive solution in this urban location and are not recommended for this site.

[21] NOABL database

7 SUMMARY AND RECOMMENDATIONS

The mandatory energy element of level 3 of the Code for Sustainable Homes is for a 25% reduction in a development's regulated CO_2 emissions by means of energy efficiency improvements, or the provision of onsite low-carbon or renewable energy generation (from a Part L 2006 emissions baseline). Richmond Upon Thames require Code Level 3 to be met in all new housing development and, in addition, for a 20% reduction of CO_2 emissions to be delivered by onsite generation of renewable energy.

7.1 Energy efficiency

A set of basic energy efficiency improvements have been recommended and these achieve a 10.8% reduction over baseline Part L 2006 emissions.

7.2 Preferred Options

An extensive range of options to provide the remaining CO_2 reduction have been assessed. Three preferred options have been identified, as follows:

1. **Biomass boiler.** A centralised biomass boiler would reduce site CO_2 emissions by 34.6% relative to Part L 2006, which provides compliance with both of Richmond's carbon reduction and sustainability targets. This is also a relatively low capital cost option.

   However, there are issues to overcome, as follows:
   - Provision of plant room space for the central biomass boiler and fuel storage.
   - Providing for the ongoing O&M of the plant and billing residents for their heat consumption.
   - Sourcing a reliable supply of biomass, ideally from local sources.

2. **Solar PV array.** A $76m^2$ PV array could generate enough electricity to exceed the requirements of Code Level 3 and meet the 20% renewables target. While this is a substantially higher capital cost option, it has the advantages of low ongoing maintenance requirements and can be incorporated relatively easily into the existing building design without loss of space for plant (apart from use of the roof space).

7.3 Recommendation

The biomass boiler option represents significantly the lowest cost approach to meeting the CO_2 target of the Shakespeare Terrace development. However, the existing design of the building does not provide the necessary plant room space for centralised boilers and biomass fuel storage. The incorporation of biomass boilers would, therefore, require a partial redesign of the development in order to be accommodated. There are also requirements for ongoing management of the biomass boiler system, both to ensure a fuel supply and to bill residents for their heat consumption.

The PV array represents the simplest solution to meet the 25% overall target, with relative ease of installation, no additional demands on internal space (assuming the inverters are installed externally) and no onerous requirements for ongoing operation and maintenance.

8 CODE FOR SUSTAINABLE HOMES – ENERGY CATEGORY REQUIREMENTS

The Richmond Upon Thames Core Strategy requires Level 3 of the Code for Sustainable Homes to be met for all new housing developments. To achieve this standard a 25% reduction of Dwelling Emissions Rate (DER) is mandatory. The earlier sections of this report have shown how this requirement can be met by combination of energy efficiency improvements with a variety of low carbon and renewable technologies.

Further credits under the Energy category of the Code can be obtained for providing certain levels of CO_2 reduction through onsite generation of renewable energy. Although not mandatory, these credits are useful in reaching the overall score required to achieve Level 3. The Code states that 1 credit should be awarded for providing a 10% reduction of CO2 emissions by onsite renewables and 2 credits should be awarded if a 15% reduction of emissions is achieved (these emissions reductions are measured from a baseline for the dwelling calculated using the Standard SAP worksheet).

Richmond Upon Thames Core Strategy also requires that a 20% reduction of CO_2 emissions be provided by onsite generation of renewable energy (following the London Plan energy hierarchy). The PV system recommended for the Shakespeare's Terrace development has been sized to also meet this policy. In so doing, the level of onsite generation is also adequate to achieve the 2 additional credits under the Energy section of the Code.

Payback period:

The payback period for the installation of the PV system is considered below. The simple payback on the capital investment and the Net Present Value of the investment has been calculated. The NPV calculation assumes a discount rate of 10% over the lifetime of the technology. Initially the economics have been assessed assuming no additional financial incentives are available.

PV system capacity	9.5	kWp
Capital cost	42750	£
Annual maintenance cost	0.5%	of capital
Electricity import tariff	10	p/kWh
Electricity export tariff	4	p/kWh
% of output consumed onsite	50%	
Technology lifetime	25	years
Discount rate	10%	
Annual electricity generated	7600	kWh
Annual capital cost	1,732.32	£/yr
Annual maintenance cost	213.75	£/yr
Total annual cost	1,946.07	£/yr
Annual revenue	532.00	£/yr
Simple payback	134	years
NPV	-7,854	
Lifetime cost of CO2 saved	433	£/tCO2

Clearly investment in the PV system does not provide an economically attractive proposition based solely on offsetting of electricity demand and sale of excess electricity to the grid. However, the government has recently announced the renewable electricity Feed-in Tariff (FiT) for renewable electricity generators of up to 5 MWe capacity. Under this scheme, the operators of renewable electricity generating plant will be guaranteed an attractive tariff for every unit of renewable electricity generated, in addition to the value of sale of electricity to the grid and offsetting of onsite use. The level of tariff proposed for PV arrays of a size relevant to Shakespeare's Terrace is 31 p/kWh. The economics have been reassessed in light of the proposed FiT.

PV system capacity	9.5	kWp
Capital cost	42750	£
Annual maintenance cost	0.5%	of capital
Feed-in tariff	31	p/kWh
Electricity import tariff	10	p/kWh
Electricity export tariff	5	p/kWh
% of output consumed onsite	50%	
Technology lifetime	25	years
Discount rate	10%	
Annual electricity generated	7600	kWh
Annual capital cost	1,732.32	£/yr
Annual maintenance cost	213.75	£/yr
Total annual cost	1,946.07	£/yr
Annual revenue	2926	£/yr
Simple payback	16	years
NPV	24,182.65	£

The Feed-in Tariff significantly improves the economics of investment in PV. The simple payback period is now within the lifetime of the technology and, based on a discount rate of 10%, the investment is NPV positive over a 25 year period to around £24k.

Cost of carbon saved

The PV system specified for Shakespeare's Terrace is expected to save approx. 4,500kgCO_2/yr over a technology lifetime of 25 years. The cost of carbon saved has been calculated at £433/tCO_2.

Noise implications of the technology

The photovoltaic installation has very little expected impact in terms of noise. All devices in the system are solid state, with no moving parts. The noise impact on residents of the flats is expected to be imperceptible.

Available grants

Grants for Photovoltaics have been available through the Low Carbon Buildings Programme, however, the stream of the grant programme applicable for businesses (such as housing developers) has now closed for new applicants.

The programme remains open for householders, who may apply for a grant of £2000/kW of installed capacity up to a maximum of £2,500 or 50% of the total eligible costs, whichever is lower.