CENTRE FOR SUSTAINABLE ENERGY

Carbon 60

EST Innovations Programme – Feasibility Report

Mark Letcher

30 July 2003

Centre for Sustainable Energy
The CREATE Centre
Smeaton Road
Bristol BS1 6XN

Tel: 0117 929 9950
Fax: 0117 929 9114
Email: info@cse.org.uk
Web: www.cse.org.uk
Registered charity no.298740

Carbon 60 Feasibility study – final report

Table of contents

1 Project details

Project Name	Carbon 60
Lead Organisation	Sanford Housing Cooperative
Contact Name	David Flindall
Job title	Cooperative Support Worker
Address	11 Sanford Walk, New Cross London, SE14 6NB
Tel	0208 692 7316
Fax	0208 694 6461
E-mail	David.flindall@cds.coop
Can material be published	By prior arrangement with the SHC and the project partners. Results should not be taken out of context.

2 Partner details

Sanford Housing Cooperative – Lead partner

Centre for Sustainable Energy – Project manager

London Borough of Lewisham – Member of the project team.

South East London Energy Efficiency Advice Centre

For a full description of the partners roles please refer to Section 4.

3 Executive summary

This study has considered the options and potential for reducing the emissions of carbon dioxide from energy use at Sanford Housing Cooperative, in Lewisham, South East London.

Burning fossil fuels releases carbon dioxide into the atmosphere. Carbon dioxide is either released directly at the point of use as in a gas boiler, or indirectly as in the case of electricity where the carbon dioxide is released at the power station. The quantity of carbon dioxide depends on the fuel being consumed; for example for every unit of electricity generated coal releases more carbon dioxide than gas.

There is a growing consensus that the global climate is warming and that the emissions of carbon dioxide resulting from human activities such as the burning of fossil fuels are contributing to this process. Whilst it is not now possible to stop the process of climate change, the Royal Commission on Environmental Pollution has suggested that in order to cut the rate of change and to stabilise the situation it is necessary to cut emissions of carbon dioxide by 60% by the year 2050. This represents a huge reduction in emissions and change in the activities which cause emissions. The aim of this study was to consider if it is feasible to achieve this in social housing constructed in the early 1970's.

The study has considered the impact of four types of measures. Firstly, changes in the way energy is used, for example, how the central heating is set, secondly, the impact of energy efficiency measures such as loft insulation and low energy light bulbs, thirdly, the impact of renewable energy measures. These fall into two groups, those that generate energy directly on site such as solar water heating, and those that use renewable fuels such as wood. Fourthly, the study has considered the impact of switching from using electricity generated using fossil fuels to electricity generated from renewable sources such as wind and hydro-electricity.

The impact of these changes has been considered by developing an energy model of the houses and flats owned by the cooperative. The model enables the impact of measures to be considered in isolation and in any number of combinations. In each case the changes in the model are applied to the figures for the energy which is actually used in the cooperative and which has been estimated from the fuel bills.

The benefits of this approach are that it provides a flexible way of predicting the impact of major changes in the way energy is used and the structure of the buildings in question without having to construct them or calculate the impact from first principles. The limitation is that it is only a model, and so cannot predict exactly what impact the changes will have or take account of human behaviour. For this reason the predictions need to be treated with care, and considered in the context of the assumptions made and listed in the report.

The first stage in developing the energy model was to survey each of the 14 houses and 6 flats at the cooperative and to record the results in the NHER Site Surveyor software. Starting with the behavioural measures the changes were then applied to the model in the order given above.

The results of the feasibility study suggest that through a combination of a reduction in energy use through behavioural changes, and the installation of energy efficiency measures carbon dioxide emissions for SHC as a whole can be cut by nearly 30%. The addition of gas condensing boilers improves this to just under 45% and the further addition of green electricity to around 75%.

The study also suggests that a package of renewable energy measures comprising, biomass district heating, solar water heating, ground source heat pumps and photovoltaic panels, combined with behavioural and energy efficiency measures could reduce the total emissions of carbon dioxide by just under 70%. Through the additional use of green electricity carbon emissions can be cut by almost 100%.

Given that a number of the houses and flats now need essential maintenance and the potential for grant funding support for renewable energy measures from government programmes, the members of Sanford Housing Cooperative now have a choice as to how far reaching to make the prospective changes. That is whether to use the refurbishment as an opportunity to change the way energy is used through awareness raising and training, and to install energy efficiency measures and new gas boilers to make a substantial cut in carbon dioxide emissions, or whether to go further and install some or all of the proposed renewable energy measures and go far beyond the 60% target and reduce emissions to their lowest practicable level.

The costs and benefits of each route are discussed in the report which contains detailed conclusions and recommendations for further consideration.

4 Description of the feasibility study

4.1 Scope of study

Geographical scope: The focus of this study has been Sanford Housing Cooperative, which is located in Lewisham, South East London. The housing cooperative has fourteen houses in two terraces and one three-storey block of six flats.

Biomass resource assessment: The assessment of the biomass resources, described below, has extended as far as the boundaries of Lewisham Borough Council.

Approach: The approach to this study has been to consider the impact of behavioural and technical measures side by side.

4.2 Background

Sanford Housing Cooperative (SHC) was established in 1973, and opened in 1974. SHC has 131 members all of whom live at the site in Lewisham. SHC is one of an estimated 300 housing cooperatives in Greater London, and 1000 housing cooperatives in the UK. SHC was one of the first housing cooperatives established in the UK and has been a leading innovator within this sector since its launch.

A number of the properties are now in need of maintenance and refurbishment. SHC wanted to take this opportunity to go beyond the normal maintenance requirements and examine the feasibility of a 60% reduction in their emissions of carbon dioxide. It is proposed to achieve this by working with residents to reduce consumption through behavioural changes, through the introduction of energy efficiency measures, and the introduction of renewable energy measures.

4.3 Purpose of the study

The purpose of the study was:

- To examine the feasibility of achieving cuts of this magnitude.
- To propose a plan for achieving these by integrating behavioural measures, energy efficiency measures and renewable energy measures.
- To provide estimates of the costs and achievable reductions in carbon dioxide emissions.

4.4 Aims and objectives for the lead organisation and any partners

Sanford Housing Cooperative: In addition to fulfilling the objectives set out above, SHC is planning to use this project as the starting point for a sustainable energy strategy, and to put itself at the forefront of tackling climate change.

Centre for Sustainable Energy: CSE's aims were to meet the brief of the client and funders and to see the project move from feasibility to implementation.

Lewisham Borough Council: LBC wishes to support SHC in cutting CO_2 emissions and developing a Sustainable Energy Strategy. LBC feels there is good tie in between this project and other activities and strategies within the borough.

4.5 Role of partners in the feasibility study

Partner Organisation	Role
Sanford Housing Cooperative	Lead partner, owner and landlord of 14 houses and 6 flats in Lewisham.
Centre for Sustainable Energy	Project Manager, technical consultant and training provider
London Borough of Lewisham	Member of the advisory team. Consultant on biomass resource, and planning issues.
South East London EEAC	Not a formal partner, but the EEAC has been kept informed of activities through Richard Hurford who is the EEAC manager.

4.6 Programme of work/methodology

4.6.1 Project brief

In considering the objective of cutting carbon dioxide emissions by 60%, Sanford Housing Cooperative asked CSE to be radical, make a statement, rule out no measures and to present a plan which would result in minimal disruption to residents at the implementation stage.

4.6.2 The use of an energy hierarchy

CSE's approach to the target for cutting CO_2 emissions has been to use a hierarchy in the application of energy efficiency and renewable energy measures. This means that measures have been applied in the following order:

i Behavioural measures
ii Energy efficiency measures
iii Renewable energy measures
iv Green electricity supply

There are several reasons for this. Behavioural measures are largely about reducing waste. As such they generally cost nothing, but as is shown below offer the potential of large savings. Research on other projects has shown that they can also have a strong knock on effect, which means that as residents become more aware of energy use at home, their awareness will also increase in other areas, such as work.

Energy efficiency measures have been considered next. This is partly to reduce waste, for example through uninsulated walls, but also to reduce the total demand for heating and summer time cooling.

The behavioural and energy efficiency measures provide good financial savings and paybacks on investment.

The final option is to consider renewable energy measures, once the consumption levels have been reduced through the use of behavioural and energy efficiency measures.

In some cases, other factors such as health and safety considerations have limited the proposed measures, as described below.

The order in which measures are applied is important as it has an impact of the relative weighting of CO_2 reductions and the total reduction in emissions.

For example, to take the case of reducing the set point temperature of the thermostat in a house by one degree C, applying this measure to the house as it is (with a gas boiler of 15 years + in age), will result in a reduction in carbon dioxide emissions resulting from reduced gas consumption. However, if we were to assume that the gas boiler was substituted for a biomass (wood) boiler, and then apply the change, the overall reduction in CO_2 would be smaller. This is because the carbon dioxide emissions from wood (from a managed source) per kWh are lower than those for gas.

For the reasons stated above, measures have been applied according to the hierarchy. The report shows the impact of applying measures at each level of the hierarchy and the impact of applying measures at different levels in the hierarchy in combination.

It should also be noted that the overall impact of applying the measures together is lower, than the summation of the impact of individual measures.

4.6.3 Overview of project methodology

The approach in this project has been to use consumption data to calculate current carbon dioxide emissions for each property and SHC as a whole. Actual emissions were then compared to modelled emissions using NHER Surveyor. The thermal model of each property was then used to examine the impact on CO_2 emissions of a variety of measures. Relative changes in the model were then applied to the actual consumption data.

Considering these steps in more detail, firstly, the data from fuel bills for the previous two years has been used to give an estimated annual running cost, and the estimated annual consumption of gas and electricity in each property. From these figures the estimated annual carbon dioxide emissions for each fuel, and the total estimated annual carbon dioxide emissions for all properties were calculated.

Secondly, each house was modelled using NHER Surveyor. In addition to providing NHER and SAP ratings the software provides predicted running costs and carbon dioxide emissions, and predicted annual fuel usage for gas and electricity.

The software was then used to model the impact on fuel usage and carbon dioxide emissions of behavioural changes in energy usage, and the addition of energy efficiency, renewable energy measures and green electricity, to a given property.

In order to achieve the overall target of a 60% reduction in Carbon Dioxide emissions a series of changes were applied, to each property, which are detailed in section 4.6.6, below.

With each iteration the relative (percentage) change in the NHER modelled electricity and gas consumption was calculated. The percentage change in gas and electricity consumption was then applied to the figures for estimated annual gas and electricity consumption (from fuel bills) for each property and from this revised carbon dioxide emissions were calculated for the property.

4.6.4 Rationale for the selection of energy efficiency and renewable energy measures

Energy efficiency measures

SELCHP – South East London Combined Heat and Power Plant Ltd

SELCHP is a waste incineration plant based in Deptford. The plant processes 420,000 tonnes of rubbish per annum and produces heat and power through a CHP plant. SELCHP plans to provide heat to 13,500 houses though the timescale for this and location of the housing stock was not clear at the time of the study. SELCHP has the following share holders, ONYX, CNIM, London Electricity, London Borough of Lewisham, London Borough of Greenwich, and Viterra Energy Systems.

SELCHP is visible from SHC, and CSE discussed the possibility of using heat from the plant at SHC. The idea was discounted early on in the study for a number of reasons.

- The plant is separated from SHC by a railway line on a raised embankment.
- There is currently no heat main from the plant from which heat could be drawn via a spur. It was considered to be uneconomical to construct a heat main solely for a development of the size of SHC, though it would be worth considering this further if a heat main was to be brought into the area for other housing.
- A number of SHC members felt strongly that SELCHP should not be considered as part of this study.

Other Energy Efficiency measures

As described above all the energy efficiency measures have been applied in the context of an energy hierarchy. With the exception of additional external wall insulation in the flats (see below), all the energy efficiency measures are standard measures applied in a conventional manner. The aim has been to improve the thermal efficiency of the building envelopes in order to reduce energy demand, prior to specifying renewable energy options. The other consideration which has applied throughout was the need to minimise disruption to residents, during installation. This has ruled out measures such as internal wall insulation/dry lining. The measures are listed and detailed below.

Renewable Energy Measures

The renewable energy measures being considered here are biomass district heating and solar water heating in the houses and ground source heat pumps and PV in the flats. The use of Green Electricity tariffs has been considered for the cooperative as a whole.

Biomass in this case refers to the use of wood chip. It has been considered for several reasons:

- When derived from managed (and sustainable sources) it is a very low CO_2 fuel, with emissions being confined to processing and transportation.
- Lewisham Borough Council have a surplus of wood chip from arboriculture and tree management works in the borough. Initial enquiries suggest that this could be free or available at low cost.
- There is widespread interest in the use of wood nationally.
- There are companies offering heat from biomass under contract, meaning that high capital outlays can be avoided.
- There is grant funding available through the Clear Skies Programme.
- There is sufficient land available for the construction of boiler housing and storage/drying facilities.

Solar water heating: For this project there are arguments in favour of and against solar water heating. Those against are that the roof pitches of the two housing terraces face west and east. Only the flats have a south facing roof pitch.

If it is assumed that biomass heating is installed and that this provides top up water heating, then the total CO_2 off-set by solar water heating is negligible. However, this will always be the case where SHW is combined with other renewable measures used for heating.

The reasons that it has been proposed here are:

- As a renewable energy technology, it is ‘mature’ having been commercially available for over 30 years, and it is reliable.
- When combined with biomass heating, it means that the biomass system can be designed to be shut down in the peak summer months, which avoids the system having to run at partial loads, i.e. less efficiently. (It is assumed that an additional hot water top-up is provided by an electric immersion heater on a green electricity tariff. An alternative arrangement is that hot water is supplied by the gas boilers which are designed to back up the biomass boiler). This also reduces losses through the distribution pipe work.
- Though the yield is 20-25% lower for an east west solar system, this can be ‘designed out’ by increasing the size of the collectors. Alternatively, a larger area of panels can be installed on the West pitch only.
- If installed at the same time that other roofing work is undertaken as is the suggestion here, some of the installation costs are removed. If the collectors are flashed into the roof, then there is a small saving in the roof covering (tiles or slates) which are not required.
- Solar collectors would provide a very visual statement about renewable energy at SHC, particularly from the railway line which runs to the west of the cooperative.
- If installed with remote sensors showing the performance of the system, SWH can be noticeable and visible to residents, in a way which biomass heating may not be. There is anecdotal evidence that renewable energy measures such as SWH can have a strong effect of raising awareness and interest about energy and modifying the manner in which it is used in a way that energy efficiency measures cannot.
- There is funding available through the Clear Skies programme.

Ground Source Heat Pumps (GSHP’s): A heat pump is a means of taking low temperature heat and upgrading it to a higher more useful temperature, so that it can be used to provide space and water heating. Though still relatively unfamiliar in the UK, over half a million systems have been installed world wide and 66,000 are installed annually.

For every unit of electricity used to drive the heat pump, between 3 and 4 units of useful heat energy is extracted from the ground. Because the ground is warmed by the sun, GSHP's are extracting a form of solar energy which is renewable.

As with the other technologies there are arguments for and against GSHP's. The main arguments against this technology are that the capital costs for installed systems tend to be high. This is partly due to the relatively low volume of systems installed in the UK annually, and partly due to the requirement to design systems specifically for each installation.

The reasons for considering the technology here are:

- They are quiet, efficient, have a long life and low maintenance requirements and when operated with a green (off peak) electricity tariff or when combined with PV – (see below) provide a virtually carbon neutral source of space and water heating.
- As a less established technology in the UK they are high profile, and will help to raise the profile of SHC, if installed.
- They provide a useful contrast to the biomass heating proposed for the houses.
- There is land available for siting horizontal trenches or vertical bore holes to set the coils to extract the heat from the ground.
- Two further factors to be considered is that large GSHP's (above 8kW) require a three phase electricity supply. GSHP's are best suited to very well insulated buildings. This is covered in further detail below.

Photovoltaic panels (PV): The purpose of specifying photo-voltaic panels in this case is to generate sufficient electricity to offset the energy demand of the Ground Source Heat Pump, over a twelve month period.

The PV system will generate most electricity in the summer months and the heat pump will be in greatest use during the winter months. For this reason, and because of night time usage, it is not feasible for the PV system to directly supply the energy requirements of the GSHP.

At times when the PV system is generating more power than is required in the flats and houses the surplus will be exported to the local distribution grid, at a price to be agreed with the energy supply company. During those times when the demand from the GSHP outstrips supply from the PV system, this will be drawn from the mains in the normal manner. In effect the local distribution network, is treated as an accumulator for the energy generated from the PV system.

PV technology has been commercially available since the space programme in the 1960's. At present time the cost per kW is high (£7 to £12 per peak watt installed). However, the government believes that it is on the point of becoming 'market ready' and is providing grant funding to increase the rate of take up through the DTI PV Grants Programme.

CSE have included it in recommendations for this project for the following reasons.

- The most cost effective time to install PV is when re-roofing work is required, as in the case of the flats, and when grant funding is available, which it is at present.
- A PV roof on the south facing side of the flats will make a very visual statement about the use of renewable energy, which will be visible from the railway line running to the west of SHC.

- Whilst it would be possible to operate the GSHP from a supply of 'green' electricity, installing PV adds a small, but measurable amount to the total installed renewable energy capacity in the UK as a whole. Purchasing 'green' electricity as a relatively small domestic consumer may not lead directly to an increase in the total capacity of the supply.
- PV if combined with appropriate monitoring is another means of raising awareness and interest in energy amongst residents.

Green electricity supply: 'Green electricity' is the last measure to be considered in the energy hierarchy for the reasons given above. It has been used to eliminate the CO_2 emissions resulting from lights and appliances. Care needs to be taken when selecting a supplier. There are many shades of green, depending on the generating mix. For example members of the cooperative will need to decide whether they wish to buy electricity from a supplier which includes energy from waste in their mix. Further information can be obtained from www.greenprices.com

4.6.5 Scope, assumptions and limitations of the energy modelling

The energy modelling in this project has been based on NHER Site Surveyor. Whilst the National Home Energy Rating system provides a useful and flexible tool, it has a number of limitations which need to borne in mind when considering the results of the study.

- The principal assumption in the use of the model is that changes made to the model will have proportionally the same impact in the dwellings themselves.

- The NHER model is based on site survey of the properties and any supporting information which is available at the time, which in this case was a rough site plan. As it is not possible to look inside the structure of key elements such as the walls, assumptions must be made about items such as cavity wall insulation.

- When considering the Base Case, in some houses the model has agreed closely with the actual consumption based on fuel bills. In others there is significant variation. This is partly because of the limitations in modelling the way residents use energy at home, and partly because there was an incomplete set of billing data, which meant that figures had to be averaged from the data which was available. (See the section below).

- There are certain parts of the NHER programme where the ability to specify features in the building being modelled are limited. For example, the greatest depth of loft insulation which can be specified is >150mm. Similarly it is not possible to specify the thickness of external wall insulation, this is simply recorded as being present or not.

- In measuring the impact of renewable energy measures on carbon dioxide emissions CSE has made the following assumptions:

Biomass and Solar Water Heating

- District heating with no CHP – The model has assumed that the heat demand and load profile is insufficient to make CHP economical.
- The boiler has a variable flow, with pre-insulated pipes.

- There will be some link between energy consumption and the price payable by residents' and controls will include a programmer and TRVs.
- The required storage capacity for each house is estimated to be 400 litres of storage, with minimum of 50mm spray foam tank insulation.
- The hot water heating is supported by an 8m^2 east/west solar hot water system (for each house). The NHER programme does not allow you to specify the roof orientation or pitch of a solar water heating system. Therefore, it has been assumed that an 8m^2 system would perform comparably to an area of 6.5m^2 on a south facing roof.
- The NHER programme assumes that the biomass system will top-up the solar hot water heating system in the summer months. However, due to the reduced heat demand placed on the boiler in summer, it may be more economical to shut the boiler down for 3 to 4 months and back up the solar hot water system with a dual immersion or modular gas boiler backup.

Ground Source Heat Pump

- The heat pump has been specified as a ground to water heat pump.
- The model has assumed that each flat would be fitted with its own heat pump. The reason for this is that it is not possible to model a single, district, ground source heat pump using the NHER software. In reality it is likely to be more practical to install a single system for all the flats. This would require a three phase supply on site. If not already available the cost of installing this is estimated to be £6-8000.
- The heat emitter has been entered as radiators, as Sanford's suspended concrete floors would make under floor heating more expensive and disruptive to install.
- The controls would consist of a room thermostat, programmer and TRVs.
- The heat pump would be used in conjunction with an Economy 7 tariff.
- The heat pump would contain an integral 110 litre hot water cylinder with 50mm spray foam insulation and dual immersion. It has been assumed that these specifications are similar to the Calorex heat pump that GeoScience specified for Sanford's flats, which has an integral hot water tank.
- The PV array will be sized to meet the heat pump's electricity demand
- Ground source heat pumps are most appropriate in well insulated properties. Therefore the flats have been modelled as being super insulated with cavity wall insulation and an extra 100mm of external insulation. The NHER software does not provide the facility to specify the thickness of the property's external render, but only that the property has been insulated externally.

Green Electricity

- The NHER programme does not provide the facility to enable users to select green electricity as a standard tariff. Therefore, as part of our calculations we have assumed that the associated emissions are zero CO_2, and Sanford would experience a tariff comparable to ecotricity[1].

4.6.6 Detailed methodology

The detailed methodology can be broken down into six stages.

[1] ecotricity green tariff is charged at 6.97p per kWh, which includes standing charges.

- Assess the base case – that is energy use, running costs and carbon dioxide emissions before any further changes are made.
- Model the impact of behavioural changes on energy consumption and carbon dioxide emissions
- Model the impact of a package of energy efficiency measures
- Model the impact of a package of renewable energy measures,
- Model the impact of green electricity supply.
- Undertake questionnaire survey of SHC members

Each stage is described in more detail below:

i Stage 1 – assess and model the base case

This was done by:

a) Calculating the estimated annual consumption of gas and electricity for each property from fuel bills.

   In doing this it was necessary to take account of anomalies which affect the overall consumption figures and patterns. These included the use of external appliances such as pond pumps and street lighting which are metered with the domestic electricity supply for some properties, and damaged heating controls which artificially raised the gas consumption in one property. The set of fuel bills was also incomplete and in some cases it was necessary to take average figures from other properties of the same type.

b) Estimating the average annual running costs and carbon dioxide emissions for each property from the fuel bills.

   This was done as follows: CSE were provided with two winter quarter bills for both gas and electricity. There was a period of twenty one months that had elapsed between each quarterly bill. Therefore, in order to obtain an estimation of yearly consumption for both fuel types, average winter consumption was calculated from the two winter bills. This was then removed from the consumption during the elapsed period of twenty one months, which effectively left two summer, spring and autumn periods of consumption or eighteen months. This was then divided to calculate an average summer, spring and autumn period for both fuel types. An annual figure for both fuel types was then calculated by adding the winter and summer, spring and autumn averages.

c) Calculating the total annual average running costs and carbon dioxide emissions for all the SHC properties, based on figures of 0.43kg of CO_2 per kWh for electricity and 0.19kg of CO_2 per kWh for gas.

d) Using NHER Surveyor to give predicted running costs, consumption figures for gas and electricity, and carbon dioxide emissions for each property. *(Consumption figures for gas and electricity are given in GJ, and were then converted into kilowatt hours).*

e) Comparing the actual and modelled base cases, for each property and for all SHC properties.

The NHER assessments were completed by undertaking site surveys in March 2003 of each of the SHC properties. This is a two-part process. Firstly, properties are surveyed following a standard procedure and template. Secondly, the survey data is entered into a computer programme (NHER Site Surveyor) from which the model is produced.

The set point of the room thermostat in each property and the heating pattern set on the heating programmer, was recorded and inputted into the NHER programme. This provided a snap-shot of the way in which the heating system was used in each house.

ii Stage 2 – model the impact of behavioural changes on energy consumption and carbon dioxide emissions

The term 'behavioural changes' encompasses all aspects of energy use where the occupant of a building has influence over how energy is used. It includes for example the use of lights, appliances and heating systems.

For the purposes of this study behavioural changes have been confined to the use of the heating system alone, as these can be modelled using the NHER software. For this reason it is anticipated that there could be additional savings from better use of lights and appliances, and therefore the figure given is an underestimate of the total saving which could be made in this area.

The impact of behavioural changes was modelled as follows:

a) The base case NHER model for each property was modified for a set point (the temperature at which the room thermostat is set) of 21 degrees C, and heating set times for a standard pattern. The NHER programmes standard heating pattern is 2 hours in the morning, following an evening period of 7 hours on week days and a set time of 16 hours each day at weekends.
b) The percentage change in the predicted (modelled) gas and electricity consumption was noted, together with the change in predicted running costs and carbon dioxide emissions.
c) The revised modelled gas consumption, electricity consumption and carbon dioxide emissions for all the SHC properties were calculated.
d) The percentage change in gas and electricity consumption from the model was applied to the estimated annual gas and electricity consumption previously calculated from fuel bills for each property.
e) Revised average annual running costs, gas and electricity consumptions and carbon dioxide emissions were calculated for all SHC properties.
f) Revised average annual carbon dioxide emissions for gas and electricity, and total carbon dioxide emissions for both fuels were recalculated.
g) The process was repeated for a set point of 20 degrees C. Following further discussions with SHC it was agreed that 20 degrees C should be used as the set-point for all further modelling. The set-point corresponds to the Zone 1 temperature in the NHER software. The default Zone 1 temperature for NHER is 21 degrees C. It is noted that this is both a challenging target and one degree lower than the temperature recommended in the living room for most social housing. The final figure around which any energy systems are designed will be a matter for the members of the SHC.

iii Stage 3 – modelling the impact of energy efficiency measures on energy consumption and carbon dioxide emissions

The third stage was to examine the impact on consumption figures and carbon dioxide emissions of introducing a package of energy efficiency measures.

These have been modelled in their own right, that is the **Base Case plus Energy Efficiency Measures**, and in conjunction with the Behavioural Changes, that **is Base Case plus Behavioural Changes plus Energy Efficiency measures.**

The following energy efficiency measures were modelled:

Houses

- Increase in loft insulation from 25 mm to >150 mm[2]
- Cavity Wall insulation
- Low energy lighting to be increased from current levels of 40% to 90%
- Fitting new half double glazed front doors with integral draught-proofing and low-e double glazing
- Upgrading existing hot water tank insulation to 50 mm of spray foam.
- Humidity controlled passive ventilation.[3]
- Low energy extractor fan in the kitchen.[4]
- Low energy extractor fan in the bathroom.[5]

Flats

- Increase in loft insulation from 25 mm to >150 mm in the two top floor flats
- Cavity Wall insulation
- Low energy lighting to be increased from current levels of 40% to 90%
- Upgrading existing hot water tank insulation to 50 mm of spray foam.
- Humidity controlled passive ventilation.[6]
- Low energy extractor fan in the kitchen (see footnotes for houses).
- Low energy extractor fan in the bathroom (see footnotes for houses).

In the first instance the list above included switching the existing electric cookers to gas cookers. However, following discussions with SHC electric cookers have been retained on health and safety grounds.

In addition to the insulation measures listed above the impact of a gas condensing boiler in each dwelling on consumption and carbon dioxide emissions has also been considered. As the existing boilers are over 15 years in age, this measure makes a big impact on carbon dioxide emissions. As the replacement of gas central heating is an option discussed below we have shown the impact of the energy efficiency measures with and without the gas condensing boiler.

---

[2] NHER Site Surveyor software does not provide a facility to specify the thickness of loft insulation greater than 150 mm, but will allow users to enter > than 150 mm.

[3] See recommendations regarding humidity controlled passive stack ventilation in each house

[4] See recommendations regarding low energy heat recovery extractor fans in the kitchen. The NHER model will not allow users to enter low energy heat recovery extractor fans.

[5] See recommendations regarding a low energy and low noise humidity controlled extractor fan in the bathroom. The NHER model will not allow users to enter low energy humidity controlled extractor fans specifically in the bathroom.

[6] See recommendations regarding a humidity controlled passive stack ventilation unit for the upper landing area of the flats.

The energy efficiency measures and the Behavioural Changes were combined at a set point of 21 degrees C and 20 degrees C. As discussed above it was agreed to standardise on 20 degrees C.

Thus, the following scenarios have been modelled at this stage:

i. Base Case plus Energy Efficiency measures, excluding gas condensing boiler
ii. Base Case plus Energy Efficiency measures including gas condensing boiler

And

1st. Base Case plus Behavioural Measures plus Energy Efficiency measures, excluding gas condensing boiler
2nd. Base Case plus Behavioural Measures plus Energy Efficiency measures, including gas condensing boiler

In all cases above, we have assumed that electric cookers are retained and a Zone 1 set point temperature of 20 degrees C.

The step by step methodology is as follows:

<u>Base Case plus Energy Efficiency Measures excluding gas condensing boiler</u>

a) The NHER model for each property was modified to incorporate the energy efficiency measures listed above.
b) The percentage change in the predicted (modelled) gas and electricity consumption was noted, together with the change in running costs and carbon dioxide emissions.
c) The revised modelled gas consumption, electricity consumption and carbon dioxide emissions for all the SHC properties were calculated.
d) The percentage change in gas and electricity consumption from the model was applied to the average annual gas and electricity consumption previously calculated from fuel bills for each property.
e) Revised average annual carbon dioxide emissions for gas and electricity, and total carbon dioxide emissions for both properties were recalculated.
f) Revised average annual running costs, gas and electricity consumptions and carbon dioxide emissions were calculated for all SHC properties.

The steps above were repeated for each of the following scenarios.

<u>Base Case plus Energy Efficiency Measures plus gas condensing boiler</u>
<u>Base Case plus Behavioural Measures plus Energy Efficiency measures, excluding gas condensing boiler</u>
<u>Base Case plus Behavioural Measures plus Energy Efficiency measures, including gas condensing boiler</u>

iv Stage 4 – model the impact on gas and electricity consumption of renewable energy measures

As with the previous stage these changes have been modelled in their own right, and in conjunction with the behavioural and energy efficiency measures. In all scenarios the electric cookers are retained.

The renewable energy measures considered are as follows:

<u>Houses:</u>

Biomass (wood chip) district heating and solar water heating

<u>Flats:</u>

Ground source heat pumps and PV.

Further details of the measures are given in Section 4.7.3. In terms of the model several points should be noted:

a) It is assumed that the biomass system will not be used during the 3 peak summer months, when space heating is not required. During this period it is assumed that hot water will be provided by the solar water heating systems with additional top up from an immersion heater.
b) The solar hot water system will be an East West system due to the orientation of the houses.
c) That the PV on the flats will be used to generate sufficient electricity to balance the electricity consumed in running the Ground Source Heat pump, over a twelve month period.
d) That the flats will be super-insulated with 100mm of external wall insulation to reduce the overall heat demand in conjunction with the Ground Source Heat Pump.

The step by step methodology for this stage is as follows:

<u>Base Case + Renewable Energy Measures</u>

a) The NHER model for each property was modified to incorporate the renewable energy measures listed above. *(N.B. this includes an additional 100mm of external wall insulation for the flats).*
b) The percentage change in the predicted (modelled) gas and electricity consumption was noted, together with the change in running costs and carbon dioxide emissions.
c) The revised modelled gas consumption, electricity consumption and carbon dioxide emissions for all the SHC properties were calculated.
d) The percentage change in gas and electricity consumption from the model was applied to the average annual gas and electricity consumption previously calculated from fuel bills for each property.
e) Revised average annual carbon dioxide emissions for gas and electricity, and total carbon dioxide emissions for both properties were recalculated.
f) Revised average annual running costs, gas and electricity consumptions and carbon dioxide emissions were calculated for all SHC properties

The steps above were repeated for the following scenario:

Base Case + Behavioural Measures + Energy Efficiency Measures + Renewable Energy Measures

v Stage 5 – model the impact of green electricity supply to all SHC properties

This is the final stage of the energy hierarchy described above.

It has been assumed that the existing brown electricity supply is replaced by a Green Electricity supply which is 100% renewable and which does not include waste incineration in the fuel mix.

The step by step methodology for this stage is as follows:

Base Case + Behavioural Measures plus Energy Efficiency measures, including gas condensing boiler and green electricity

a) The NHER model for each property was modified incorporating the energy efficiency measures listed above.
b) The percentage change in the predicted (modelled) gas and electricity consumption was noted, together with the change in running costs and carbon dioxide emissions.
c) The revised modelled gas consumption, electricity consumption and carbon dioxide emissions for all the SHC properties were calculated.
d) The percentage change in gas and electricity consumption from the model was applied to the average annual gas and electricity consumption previously calculated from fuel bills for each property.
e) Revised average annual carbon dioxide emissions for gas and electricity, and total carbon dioxide emissions for both properties were recalculated.
f) Revised average annual running costs, gas and electricity consumptions and carbon dioxide emissions were calculated for all SHC properties.
g) The annual running costs for electricity were then modified to incorporate a green electricity tariff.
h) The carbon dioxide emissions associated with electricity use were assumed to be zero.
i) Revised annual carbon dioxide emissions for electricity were then calculated, and total carbon dioxide emissions for both properties were recalculated.
j) The total change in actual average annual carbon dioxide emissions for all properties was calculated.

The steps above were repeated for the following scenario:

Base Case + Behavioural Measures + Energy Efficiency Measures + Renewable Energy Measures + Green Tariff.

vi Survey of SHC members

A brief survey of members of SHC was undertaken to gauge the level of understanding and interest in the use of energy.

The survey was developed in collaboration with 6 members and the Housing Support Worker, and distributed by hand to all members.

The results of the survey may be found below in Section 4.7.

4.7 Results

The results of the feasibility study are presented as follows:

- Findings from the site surveys
- Results of modelling the impact of measures
- Estimated costs and savings for recommended measures
- Grant funding
- Technical considerations and assumptions relating to energy efficiency and renewable energy measures.
- Findings from consultation with residents

4.7.1 Findings from the site survey

During the three days spent on site a number of issues were noted:

i. Residents have a tendency to have the heating set to a very high temperature, (23-26 degrees C), and the windows open.
ii. Ventilation in the upstairs corridors and in the bathrooms is poor.
iii. The perception of what temperature the heating is set at can be as important as the temperature itself. In one house, the thermostat had been ‘modified’ so that it appeared to be set at 23 degrees C, when it was in fact set to 19 degrees C. Residents did not appear to have noticed or compensated for this change by resetting the thermostat.
iv. Residents find the existing hot water tank too small for 10 people.

4.7.2 Results from modelling the impact of measures – changes in modelled gas and electricity consumption applied to actual gas and electricity consumption estimated from fuel bills, with CO_2 emissions calculated from revised gas and electricity consumption

Scenario	Green Elec.	Gas kWh	Electricity kWh	Total Annual Bill £	Total CO2 (t)	Reduction (t)	% Reduction	Reduction in Buses
Baseline	No	798368	183058	£22,596	235	n/a	n/a	n/a
Behavioral (20oC)	No	705386	183058	£19,815	217	18.0	-7.7%	102
Energy Efficiency Measures	No	524118	171333	£17,300	177	58.2	-24.8%	330
Energy Efficiency Measures (20oC)	No	472532	172553	£16,858	167	67.7	-28.8%	384
Energy Efficiency & Cond. Boiler (20oC)	No	292209	173783	£15,128	133	102.2	-43.5%	579
Energy Efficiency & Cond. Boiler (20oC)	Yes	292209	173783	£16,086	57	178.3	-75.9%	1010

Scenario	Green Elec.	Biomass kWh	Electricity kWh	Total Annual Bill £	Total CO2 (t)	Reduction (t)	% Reduction	Red. Buses
Renewables Only	No	322278	202507	£12,574	79	156.2	-66.5%	885
Renewables & Energy Efficiency Measures (20oC)	No	193295	192379	£12,029	74	160.9	-68.5%	912
Renewables & Energy Efficiency Measures (20oC)	Yes	193295	192379	£12,941	0	235.0	-100.0%	1332

Annual Saving based on Renewables, Energy Efficiency and Behavioural Changes	£9,656

N.B. Annual savings and CO_2 reductions are calculated, please refer to text and conclusions for discussion of results.

Notes:

Reduction in buses: Refers to the total reduction in CO_2 in tonnes converted into volume and equated to the number of double decker buses.

4.7.3 Details of Renewable Energy Measures

Biomass district heating

- The exact specification of the biomass district heating will depend on the design proposed by the contractors invited to tender for the installation. However, it is envisaged that the system would have the following features.

- A biomass boiler burning wood chip and supplying heat to the houses on site via a district heat main. Heat would be supplied to each house via a heat exchanger which takes the place of a boiler, and is similar in size to a wall hung gas boiler. The heat exchanger supplies the hot water for the radiators (normally on a separate circuit) and to top up the hot water (when the solar system is unable to provide sufficient heat).

- The wood chip boiler is supported by one or more gas boilers. These are used to provide additional heat during periods of exceptional demand (for example during an abnormal cold spell), or when the biomass boiler is shut down for maintenance or servicing. The system is designed such that the gas boilers can match the maximum heat demand if the biomass boiler is out of service.

- Unlike a gas boiler which can be turned on or off as required, a biomass boiler is designed to run continuously. Whilst the heat output from a biomass boiler can be reduced to down to 15-20% of the maximum output, the boiler is at its most efficient when operating at full load or as close to it as feasible. For this reason, during the warmest three months of the year, the system may be designed such that the biomass boiler is shut down. During this time, there would be no demand for space heating. Hot water would primarily be supplied by the solar water heating systems on the houses, backed up by immersion heaters. In the event of a sudden cold spell, when space heating is required, this would be supplied by the gas boilers feeding the district heating system.

- It should be noted that in the NHER model used here, it is assumed that for the purposes of supplying hot water, the solar hot water system will be backed up by the biomass district-heating scheme. Therefore, the estimates for the volume of fuel required (wood chip) and storage space needed are based on the boiler operating throughout the year. This should provide a approximate indication of both wood chip required and storage space needed, as the summer fuel demands are likely to be relatively low. The implementation phase will include a detailed feasibility report that will provide accurate indications of fuel required and storage volume.

- It is assumed that wood chip would be supplied ‘wet’ and stored in purpose designed drying sheds prior to being burnt. Most boilers are automatically fed via an auger feed. The quality of the wood chip and moisture content is important. ‘Slithers’ need to be screened out as they can clog the auger feed. The moisture content of the wood needs to be between 20 to 30% to ensure efficient combustion.

- Based on an estimated annual energy demand of approximately 173000 kWh the size of the biomass boiler is estimated to be 200kW maximum output.

- The size of the biomass boiler to be specified will be dependent on a number of factors:

    - The thermal efficiency of the properties to be heated.
    - The design temperature of the houses, e.g. 20 or 21 degrees C.
    - The proportion of the total heat demand which is to be met by the biomass boiler, as opposed to the back up gas boilers.
    - The number of months a year the system is to be operational.

- For the reasons above, the figure given here is an estimate and a design survey will be required prior to specifying the final system. The factors above will effect the size and capital cost of the specified system.

- Based on an assumed seasonal system efficiency of 80%

- The estimated consumption of the boiler is estimated to be 58 tonnes of wood chip assuming moisture content of 25%.

- 58 tonnes of wood chip at moisture content of 25% equates to 96 tonnes of wet wood chip per annum at a moisture content of 50%.

- Assuming a packing density of 0.35 this equates to a volume of 274 m^3

- Allowing 6 months for the wet wood chip to reach the required moisture content, this gives an estimated storage volume of 137 m^3

- This is roughly equivalent to a storage shed 18 x 5 x 1.5 m in dimension.

Solar water heating system

- The specification of the solar water heating system needs to be drawn up in parallel with the biomass district heating so that the two systems are designed to operate in combination.

- A solar water heating system will normally be designed to provide 50% of the domestic hot water requirements over a 12 month period. The orientation of the houses means that a greater area of collectors will be required to achieve this than if the houses had a south facing roof pitch.

- As re-roofing work is required on the houses the solar collectors will be roof integrated. CSE recommends that the systems be fitted with a remote temperature sensor and control panel, so that residents can adjust their water use to get the most from their solar system. If systems are designed such that the pump is powered by a PV panel this will eliminate the ‘parasitic’ losses from the energy used to drive the pump.

- All solar systems should be fitted with mixer valves to prevent scalding in the summer and if a mains pressure system is fitted low flow shower heads should be fitted to minimise hot water usage.

- Based on an estimated daily hot water usage of 40 litres per person, and tank of 320 to 400 litres would be required depending on whether the house had 8 or 10 residents. Additional monitoring may be required to ascertain if the estimated daily water usage is realistic.

(N.B. the final tank size should be checked with a structural engineer before specification to check that the floors are capable of supporting the weight of the tank).

- With a tank of 400 litres a solar collector area of approximately 8 m^2 would be required for a south facing roof. The size of the collector is dependent on its efficiency. The estimate of $8m^2$ is based on a flat plate collector. It is recommended that suppliers should required to specify the tank and panel size for their own systems based on hot water requirements for the house.

- Allowing for the orientation of the houses and a reduced system efficiency of 80%, the estimated area of solar collectors is $10m^2$.

(N.B. The NHER model has been calculated based on an $8m^2$ east/west system with a 400 litre storage tank, which would equates to a $6.5m^2$ south facing system. The installed solar hot water heating system would be backed up by a dual immersion to meet any additional hot water demands during the summer months when the biomass boiler is not operational. The implementation phase will include an accurate survey of hot water usage and report detailing the solar system specification.)

Ground source heat pumps

- There are two options for the use of Ground Source Heat pumps to provide space and water heating in the flats. Firstly, a heat pump is fitted in each flat to provide space heating and hot water. The advantages of this set up are; independent control by the resident and no requirement for a three phase supply to the flats. However, it would mean disruption to each flat during the installation phase and a reduction in the space within each flat; it would also require more complicated pipe work to connect the ground source heat pump to the external collector.

- The alternative arrangement is for a single heat pump to supply heating and hot water to all six flats in the same way the existing boiler does. The advantages of this approach are less internal disruption and no loss of space in four of the flats. The main disadvantage is that a three phase power supply would be required for a larger heat pump.

- In both cases, the heat pump would not be designed to meet the maximum heat demand, as it is more cost effective to meet a proportion of this and to rely on electric top up heating via an immersion heater for times of exceptional demand.

- The heat pumps are connected to the ground heat exchanger which extracts low grade heat from the ground. The ground heat exchanger is a closed system of pipes through which an antifreeze mixture is pumped. The pipes can either be laid in horizontal trenches or vertical bore holes. The greater the heat demand the longer the ground heat exchanger needs to be. In this case there would appear to be insufficient space close to the flats for the use of horizontal trenches and vertical bore holes are a more likely option.

Photovoltaic panels

- The purpose of the PV system is to meet the energy requirements of the Ground Source Heat pump. It is assumed that the PV system would be integrated into the south facing roof of the flats, however as this is too small to accommodate a full array it is assumed that PV panels would be integrated into the roof of the proposed community building.
- The estimated annual space and water heating demand for the six flats is 17,600 kWh.
- *(The estimate is based on the useful heat demand as given in the SAP worksheet for each flat. It assumes the installation of the full package of energy efficiency measures including external cladding. The calculation of heat demand also assumes the installation of a single heat pump in each flat, as it is not possible, to specify a district based ground source heat pump system. For this reason it is recommended that suppliers should undertake their own calculation of heat demand for the 6 flats).*
- Assuming a coefficient of performance of 3.2 and making an allowance of 783kWh to run the circulation pumps for the GSHP,
- The annual energy demand for a single GSHP is:-
- (17600/3.2) + 783 = 6281 or approximately = 6300kWh
- Based on an annual yield of 900 kWh per peak kW installed for amorphous PV tiles (assuming 30 degree tilt, facing due south and no over-shading) this equates to a required peak output for the array of 6300/900 = 7kWpeak
- At a peak output of 1kWp per 20m^2 for amorphous tiles this equates to a total area of 140m^2, or a roof of just under 12m by 12m.

4.7.4 Estimated costs and savings for recommended energy efficiency measures

Measure	**Estimated cost £**	**Unit**	**Estimated Saving £/yr**	**Estimated payback years**	**Source**	**Comment**
DHW tank jacket	From £20	Per 80mm jacket	£10-20	1 to 2 years	GPG 171 CE	Cost is DIY cost
DHW tank jacket	Approx £300	All houses and flats	£150-300	1 to 2 years	Calculated from figures in GPG 171 CE	Assumes one jacket per house and one jacket for the flats
Compact Fluorescent lamps	Approx £20	4 CFL's	Approx £20	1 year	GPG 171 CE	DIY cost
Compact fluorescent lamps	£400	80 CFL's	Approx £400	1 year	Calculated from figures for 4 lamps	Assume 4 lamps per house and flat
Cavity wall insulation	£260-380	End of terrace house	£70-£100	3 – 5 years	GPG 171 CE	
Cavity wall insulation	£210-300	Mid-terrace	£40-£70	3 – 8 years	GPG 171 CE	
Cavity wall insulation	£170-265	Flat	£30-40	4 – 9	GPG 171 CE	
Cavity wall insulation	£4160-£6110	10 mid-terrace 4 end terrace 6 flats	£860-1340	3 – 9 years	Calculated from GPG 171 CE figures	Figures based on individual costs and savings per house type.
Loft insulation	£210-£240	Mid-terrace	£80-£100	2 – 3 years	GPG 171 CE	Assumes all existing loft insulation removed
Loft insulation	£220-£250	End terrace	£80-£100	2 – 3 years	GPG 171 CE	As above
Loft insulation	£225-£250	Flat	£130-150	Around 2 years	GPG 171 CE	As above
Loft insulation	*£3430-£3900*	*10 mid terrace, 4 end terrace, 2 flats*	*£1380-1700*	*2-3 years*	*Calculated from GPG 171 CE figures*	*As above*
Gas condensing boiler	From £150 additional cost of installing a condensing boiler vv non-condensing boiler	Single gas condensing boiler	£20-40	Approx 4 – 8 years	GPG 171 CE	Payback is for the additional costs of a condensing boiler assuming that existing boiler is being replaced anyway.
Gas condensing boiler	£2250-3000	14 houses and 1 boiler in flats	See NHER calculations	See NHER calculation	Estimated cost	Costs are estimates for condensing boiler vv non condensing boiler
Full heating controls	£125 - £250	Mid terrace	£40-£50	3-6 years	GPG 171 CE	Costs of full heating controls package.

Full heating controls	£125-£250	End terrace	£50-60	2-5 years	GPG 171 CE	Costs of full heating controls package
Full heating controls	£125-£250	Flat	£30-40	3-8 years	GPG 171 CE	Costs of full heating controls package
Kitchen extractor hood	£90-£300	Per unit	N/A	N/A	Estimated cost	
Humidity controlled heat recover extractor fan	£150-£300	Per unit	N/a	N/a	Estimated cost	
Passive ventilator	£300-£700	Modification to existing skylight	N/A	N/A	Estimated cost for works to existing skylight to improve passive ventilation	

4.7.5 Estimated costs for renewable measures

Solar water heating system

The estimated cost for a solar water heating system installed on the west and east facing roof pitches of the terraced houses, with a 400 litre storage tank is approximately £6,000 per house[7]. This does not take into account discounts for the bulk purchase of multiple systems. The cost of a flat plate system on a south facing roof for an average domestic property will normally be in the range of £2000 to £4500. The reason for the price differential is partly due to the size of the system required and partly due to the additional panel required for an East West system and a more complicated control system. One option which may reduce costs would be to specify a system on the west side of each house with a larger solar collector.

Biomass district heating

The cost of installing a biomass district heating with modular gas back up has been estimated as approximately £4850 per house[8]. It should be emphasised that a full site survey will be required to provide detailed estimates of the costs of such a system. It is recommended that these estimates should include the cost of including the flats as part of the biomass district heating system.

Ground source heat pump

The cost of a single phase ground source heat pump (assuming one installation per flat) has been estimated as being approximately £4,000 per flat[9]. As with the biomass heating a full site survey would be required to provide a detailed estimate of the installed cost. The survey should include an investigation of the options for using a single GSHP to supply all six flats. This would require the installation of a three phase power supply to the site, however, there may be

[7] Approximate costs supplied by Imagination Solar
[8] Approximate costs supplied by Econergy
[9] Approximate costs supplied by GeoScience, and based on six 4kW Calorex heat pumps with an integral hot water tank.

economies of scale with a larger system. It has been assumed that the ground collection loops will be installed vertically due to the lack of space for horizontal systems.

Guideline capital costs for GSHP's:

System type	Ground coil costs (£/kW)	Heat pump cost (£/kW)	Total system costs (£/kW)
Horizontal	£250-350	£350-650	£600-1000
Vertical (indirect)	£450-600	£350-650	£800-1250

Note: costs include installation and commissioning but exclude the distribution system, in this case wet under floor heating.

Source: Good Practice Guide 339. Domestic Ground Source Heat Pumps.

Based on the Guideline prices the estimated cost for a 4kW vertical system is:-

Ground coil costs:	£1800 -	£2400 per flat
Heat pump cost:	£1400 -	£2600 per flat
Total estimated cost per flat:	£3200 -	£5000 per flat
Total estimated cost for six flats	**£19,200 -**	**£30,000**

<u>Photo-voltaic array</u>

The estimated installed cost for a PV array is £7.3 - £12.4 per Wp[10]

Based on a PV array with a peak output of 7kW, the estimated installed cost is:

(7000 X 7.3) to (7000 X 12.4) = approximately £51,000 to £87,000

This assumes a total area of 140m^2.

[10] Price per installed Wp in £ for roof integrated tiles or slates taken from National Survey Report of PV Power Applications in the UK 2001, IT Power on behalf of DTI, May 2002

4.7.6 Grant funding for renewable energy measures

Name of fund	Who can apply?	Minimum and maximum application	Specific conditions	Application by	Date of next call	Further information
Powergen – The GreenPlan Fund	Local community groups and not for profit organisations	£2,500 to £25,000	Must result in creation of renewable energy + other conditions. Powergen must be sole corporate sponsors of the project	Application form	31st November 2003 for review in December 2003	www.powergen.co.uk Ben Bradshaw 0115 906 2598
Scottish Power Green Energy Trust	No specific groups given. Fund designed to support new renewables, r & d, & promote education in community on renewable energy generation	Up to 50% of project costs. No maximum value given	Awards to comply with conditions set out by the Trust	No form, but headings provided.	Applications must be submitted 21 days before Trustees meetings. Dates available on request	www.scottishpower.co.uk/green 0800 027 7776 greenenergytrust@scottishpower.com
LE/SWEB Green Fund	Non profit or charitable organisations and or organisations involved in education and or work at a community level	No minimum, max normally £30,000 by could be £50,000 for projects of a significantly high quality	Fund should support less established technologies where possible. Installations should benefit local community + environment. Fund should support a wide variety of technologies. Fund must be for the generation of renewable energy plant. Proportion may be used for education and training purposes (% not specified)	No more than 4 pages of A4, headings provided	Non given. Has been flexible and rolling in the past	Nigel_French@sweb.co.uk Tel: Not provided
Clear Skies	Individuals, community groups, housing associations, not for profit organizations	Up to 50% of total cost of project. Maximum value £100,000	Schemes should enhance public awareness and understandin	Application form.	Friday 1st August 2003	www.clear-skies.org or phone 08702 430 930

	involved with renewable energy and energy efficiency.		g of renewable energy showing links to energy efficiency, wider sustainability issues, value for money and demonstrate match funding.			
DTI £20 million Photovoltaic Demonstration Programme	Householder, business or social housing group.	1) Bolt-on-cap= the lesser of £3000/kWp or 50% of total eligible costs. 2) Integrated cap=the lesser of £4250/kWp or total eligible costs.		Application form including installer cost estimate.	Small scale applications are on-going, no set closing/ending date for the scheme.	www.solarpvgrants.co.uk or phone 0800 298 3978

4.7.7 Results of residents' survey

The residents of Sanford Housing Cooperative were asked to complete a paper questionnaire which is included in Appendix 4. Sixty nine residents in all completed the questionnaire, though not all provided a response to every question.

- When asked, most Sanford residents find the property they live in too warm. 62% find the house generally too hot, 54% find the kitchen/living room too hot, 51% found the first floor too hot and 54% found the top floors too hot.
- When asked what action they would take first if their room became too hot, 41% would firstly open the window followed by 39% firstly turning down/off the radiator as opposed to only 10% adjusting the thermostat or taking off some clothes. Should the property become too cold, 55% said they would put on more clothes followed by 41% turning on the radiator and only 1% adjusting the thermostat. Also 3% said they would plug in another heating system like a fan heater.
- When asked if they knew at what temperature the room thermostat was set and the typical day time temperature in the kitchen, most residents under estimated the temperature when compared to the temperature noted during the site surveys. The average temperature given by residents for both was approximately 21 degrees Celsius.
- Questions 6, 7 and 8 were included to give an indication of how much residents understood about the energy use of appliances. Residents were asked to guess what percent of energy a low energy light bulb uses compared to an incandescent bulb, and, how much energy a computer, television and video player use when on standby. The responses showed a low to moderate awareness.
- Question 10 asked residents to guess what proportion of their rent went to cover the cost of fuel usage. There was a wide range of responses with an average value of around £7.00.

- Question 11 showed a graph with the total and per capita carbon dioxide emissions for Asia, Europe, North, Central and South America and Oceania. Residents were asked to guess which bar represented Europe. 56% were correct.
- The final question asked if Sanford Housing Cooperative was to invest money in improving the houses and flats which of the following options should be a priority:-
    - Reducing Fuel Bills
    - Reducing Carbon Dioxide Emissions
    - A Better Heating System in your home
    - Better Ventilation
    - Making use of Renewables

The option most residents thought should be a priority was making use of renewables with a reduction in carbon dioxide emissions coming second.

5 Key Issues and Lessons Learnt

In focusing on a target for the reduction of CO_2 measures, the order in which measures are applied to the equation is significant.

Establishing a clear energy hierarchy or order in which measures are to be applied helps to ensure a consistent approach and that the significance of behavioural measures is not lost.

Achieving a 60% target is not an end in itself and should be seen as part of an on-going process of reducing energy use and minimising environmental impact. SHC regard this project as the starting point of a sustainable energy strategy.

As discussed above there are limitations in modelling and predicting the performance of domestic properties using NHER Surveyor.

Care should be taken not to attach a spurious level of accuracy to the results, for three reasons. The results are based on software model, which itself has limitations, the baseline data is based on an incomplete set of energy consumption data from fuel bills for which it was necessary to extrapolate the missing data, and the overall predicted savings for carbon dioxide depend in part on changes in the way energy is used, which is dependent on the actions of many individuals.

6 Recommendations

The feasibility study and the consultation with the residents of Sanford Housing Cooperative has shown that the initial proposition of achieving a 60% reduction in carbon dioxide emissions is feasible. Following the completion of the feasibility study the following recommendations are made:

6.1 Behavioural measures – changing the way energy is used

Sanford Housing Cooperative should consider running a campaign to raise energy awareness and cut energy use. This should include all members and staff. On the basis of the survey results it is felt that the development of the ‘campaign’ needs to involve members from the start so that it builds on their interests and addresses their needs.

CSE suggest that there could be several strands to the campaign:

- A publicity campaign to raise interest and awareness.
- A series of information and training events for all residents and staff
- An induction programme for all new residents

CSE also propose:

- That energy use should become a rolling agenda item at residents' meetings.
- That SHC should appoint/elect one or more energy coordinators/officers/stewards/champions (title to be agreed) who should be responsible for reporting back on energy use and issues at residents meetings.
- That SHC should set targets for annual consumption of gas and electricity and consider the use of incentives to help achieve these (see below).

6.2 Energy metering and bill payment

At the present time there is no direct link between the amount of energy used by the cooperative as a whole and rent. CSE recommend that this be changed so that there is a direct link between energy use and the cost of living at SHC. This could be done in a number of ways. CSE have suggested four options for consideration by SHC as part of the implementation of this project, but there are a number of alternatives which may be considered.

i. That all meters are read monthly for each property, and from these consumption figures calculated. The total cost of the energy used in the month is then divided by the number of residents living in the property and the energy cost added to the monthly rent bill. The advantage of this system is that there is a direct link between energy used and the cost of living. The disadvantage is that it increases the administration for SHC staff. It would also necessitate putting the external appliances such as the street lights and pond pumps on a separate meter. It would also be helpful to residents if the meters were moved to a more prominent position, say in the kitchen and replaced with digital meters.

ii. The second option is a rent link system. Here the rent chargeable to members is directly linked to the thermal efficiency of the property in which they live. As the efficiency of a property is increased (through the introduction of energy efficiency measures detailed in the report), the monthly rent is increased. This is compensated by the cheaper energy costs as a result of the energy efficiency measures. The idea is to increase the rent in the property to compensate for the reduced running costs. This can also be used to take account of behavioural factors. Thus, the rent may be based on a set point temperature of 20 degrees C. Residents would still be billed for actual energy use as illustrated above. The advantage of this system is that it helps to offset the cost of the measures installed in the dwellings. A change in rent can also have a big impact on existing residents. The disadvantage is that this may be short-lived and may not be so relevant to members joining the cooperative after the change has been made.

iii. The third option is additional to the previous two. In this a target consumption is set for each property, based on the modelled consumption with some leeway to allow for exceptional weather variations. Up to this target level energy is charged at the standard rate, or may even be included in the rent. Once this consumption is exceeded energy is charged at a premium, which can be defined in bands based on the level of consumption. The premiums can then be collected and either invested into further energy saving measures or distributed in some other way as agreed by members.

iv. The fourth suggestion applies mainly to the scenario where biomass district heating is installed. Here each room is fitted with a heat meter, which measures the amount of heat in kWh's delivered to the room. In this case a residents bill for electricity would be as in scenario one above. The bill for heat would be based on their consumption for their room and a proportion of the consumption in the common areas of the house such as the kitchen. The advantage of this system is that bills are based most closely on their own consumption. The disadvantage is that is can be expensive to administer and to install the relevant heat meters.

Whichever system SHC considers, CSE recommends that external appliances such as pond pumps and lighting should be put on a separate supply and meter. Moving meters to a more prominent position is also recommended.

6.3 Energy efficiency and ventilation measures

CSE recommend the installation of a package of energy efficiency and ventilation measures to the houses and flats.

6.3.1 Energy efficiency measures in the houses

- Fitting hot water cylinder jackets (equivalent to 50mm of spray foam insulation). This will normally require two glass fibre quilts. However, if the renewable energy measures are implemented below this will require the replacement of the hot water tanks with pre-insulated hot water tanks.
- The replacement of conventional incandescent lights with compact fluorescent lamps. It is assumed that these will be used in 90% of the fittings.
- Cavity wall insulation.
- The installation of at least 250mm of loft insulation. It has been assumed that the existing loft insulation will be removed.

If it is decided not to proceed with the renewable energy measures proposed below then CSE recommend that:

- A new condensing boiler is installed in each house and a single boiler in the block of flats. This should be of a Sedbuk A rating, with radiators fitted with thermostatic radiator valves(TRV's), a programmer and boiler manager with weather compensation, or TRV's, room thermostat and programmer.
- SHC could also consider the use of centralised heating controls which cannot be directly adjusted from individual houses. This is likely to be controversial and would need careful consideration in case it makes residents feel less connected with the energy they use.
- It is also assumed that new radiators will be fitted and the existing hot water tank replaced with a new hot water tank of 400 litres pre-insulated with 50mm of polyurethane foam (to BS 1566:2002). *(The tank capacity of 400 litres has been estimated from the number of residents in each house. Monitoring of actual hot water consumption is recommended prior to specifying new hot water tanks).*

- The hot water cylinder should be of the rapid recovery type to the same standard as above. SHC should consider the use of a mains pressure system in order to remove tanks and pipe work from the loft. However, if this option is chosen, CSE also recommend the use of flow restrictors with showers to reduce water usage.

6.3.2 Energy efficiency measures in the flats:

- Hot water tank jacket as described above
- The use of low energy lighting as described above
- Cavity wall insulation

- As with the houses, if it is decided not to proceed with the renewable energy options for the flats it is suggested that the existing gas boiler is replaced with a new gas condensing boiler with a SEDBUK A rating, the existing hot water cylinder is replaced with a new pre-insulated hot water cylinder of 240 litres to BS 1566:2002, and the controls are replaced with thermostatic radiator valves (TRV's), and a programmer and boiler energy manager with weather compensation, or TRV's, programmer and room thermostat.

6.3.3 Improved ventilation measures

Ventilation in the houses and flats is poor. This is partly because existing measures such as extract fans are in a poor state of repair or broken, and partly because of the design of the properties themselves.

Recommended ventilation measures in the houses

- Fitting a new low energy extractor fan/hood in the kitchen
- Fitting a passive humidity controlled vent in the kitchen
- Fitting a low energy extractor fan with humidity control in each bathroom
- Fitting a passive ventilation system on the top landing of each house, to create a passive stack effect.

Recommended ventilation measures in the Flats

- Fitting a low energy extractor fan/hood in the kitchen
- Fitting a low energy extractor fan with humidity control in the bathroom.

6.4 Renewable energy measures

CSE has proposed different solutions in the houses and flats.

6.4.1 Recommendations for renewable energy measures in the houses

Biomass district heating.

- It is proposed that the existing system of gas condensing boilers should be replaced by a district, wood chip heating system. This will be supported by modular gas boilers which will augment the biomass system at times of peak load and when shut down for servicing. It is envisaged that wood chip will be supplied by Lewisham Borough Council (or a third party) for

storage and drying on site prior to use in the boiler. Heat use in the houses will be monitored via heat meters, which will either be fitted in each house or each room of each house.
- There are two main options for the supply and operation of such a system. Firstly, SHC are responsible for the purchase, installation and management of the plant. Secondly, SHC enters into a heat only contract with a supplier, under which SHC contracts for the supply of a given quantity of heat over a predefined period, normally 5-10 years. In the second scenario, the contractor is responsible for the installation and maintenance of the plant including the capital costs.
- In the first scenario it would probably be necessary to train 2 members of staff to oversee the operation of the plant on a weekly basis.

Solar water heating:

- It is proposed that each house should be fitted with a solar hot water system. This will provide preheating of the hot water in the winter months and the bulk of hot water heating in the summer months, (with electric immersion heater back up), during which time the biomass boiler will be switched off. As discussed above, solar water heating is best suited where the roof is orientated between south west and south east. In this case the two pitches of each roof face west and east. Therefore there are two options, one to fit an East West system where a solar collector is fitted on each pitch. This increases the capital cost as two panels are required and extra roof work is involved. The second is to fit a west only system and accept a lower yield, or increase the area of panels to compensate for this.

- CSE recommend that quotes are obtained for both types of system from suppliers
- CSE also recommends the installation of remote temperature readouts for each system so that residents can get the most from the solar system.
- It is also recommended that every new resident is given advice on how to get the most from their solar system when joining the cooperative.

6.4.2 Recommendations for renewable energy measures in the flats

- In line with the original brief to consider radical options, CSE propose the installation of ground source heat pumps (GSHP's) in the flats to provide space and water heating, and the installation of a PV array on the south facing roof of the flats, to meet the net demand for electricity of the GSHP.
- There are two options for the installation of a ground source heat pump system. The first is that the flats are supplied from a single GSHP. This would require the installation of a three phase supply on site. The second is that each flat is fitted with its own GSHP to provide space and water heating. It is recommended that quotes are obtained for both options.
- The purpose of the PV array is to provide sufficient energy in a twelve month period to offset the net energy requirements of the GSHP.
- SHC is also recommended to consider the option of extending the biomass district heating system to include the flats, and fitting solar water heating panels on the flats. This could lead to significantly lower capital costs for the installation of renewable energy measures.

6.5 Recommendations for implementation

- It is recommended that SHC should proceed to the implementation phase of this project.
- The awareness campaign and training should precede and run in parallel with the other works.
- The awareness campaign should form part of a broader sustainable energy strategy for SHC.
- SHC should appoint a Project Manager for the implementation phase of this project.
- SHC should invite tenders for the energy efficiency and renewable energy measures proposed.
- Given the limitations of the energy model, particularly with regard to modelling Ground Source Heat Pumps and the incomplete billing data used in conjunction with the model, SHC are strongly advised to get companies tendering for the installation of the biomass district heating, solar water heating systems and ground source heat pump(s) and PV array to conduct their own assessments of the demand for space and water heating in the houses and flats.
- If constructing a ‘community building’ on site SHC should consider designing this as a low energy passive solar building and a space to provide information on the other measures installed on site.
- SHC should consider building in monitoring of the renewable energy systems on site for further dissemination of their impact.

7 Conclusions

- The results of the feasibility study suggest that through a combination of a reduction in energy use through behavioural changes, and the installation of energy efficiency measures carbon dioxide emissions for SHC as a whole can be cut by nearly 30%. The addition of gas condensing boilers improves this to just under 45% and the further addition of green electricity to around 75%.

- The study also suggests that a package of renewable energy measures comprising, biomass district heating, solar water heating, ground source heat pumps and photovoltaic panels, combined with behavioural and energy efficiency measures could reduce the total emissions of carbon dioxide by just under 70%. Through the additional use of green electricity carbon emissions can be cut by almost 100%. *(It should be noted that because the biomass district heating has been designed to work in combination with a gas boiler when shut down for servicing or at times of exceptional demand, it will not be possible to entirely eliminate all CO_2 emissions without increasing the size of the PV array to offset the residual emissions of CO_2 from the use of the gas boiler)*.

- Measures have been considered on the basis of an energy hierarchy, in which behavioural measures have been applied before, energy efficiency measures, before renewable energy measures, before the use of a green electricity supply.

- The houses and flats have been ‘modelled’ using the NHER Site Surveyor software. The model provides a useful tool for predicting the impact of measures singularly and in combination, however, it does have certain limitations particularly when considering ‘super-insulation’ certain combinations of renewable energy measures and district heating. For this reason CSE recommend that suppliers of renewable energy systems should be required to undertake their own assessments of energy demand prior to specifying the size of the systems required.

- The energy model has been related to the actual consumption data which has been derived from fuel bills. Due to gaps in the billing data, it has been necessary to estimate actual consumption and extrapolate from the available data. It has also been necessary to make allowances for the use of external appliances such as pond pumps and street lighting.

- For the reasons listed above, care should be taken not to attach a spurious level of accuracy to the predicted carbon dioxide savings. The results are estimates based on a model and incomplete billing data, and should only be presented as estimates and where possible quoted in the context of the study as a whole.

- The energy model provides a tool for considering the impact of measures in combination. The relative change in the reduction of CO_2 emissions when considering the impact of renewable measures alone and renewable measures in combination with energy efficiency and behavioural changes is small, 67% to 69%. However, the inclusion of the energy efficiency measures means that size of the renewable energy measures required is reduced along with the capital and running costs.

- The way in which members of SHC use and control the space and water heating in the houses and flats creates an opportunity for big savings through behavioural changes. For the purposes of this study, a set point temperature of 20 degrees C has been used to model the impact of behavioural changes. This is one degree lower than the recommended temperature in social housing. SHC may decide to design systems around a set point of 21 degrees Celsius.

- Prior to specifying any renewable energy measures SHC need to have a clear target for the heating regimes they wish to adopt in the houses and flats. This is because the demand temperature has an impact of the scale and capital cost of the systems required. Thus, a system designed to operate around a demand temperature of 24 degrees C will have a higher output than a system designed to meet a demand temperature of 20 degrees C.

- The use of single or multiple ground source heat pumps in combination with a PV array offers a radical alternative to the existing gas boiler in the flats. However, both technologies have high capital costs, even taking into consideration the available grant funding. SHC may wish to consider simplifying the proposed system around a single biomass district heating system, in combination with solar water heating systems for the houses and flats. This would provide a much simpler and potentially cheaper alternative, whilst retaining the switch away from fossil fuels.

- The specification of ‘east-west’ solar systems for the terraced houses will add significantly to the installed costs. SHC may consider the option of using west facing systems with larger collectors.

- Contract energy management offers one option for the installation of renewable energy measures without incurring the upfront capital costs of installing plant. SHC may consider this in more detail.

- The survey of members indicates that there is a strong level of interest in the idea of reducing carbon dioxide emissions and energy use within SHC. This will provide a good base from which to develop an awareness or training programme for members of the cooperative.

- The combination of a need to undertake refurbishment work and the availability of grant funding for energy efficiency and renewable energy measures, provides SHC with a unique opportunity to make a significant and permanent contribution to the reduction in carbon dioxide emissions which is now required in response to climatic change. It is now up to the members of the Cooperative to decide how far they wish to reduce carbon emissions.

Appendix 1

Results of modelling the impact of behaviour, energy efficiency and renewable energy measures

Base Case Table 1.1: Base Case as Calculated from Bills

Property	Annual Average Consumption of Gas kWh calculated from Fuel Bills	Annual Average Consumption of Electricity kWh calculated from Fuel Bills	Annual Average Cost of Gas £ calculated from Fuel Bills	Annual Average Cost of Electricity £ calculated from Fuel Bills	Annual Average Cost of Fuel Bills £	Annual Average CO2 from Gas Use as calculated from Fuel Bills	Annual Average CO2 from Electricity Use as calculated from Fuel Bills	Annual Average CO2 from All Fuel Use as calculated from Fuel Bills
House 1	62,014	10,625	£354	£707	£1,062	12.0	4.6	16.6
House 2	44,823	12,114	£623	£801	£1,424	8.7	5.2	13.9
House 3	49,265	11,319	£664	£751	£1,415	9.6	4.9	14.4
House 4	38,337	12,596	£530	£831	£1,361	7.4	5.4	12.9
House 5	48,340	11,334	£732	£752	£1,484	9.4	4.9	14.3
House 6	61,871	9,134	£817	£614	£1,430	12.0	3.9	15.9
House 7	44,156	10,178	£604	£679	£1,283	8.6	4.4	12.9
House 8	56,782	11,291	£753	£749	£1,502	11.0	4.9	15.9
House 9	39,886	11,304	£535	£750	£1,285	7.7	4.9	12.6
House 10	46,960	13,471	£646	£886	£1,533	9.1	5.8	14.9
House 11	52,832	12,767	£714	£842	£1,556	10.2	5.5	15.7
House 12	47,621	10,919	£640	£726	£1,366	9.2	4.7	13.9
House 13	52,318	16,895	£700	£1,102	£1,801	10.1	7.3	17.4
House 14	55,162	11,812	£741	£782	£1,523	10.7	5.1	15.8
Flat 15	16,334	2,883	£241	£188	£429	3.2	1.2	4.4
Flat 16	16,334	2,883	£241	£188	£429	3.2	1.2	4.4
Flat 17	16,334	2,883	£241	£188	£429	3.2	1.2	4.4
Flat 18	16,334	2,883	£241	£188	£429	3.2	1.2	4.4
Flat 19	16,334	2,883	£241	£188	£429	3.2	1.2	4.4
Flat 20	16,334	2,883	£241	£188	£429	3.2	1.2	4.4
Avs Houses	50026	11840	£647	£784	£1,430	9.7	5.1	14.8
Avs Flats	16334	2883	£241	£188	£429	3.2	1.2	4.4
Av Sanford	39918	9153	£525	£605	£1,130	7.7	3.9	11.7
Sanford Total	**798368**	**183058**	**£10,496**	**£12,100**	**£22,596**	**154.9**	**78.7**	**235.0**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Base Case Table 1.2: Base Case as Calculated from NHER Modelling

Property	Consumption of Gas kWh calculated from NHER GJ/yr	Consumption of Electricity kWh calculated from NHER GJ/yr	Cost of Gas £ from NHER	Cost of Electricity £ from NHER	CO2 emissions from Gas Use from NHER	CO2 emissions from Electricity Use from NHER	CO2 emissions for All Fuel Use from NHER
House 1	52,389	8,028	£705	£569	10.2	4.1	14.3
House 2	34,778	8,000	£468	£568	6.8	4.1	10.9
House 3	46,223	8,389	£622	£594	9.0	4.3	13.3
House 4	48,306	8,000	£650	£568	9.4	4.1	13.5
House 5	29,361	8,000	£395	£568	5.7	4.1	9.8
House 6	46,223	8,389	£622	£594	9.0	4.3	13.3
House 7	26,861	8,389	£362	£594	5.2	4.3	9.5
House 8	60,612	8,000	£816	£568	11.8	4.1	15.9
House 9	34,611	8,389	£466	£594	6.7	4.3	11.0
House 10	48,278	8,028	£650	£569	9.4	4.1	13.5
House 11	50,389	8,028	£679	£569	9.8	4.1	13.9
House 12	43,834	8,667	£589	£614	8.5	4.4	12.9
House 13	42,611	8,000	£574	£568	8.3	4.1	12.4
House 14	49,306	8,722	£728	£617	9.6	4.4	14.0
Flat 15	17,639	1,417	£237	£102	3.4	0.7	4.1
Flat 16	17,639	1,417	£237	£102	3.4	0.7	4.1
Flat 17	13,695	1,417	£184	£102	2.7	0.7	3.4
Flat 18	13,695	1,417	£184	£102	2.7	0.7	3.4
Flat 19	15,750	1,417	£212	£102	3.1	0.7	3.8
Flat 20	15,750	1,417	£212	£102	3.1	0.7	3.8
Avs Houses	43842	8216	£595	£582	8.5	4.2	12.7
Avs Flats	15695	1417	£211	£102	3.1	0.7	3.8
Av Sanford	35398	6176	£480	£438	6.9	3.2	10.0
Sanford Total	**707950**	**123529**	**£9,592**	**£8,766**	**137.8**	**63.0**	**200.8**

Figure 1.1: NHER for Sanford Housing Co-operative

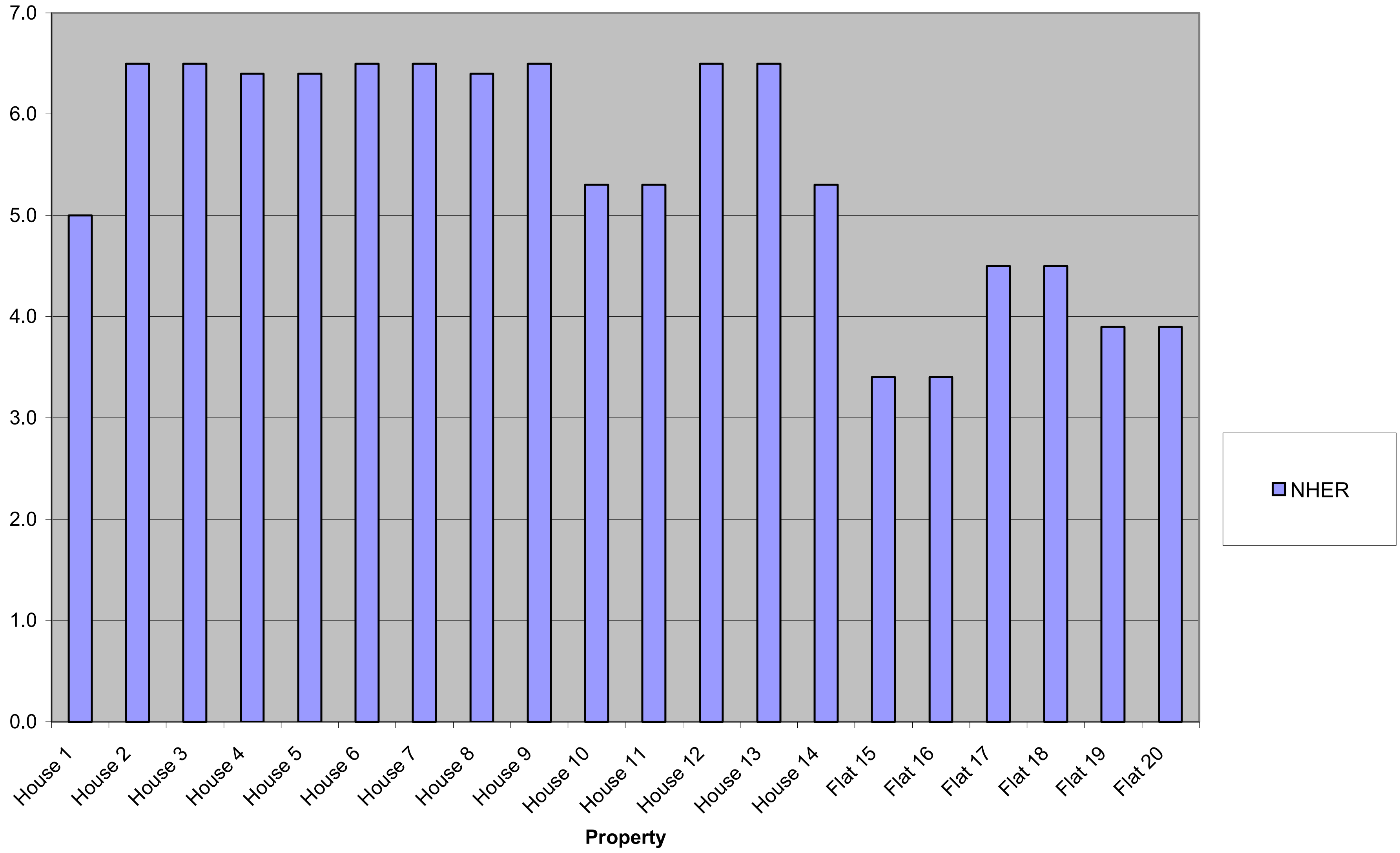
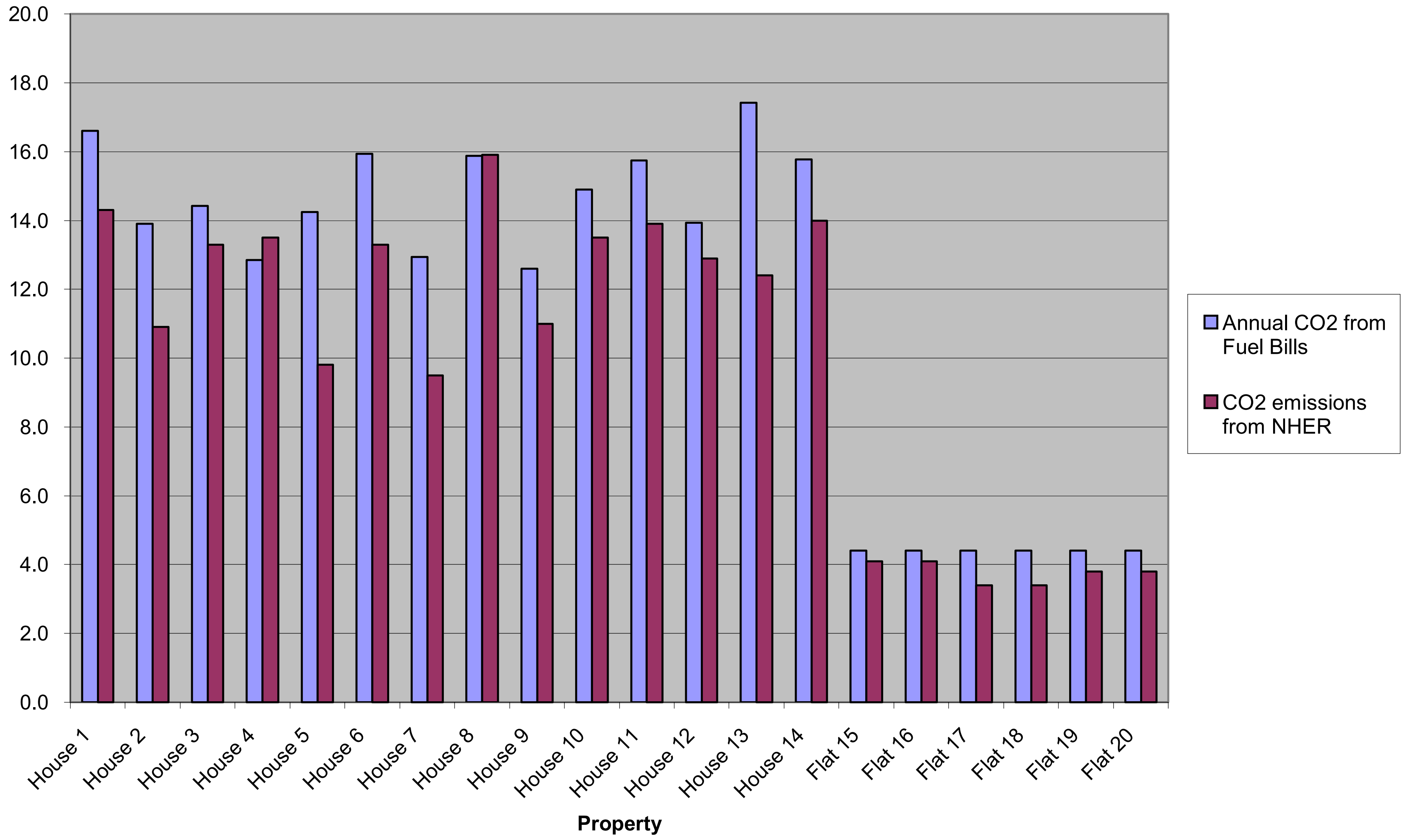


Figure 1.2: Actual total CO2 emissions for each property vs modelled CO2 emissions



Impact of Behavioural Changes

Table 2.1: Impact of Behavioural Changes on NHER Model

Property	Revised modelled gas consumption for all properties following application of behavioural changes	Revised modelled electricity consumption for all properties following application of behavioural changes	Revised modelled CO2 emissions for gas and electricity combined for all properties following behavioural changes	Revised modelled running costs for all properties following behavioural changes
House 1	48,973	8,028	13.6	£1,256.00
House 2	34,195	8,000	10.8	£1,056.00
House 3	34,472	8,389	11.0	£1,086.00
House 4	35,389	8,000	11.0	£1,073.00
House 5	35,389	8,000	11.0	£1,073.00
House 6	34,472	8,389	11.0	£1,086.00
House 7	34,389	8,389	11.0	£1,085.00
House 8	35,139	8,000	10.4	£1,069.00
House 9	34,361	8,389	11.0	£1,084.00
House 10	45,750	8,028	13.0	£1,213.00
House 11	46,473	8,028	13.1	£1,223.00
House 12	37,500	8,667	11.7	£1,118.00
House 13	35,445	8,000	11.0	£1,073.00
House 14	47,973	8,722	13.7	£1,290.00
Flat 15	13,028	1,417	3.3	£305.00
Flat 16	13,028	1,417	3.3	£305.00
Flat 17	10,556	1,417	2.8	£272.00
Flat 18	10,556	1,417	2.8	£272.00
Flat 19	11,861	1,417	3.0	£290.00
Flat 20	11,861	1,417	3.0	£290.00
Avs Houses	38566	8216	11.7	£1,127.50
Avs Flats	11815	1417	3.0	£289.00
Av Sanford	30541	6176	9.1	£875.95
Sanford Total	**610810**	**123529**	**182**	**£17,519.00**

Table 2.2: Impact of Behavioural Changes on Actual Consumption

Property	Revised actual average annual gas consumption for all properties following application of behavioural changes	Revised actual average annual electricity consumption for all properties following application of behavioural changes	Revised actual average CO2 emissions for all properties following behavioural changes	Revised actual average running costs for both fuels and all properties following behavioural changes	Percentage change in Base Case actual CO2 emissions vs revised actual CO2 emissions for all properties
House 1	57,969	10,625	15.8	£1,305.95	-5%
House 2	44,071	12,114	13.8	£1,256.14	-1%
House 3	36,741	11,319	12.0	£1,135.25	-17%
House 4	28,086	12,596	10.9	£1,125.15	-15%
House 5	58,264	11,334	16.2	£1,351.37	14%
House 6	46,143	9,134	12.9	£1,098.39	-19%
House 7	56,530	10,178	15.3	£1,264.76	19%
House 8	32,919	11,291	11.2	£1,095.34	-29%
House 9	39,598	11,304	12.5	£1,162.88	0%
House 10	44,501	13,471	14.4	£1,341.74	-3%
House 11	48,725	12,767	14.9	£1,341.81	-5%
House 12	40,741	10,919	12.6	£1,151.27	-10%
House 13	43,519	16,895	15.7	£1,537.00	-10%
House 14	53,670	11,812	15.5	£1,334.03	-2%
Flat 15	12,064	2,883	3.6	£383.18	-19%
Flat 16	12,064	2,883	3.6	£383.18	-19%
Flat 17	12,590	2,883	3.7	£388.44	-16%
Flat 18	12,590	2,883	3.7	£388.44	-16%
Flat 19	12,301	2,883	3.6	£385.55	-18%
Flat 20	12,301	2,883	3.6	£385.55	-18%
Avs Houses	45105	11840	13.8	£1,250.08	-6%
Avs Flats	12318	2883	3.6	£385.72	-18%
Av Sanford	35269	9153	10.8	£990.77	-10%
Sanford Total	**705386**	**183058**	**217**	**£19,815.43**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Impact of Energy Efficiency Changes

Table 3.1: Impact of Energy Efficiency Measures on NHER Model

Property	Revised modelled gas consumption for all properties following application of energy efficiency measures	Revised modelled electricity consumption for all properties following application of energy efficiency measures	Revised modelled CO2 emissions for gas and electricity combined for all properties following energy efficiency measures	Revised modelled running costs for all properties following energy efficiency measures
House 1	31,528	7,472	10.0	£983.00
House 2	24,111	7,472	8.5	£882.00
House 3	31,084	7,833	10.1	£1,002.00
House 4	32,084	7,528	10.1	£993.00
House 5	19,583	7,472	7.6	£821.00
House 6	31,084	7,833	10.1	£1,002.00
House 7	18,972	7,833	7.7	£839.00
House 8	41,667	7,472	11.9	£1,118.00
House 9	23,389	7,833	8.6	£898.00
House 10	28,834	7,472	9.4	£947.00
House 11	34,278	7,472	10.5	£1,021.00
House 12	26,889	8,139	9.4	£938.00
House 13	29,028	7,472	9.5	£948.00
House 14	30,806	8,139	10.1	£1,018.00
Flat 15	12,611	1,333	3.2	£293.00
Flat 16	12,611	1,333	3.2	£293.00
Flat 17	8,639	1,333	2.4	£240.00
Flat 18	8,639	1,333	2.4	£240.00
Flat 19	9,083	1,389	2.5	£250.00
Flat 20	9,083	1,389	2.5	£250.00
Avs Houses	28810	7675	9.5	£957.86
Avs Flats	10111	1352	2.7	£261.00
Av Sanford	23200	5778	7.5	£748.80
Sanford Total	**464004**	**115556**	**150**	**£14,976.00**

Table 3.2: Impact of Energy Efficiency Measures on Actual Consumption

Property	Revised actual average annual gas consumption for all properties following application of energy efficiency measures	Revised actual average annual electricity consumption for all properties following application of energy efficiency measures	Revised actual average CO2 emissions for all properties following energy efficiency measures	Revised actual average running costs for both fuels and all properties following energy efficiency measures	Percentage change in Base Case actual CO2 emissions vs revised actual CO2 emissions for all properties
House 1	37,320	9,890	11.5	£1,055.41	-31%
House 2	31,075	11,315	10.9	£1,078.31	-22%
House 3	33,129	10,570	11.0	£1,054.23	-24%
House 4	25,462	11,852	10.0	£1,054.38	-22%
House 5	32,242	10,586	10.8	£1,046.36	-24%
House 6	41,607	8,529	11.7	£1,016.79	-26%
House 7	31,188	9,504	10.1	£970.96	-22%
House 8	39,034	10,546	12.1	£1,111.87	-24%
House 9	26,953	10,555	9.8	£991.60	-22%
House 10	28,046	12,539	10.8	£1,121.35	-27%
House 11	35,940	11,883	12.1	£1,161.03	-23%
House 12	29,213	10,254	10.1	£996.16	-28%
House 13	35,641	15,780	13.7	£1,391.45	-21%
House 14	34,464	11,022	11.4	£1,094.66	-28%
Flat 15	11,678	2,714	3.4	£369.16	-22%
Flat 16	11,678	2,714	3.4	£369.16	-22%
Flat 17	10,304	2,714	3.2	£355.42	-28%
Flat 18	10,304	2,714	3.2	£355.42	-28%
Flat 19	9,420	2,827	3.0	£353.36	-31%
Flat 20	9,420	2,827	3.0	£353.36	-31%
Avs Houses	32951	11059	11.1	£1,081.76	-25%
Avs Flats	10467	2752	3.2	£359.31	-27%
Av Sanford	26206	8567	8.8	£865.02	-25%
Sanford Total	**524118**	**171333**	**177**	**£17,300.45**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Impact of Energy Efficiency Measures and Behavioural Changes

Table 4.1: Impact of Energy Efficiency Measures and Behavioural Changes on NHER Model

Property	Revised modelled gas consumption for all properties following application of energy efficiency measures and behavioral changes	Revised modelled electricity consumption for all properties following application of energy efficiency measures and behavioral changes	Revised modelled CO2 emissions for gas and electricity combined for all properties following energy efficiency measures and behavioral changes	Revised modelled running costs for all properties following energy efficiency measures and behavioral changes
House 1	30,639	7,472	9.8	£971.00
House 2	22,861	8,278	8.7	£873.00
House 3	23,750	7,833	8.7	£903.00
House 4	23,445	7,528	8.4	£877.00
House 5	23,972	7,472	8.5	£880.00
House 6	23,750	7,833	8.7	£903.00
House 7	23,750	7,833	8.6	£903.00
House 8	24,361	7,472	8.6	£885.00
House 9	23,750	7,833	8.6	£903.00
House 10	28,472	7,472	9.4	£942.00
House 11	28,722	7,472	9.6	£956.00
House 12	26,889	8,139	9.4	£966.00
House 13	24,722	7,472	8.6	£890.00
House 14	30,500	8,139	10.7	£1,014.00
Flat 15	9,750	1,333	2.6	£255.00
Flat 16	9,750	1,333	2.6	£255.00
Flat 17	7,195	1,333	2.1	£220.00
Flat 18	7,195	1,333	2.1	£220.00
Flat 19	7,556	1,389	2.2	£229.00
Flat 20	7,556	1,389	2.2	£229.00
Avs Houses	25685	7732	9.0	£919.00
Avs Flats	8167	1352	2.3	£234.67
Av Sanford	20429	5818	7.0	£713.70
Sanford Total	**408587**	**116362**	**140**	**£14,274.00**

Table 4.2: Impact of Energy Efficiency Measures and Behavioural Changes on Actual Consumption

Property	Revised actual average annual gas consumption for all properties following application of energy efficiency measures and behavioural changes	Revised actual average annual electricity consumption for all properties following application of energy efficiency measures and behavioural changes	Revised actual average CO2 emissions for all properties following energy efficiency measures and behavioural changes	Revised actual average running costs for both fuels and all properties following energy efficiency measures and behavioural changes	Percentage change in Base Case actual CO_2 emissions vs revised actual CO_2 emissions for all properties
House 1	36,268	9,890	11.3	£1,044.89	-32%
House 2	29,464	12,534	11.1	£1,135.27	-20%
House 3	25,313	10,570	9.5	£976.07	-34%
House 4	18,606	11,852	8.7	£985.82	-32%
House 5	39,468	10,586	12.2	£1,118.62	-14%
House 6	31,791	8,529	9.8	£918.63	-38%
House 7	39,042	9,504	11.7	£1,049.50	-10%
House 8	22,822	10,546	9.0	£949.75	-44%
House 9	27,369	10,555	9.8	£995.76	-22%
House 10	27,695	12,539	10.8	£1,117.84	-28%
House 11	30,115	11,883	11.0	£1,102.78	-30%
House 12	29,213	10,254	10.1	£996.16	-28%
House 13	30,354	15,780	12.7	£1,338.59	-27%
House 14	34,123	11,022	11.4	£1,091.24	-28%
Flat 15	9,029	2,714	2.9	£342.67	-34%
Flat 16	9,029	2,714	2.9	£342.67	-34%
Flat 17	8,581	2,714	2.8	£338.19	-36%
Flat 18	8,581	2,714	2.8	£338.19	-36%
Flat 19	7,836	2,827	2.7	£337.51	-38%
Flat 20	7,836	2,827	2.7	£337.51	-38%
Avs Houses	30117	11146	10.6	£1,058.64	-28%
Avs Flats	8482	2752	2.8	£339.46	-36%
Av Sanford	23627	8628	8.3	£842.88	-30%
Sanford Total	**472532**	**172553**	**167**	**£16,857.66**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Impact of Energy Efficiency Measures, Behavioural Changes and Gas Condensing Boiler

Table 5.1: Impact of Energy Efficiency Measures, Behavioural Changes and Gas Condensing Boiler on NHER Model

Property	Revised modelled gas consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised modelled electricity consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised modelled CO2 emissions for gas and electricity combined for all properties following energy efficiency measures, behavioral changes and gas condensing boiler	Revised modelled running costs for all properties following energy efficiency measures, behavioral changes and gas condensing boiler
House 1	17,028	8,361	7.5	£850.00
House 2	14,583	7,528	6.6	£758.00
House 3	14,750	7,889	6.9	£784.00
House 4	14,556	7,556	6.6	£761.00
House 5	14,861	7,528	6.6	£761.00
House 6	14,750	7,889	6.9	£784.00
House 7	14,722	7,889	6.9	£784.00
House 8	15,083	7,528	6.7	£764.00
House 9	14,750	7,889	6.9	£784.00
House 10	17,556	7,528	7.2	£799.00
House 11	17,167	7,528	7.1	£794.00
House 12	16,695	8,167	7.5	£831.00
House 13	15,361	7,528	6.7	£768.00
House 14	19,806	8,167	8.0	£873.00
Flat 15	6,056	1,361	1.9	£223.00
Flat 16	6,056	1,361	1.9	£223.00
Flat 17	4,528	1,361	1.6	£185.00
Flat 18	4,528	1,361	1.6	£185.00
Flat 19	4,917	1,417	1.7	£195.00
Flat 20	4,917	1,417	1.7	£195.00
Avs Houses	15833	7784	7.0	£792.50
Avs Flats	5167	1380	1.7	£201.00
Av Sanford	12633	5863	5.4	£615.05
Sanford Total	**252669**	**117251**	**109**	**£12,301.00**

Table 5.2: Impact of Energy Efficiency Measures, Behavioural Changes and Gas Condensing Boiler on Actual Consumption

Property	Revised actual average annual gas consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised actual average annual electricity consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised actual average CO2 emissions for all properties following energy efficiency measures, behavioral changes and gas condensing boiler	Revised actual average running costs for both fuels and all properties following energy efficiency measures, behavioral changes and gas condensing boiler	Percentage change in Base Case actual CO_2 emissions vs revised actual CO_2 emissions for all properties
House 1	20,156	11,066	8.7	£954.24	-48%
House 2	18,795	11,399	8.5	£960.56	-39%
House 3	15,721	10,644	7.6	£884.63	-47%
House 4	11,552	11,896	7.4	£917.89	-43%
House 5	24,467	10,665	9.3	£973.33	-35%
House 6	19,744	8,590	7.5	£801.79	-53%
House 7	24,201	9,571	8.8	£905.13	-32%
House 8	14,130	10,625	7.3	£867.53	-54%
House 9	16,998	10,630	7.9	£896.53	-38%
House 10	17,076	12,632	8.7	£1,017.24	-41%
House 11	17,999	11,972	8.6	£986.91	-45%
House 12	18,137	10,289	7.9	£887.51	-43%
House 13	18,861	15,897	10.5	£1,230.68	-40%
House 14	22,158	11,059	9.1	£973.84	-43%
Flat 15	5,608	2,770	2.3	£311.84	-48%
Flat 16	5,608	2,770	2.3	£311.84	-48%
Flat 17	5,400	2,770	2.2	£309.77	-49%
Flat 18	5,400	2,770	2.2	£309.77	-49%
Flat 19	5,099	2,883	2.2	£313.53	-49%
Flat 20	5,099	2,883	2.2	£313.53	-49%
Avs Houses	18571	11210	8.4	£946.99	-43%
Avs Flats	5369	2808	2.2	£311.72	-49%
Av Sanford	14610	8689	6.6	£756.41	-45%
Sanford Total	**292209**	**173783**	**133**	**£15,128.11**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Impact of Renewable Energy Measures

Table 6.1: Impact of Renewable Technologies on NHER Model

Property	Revised modelled gas consumption for all properties following application of renewable technologies	Revised modelled electricity consumption for all properties following application of renewable technologies	Revised modelled CO2 emissions for gas and electricity combined for all properties following renewable technologies	Revised modelled running costs for all properties following renewable technologies
House 1	22,917	7,861	4.0	£981.00
House 2	15,500	7,861	4.0	£853.00
House 3	21,889	8,250	4.2	£990.00
House 4	21,500	7,861	4.0	£957.00
House 5	13,028	7,861	4.0	£811.00
House 6	21,889	8,250	4.2	£990.00
House 7	11,361	8,250	4.2	£808.00
House 8	30,056	7,806	4.0	£1,100.00
House 9	15,750	8,250	4.2	£884.00
House 10	23,000	7,861	4.0	£982.00
House 11	22,611	7,861	4.0	£976.00
House 12	20,333	8,528	4.3	£983.00
House 13	20,306	7,861	4.0	£936.00
House 14	23,195	8,556	4.3	£1,034.00
Flat 15	0	4,889	2.6	£283.00
Flat 16	0	4,889	2.6	£283.00
Flat 17	0	4,306	2.3	£246.00
Flat 18	0	4,306	2.3	£246.00
Flat 19	0	4,611	2.4	£265.00
Flat 20	0	4,611	2.4	£265.00
Avs Houses	20238	8066	4.1	£948.93
Avs Flats	0	4602	2.4	£264.67
Av Sanford	14167	7026	3.6	£743.65
Sanford Total	**283336**	**140529**	**72**	**£14,873.00**

Table 6.2: Impact of Renewable Technologies on Actual Consumption

Property	Revised actual average annual gas consumption for all properties following application of renewable technologies	Revised actual average annual electricity consumption for all properties following application of renewable technologies	Revised actual average CO2 emissions for all properties following renewable technologies	Revised actual average running costs for both fuels and all properties following renewable technologies	Percentage change in Base Case actual CO_2 emissions vs revised actual CO_2 emissions for all properties
House 1	27,127	10,404	4.5	£720.48	-73%
House 2	19,977	11,903	5.1	£810.28	-63%
House 3	23,330	11,132	4.8	£764.05	-67%
House 4	17,063	12,377	5.3	£838.63	-59%
House 5	21,449	11,137	4.8	£764.39	-66%
House 6	29,299	8,983	3.9	£635.34	-76%
House 7	18,676	10,009	4.3	£696.81	-67%
House 8	28,157	11,017	4.7	£757.15	-70%
House 9	18,150	11,116	4.8	£763.14	-62%
House 10	22,372	13,191	5.7	£887.42	-62%
House 11	23,707	12,502	5.4	£846.12	-66%
House 12	22,090	10,744	4.6	£740.83	-67%
House 13	24,931	16,601	7.1	£1,091.68	-59%
House 14	25,949	11,586	5.0	£791.25	-68%
Flat 15	0	7,180	1.2	£241.72	-100%
Flat 16	0	7,180	1.2	£241.72	-100%
Flat 17	0	6,389	1.2	£241.72	-100%
Flat 18	0	6,389	1.2	£241.72	-100%
Flat 19	0	6,332	1.2	£249.60	-100%
Flat 20	0	6,332	1.2	£249.60	-100%
Avs Houses	23020	11622	5.0	£793.40	-66%
Avs Flats	0	6634	1.2	£244.34	-100%
Av Sanford	16114	10125	3.9	£628.68	-76%
Sanford Total	**322278**	**202507**	**79**	**£12,573.63**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Table 6.3: Impact of Renewable Technologies, Energy Efficiency Measures and Behavioural Changes on NHER Model

Property	Revised modelled gas consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised modelled electricity consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised modelled CO2 emissions for gas and electricity combined for all properties following renewable technologies, energy efficiency measures and behavioural changes	Revised modelled running costs for all properties following renewable technologies, energy efficiency measures and behavioural changes
House 1	13,028	7,361	3.7	£775.00
House 2	10,695	7,361	3.7	£735.00
House 3	10,833	7,722	4.0	£763.00
House 4	10,695	7,417	3.8	£739.00
House 5	10,945	7,361	3.7	£739.00
House 6	10,833	7,722	4.0	£763.00
House 7	10,833	7,722	4.0	£762.00
House 8	11,111	7,361	3.7	£742.00
House 9	10,806	7,722	4.0	£762.00
House 10	13,556	7,361	3.7	£784.00
House 11	13,556	7,361	3.7	£784.00
House 12	12,417	8,028	4.1	£810.00
House 13	11,306	7,361	3.7	£745.00
House 14	14,389	8,028	4.1	£844.00
Flat 15	0	3,528	0.7	£197.00
Flat 16	0	3,528	0.7	£197.00
Flat 17	0	3,139	0.7	£173.00
Flat 18	0	3,139	0.7	£173.00
Flat 19	0	3,111	0.7	£182.00
Flat 20	0	3,111	0.7	£182.00
Avs Houses	11786	7564	3.9	£767.64
Avs Flats	0	3259	0.7	£184.00
Av Sanford	8250	6272	2.9	£592.55
Sanford Total	**165001**	**125445**	**58**	**£11,851.00**

Table 6.4: Impact of Renewable Technologies, Energy Efficiency Measures and Behavioural Changes on Actual Consumption

Property	Revised actual average annual gas consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised actual average annual electricity consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised actual average CO2 emissions for all properties following renewable technologies, energy efficiency measures and behavioural changes	Revised actual average running costs for both fuels and all properties following renewable technologies, energy efficiency measures and behavioural changes	Percentage change in Base Case actual CO2 emissions vs revised actual CO2 emissions for all properties
House 1	15,421	9,743	4.2	£680.84	-75%
House 2	13,783	11,146	4.8	£764.93	-66%
House 3	11,546	10,420	4.5	£721.39	-69%
House 4	8,487	11,677	5.0	£796.72	-61%
House 5	18,019	10,429	4.5	£721.95	-69%
House 6	14,501	8,408	3.6	£600.92	-77%
House 7	17,808	9,369	4.0	£658.45	-69%
House 8	10,409	10,389	4.5	£719.58	-72%
House 9	12,452	10,405	4.5	£720.54	-64%
House 10	13,185	12,352	5.3	£837.16	-64%
House 11	14,213	11,707	5.0	£798.49	-68%
House 12	13,490	10,114	4.3	£703.09	-69%
House 13	13,881	15,545	6.7	£1,028.43	-62%
House 14	16,098	10,871	4.7	£748.44	-70%
Flat 15	0	7,180	1.2	£252.38	-74%
Flat 16	0	7,180	1.2	£252.38	-74%
Flat 17	0	6,389	1.2	£252.38	-74%
Flat 18	0	6,389	1.2	£252.38	-74%
Flat 19	0	6,332	1.2	£259.15	-72%
Flat 20	0	6,332	1.2	£259.15	-72%
Avs Houses	13807	10898	4.7	£750.07	-68%
Avs Flats	0	6634	1.2	£254.64	-73%
Av Sanford	9665	9619	3.6	£601.44	-70%
Sanford Total	**193295**	**192379**	**74**	**£12,028.77**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	1.4

Table 7.1: Impact of Energy Efficiency Measures, Behavioural Changes and Gas Condensing Boiler on NHER Model, including Green Electricity

Property	Revised modelled gas consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised modelled electricity consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised modelled CO2 emissions for gas and electricity combined for all properties following energy efficiency measures, behavioral changes and gas condensing boiler	Revised modelled running costs for all properties following energy efficiency measures, behavioral changes and gas condensing boiler
House 1	17,028	8,361	3.3	£850.00
House 2	14,583	7,528	2.8	£758.00
House 3	14,750	7,889	2.9	£784.00
House 4	14,556	7,556	2.8	£761.00
House 5	14,861	7,528	2.8	£761.00
House 6	14,750	7,889	2.9	£784.00
House 7	14,722	7,889	2.9	£784.00
House 8	15,083	7,528	2.9	£764.00
House 9	14,750	7,889	2.9	£784.00
House 10	17,556	7,528	3.4	£799.00
House 11	17,167	7,528	3.3	£794.00
House 12	16,695	8,167	3.3	£831.00
House 13	15,361	7,528	2.9	£768.00
House 14	19,806	8,167	3.8	£873.00
Flat 15	6,056	1,361	1.2	£223.00
Flat 16	6,056	1,361	1.2	£223.00
Flat 17	4,528	1,361	0.9	£185.00
Flat 18	4,528	1,361	0.9	£185.00
Flat 19	4,917	1,417	1.0	£195.00
Flat 20	4,917	1,417	1.0	£195.00
Avs Houses	15833	7784	3.1	£792.50
Avs Flats	5167	1380	1.0	£201.00
Av Sanford	12633	5863	2.5	£615.05
Sanford Total	**252669**	**117251**	**49**	**£12,301.00**

Table 7.2: Impact of Energy Efficiency Measures, Behavioural Changes and Gas Condensing Boiler on Actual Consumption, including Green Electricity

Property	Revised actual average annual gas consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised actual average annual electricity consumption for all properties following application of energy efficiency measures, behavioral changes and gas condensing boiler	Revised actual average CO2 emissions for all properties following energy efficiency measures, behavioral changes and gas condensing boiler	Revised actual average running costs for both fuels and all properties following energy efficiency measures, behavioral changes and gas condensing boiler	Percentage change in Base Case actual CO_2 emissions vs revised actual CO_2 emissions for all properties
House 1	20,156	11,066	3.9	£1,025.43	-76%
House 2	18,795	11,399	3.6	£1,035.00	-74%
House 3	15,721	10,644	3.0	£951.69	-79%
House 4	11,552	11,896	2.2	£997.21	-83%
House 5	24,467	10,665	4.7	£1,040.59	-67%
House 6	19,744	8,590	3.8	£848.71	-76%
House 7	24,201	9,571	4.7	£961.67	-64%
House 8	14,130	10,625	2.7	£934.39	-83%
House 9	16,998	10,630	3.3	£963.44	-74%
House 10	17,076	12,632	3.3	£1,103.77	-78%
House 11	17,999	11,972	3.5	£1,066.98	-78%
House 12	18,137	10,289	3.5	£951.08	-75%
House 13	18,861	15,897	3.7	£1,349.21	-79%
House 14	22,158	11,059	4.3	£1,044.96	-73%
Flat 15	5,608	2,770	1.1	£301.73	-75%
Flat 16	5,608	2,770	1.1	£301.73	-75%
Flat 17	5,400	2,770	1.0	£299.66	-76%
Flat 18	5,400	2,770	1.0	£299.66	-76%
Flat 19	5,099	2,883	1.0	£304.53	-78%
Flat 20	5,099	2,883	1.0	£304.53	-78%
Avs Houses	18571	11210	3.6	£1,019.58	-75%
Avs Flats	5369	2808	1.0	£301.98	-76%
Av Sanford	14610	8689	2.8	£804.30	-76%
Sanford Total	**292209**	**173783**	**57**	**£16,085.99**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	0.0

Table 7.3: Impact of Renewable Technologies, Energy Efficiency Measures and Behavioural Changes on NHER Model, including Green Electricity

Property	Revised modelled gas consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised modelled electricity consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised modelled CO2 emissions for gas and electricity combined for all properties following renewable technologies, energy efficiency measures and behavioural changes	Revised modelled running costs for all properties following renewable technologies, energy efficiency measures and behavioural changes
House 1	22,917	7,861	0.0	£775.00
House 2	15,500	7,861	0.0	£735.00
House 3	21,889	8,250	0.0	£763.00
House 4	21,500	7,861	0.0	£739.00
House 5	13,028	7,861	0.0	£739.00
House 6	21,889	8,250	0.0	£763.00
House 7	11,361	8,250	0.0	£762.00
House 8	30,056	7,806	0.0	£742.00
House 9	15,750	8,250	0.0	£762.00
House 10	23,000	7,861	0.0	£784.00
House 11	22,611	7,861	0.0	£784.00
House 12	20,333	8,528	0.0	£810.00
House 13	20,306	7,861	0.0	£745.00
House 14	23,195	8,556	0.0	£844.00
Flat 15	0	3,528	0.0	£197.00
Flat 16	0	3,528	0.0	£197.00
Flat 17	0	3,139	0.0	£173.00
Flat 18	0	3,139	0.0	£173.00
Flat 19	0	3,111	0.0	£182.00
Flat 20	0	3,111	0.0	£182.00
Avs Houses	20238	8066	0.0	£767.64
Avs Flats	0	3259	0.0	£184.00
Av Sanford	14167	6624	0.0	£592.55
Sanford Total	**283336**	**132473**	**0.0**	**£11,851.00**

Table 7.4: Impact of Renewable Technologies, Energy Efficiency Measures and Behavioural Changes on Actual Consumption, including Green Electricity

Property	Revised actual average annual gas consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised actual average annual electricity consumption for all properties following application of renewable technologies, energy efficiency measures and behavioural changes	Revised actual average CO2 emissions for all properties following renewable technologies, energy efficiency measures and behavioural changes	Revised actual average running costs for both fuels and all properties following renewable technologies, energy efficiency measures and behavioural changes	Percentage change in Base Case actual CO2 emissions vs revised actual CO2 emissions for all properties
House 1	15,421	9,743	0.0	£739.06	-100%
House 2	13,783	11,146	0.0	£836.90	-100%
House 3	11,546	10,420	0.0	£786.24	-100%
House 4	8,487	11,677	0.0	£873.89	-100%
House 5	18,019	10,429	0.0	£786.90	-100%
House 6	14,501	8,408	0.0	£646.06	-100%
House 7	17,808	9,369	0.0	£713.01	-100%
House 8	10,409	10,389	0.0	£784.13	-100%
House 9	12,452	10,405	0.0	£785.25	-100%
House 10	13,185	12,352	0.0	£920.96	-100%
House 11	14,213	11,707	0.0	£875.95	-100%
House 12	13,490	10,114	0.0	£764.95	-100%
House 13	13,881	15,545	0.0	£1,143.51	-100%
House 14	16,098	10,871	0.0	£817.72	-100%
Flat 15	0	7,180	0.0	£241.72	-100%
Flat 16	0	7,180	0.0	£241.72	-100%
Flat 17	0	6,389	0.0	£241.72	-100%
Flat 18	0	6,389	0.0	£241.72	-100%
Flat 19	0	6,332	0.0	£249.60	-100%
Flat 20	0	6,332	0.0	£249.60	-100%
Avs Houses	13807	10898	0.0	£819.61	-100%
Avs Flats	0	6634	0.0	£244.34	-100%
Av Sanford	9665	9619	0.0	£647.03	-100%
Sanford Total	**193295**	**192379**	**0.0**	**£12,940.60**	**n/a**

Additional electricity usage from external lights and ponds

kWh	CO2
3247	0.0

Appendix 2

Residents' questionnaire.

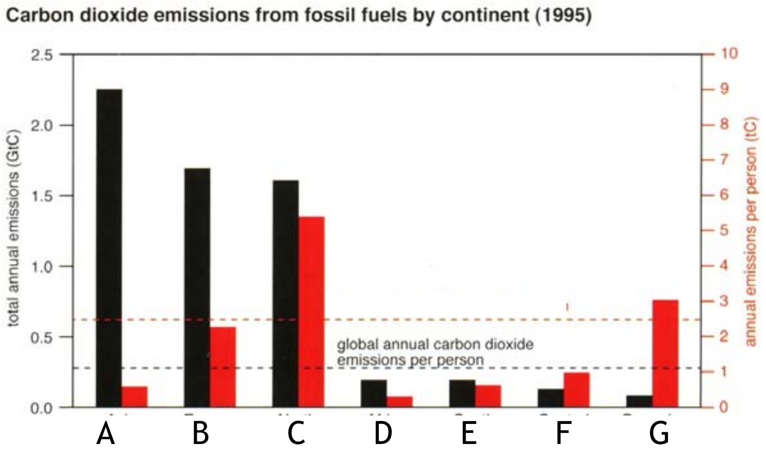
Tell us what you think….
And win a solar radio!



The Centre for Sustainable Energy is working with Sanford Housing Cooperative to find ways of **cutting your fuel bills and reducing carbon dioxide emissions**. To find out what things we might be able to do we need your help. Please take a few minutes to complete this questionnaire. **Don't worry if you don't know the answer to a question - have a guess.**

1	In general do you find your **house…** *(please tick your response)***.**	Too hot Too cold About right
1a	What about the kitchen?	Too hot Too cold About right
1b	And the first floor?	Too hot Too cold About right
1c	And the top floor(s)?	Too hot Too cold About right
2	Imagine your room is too hot, what would you do first?	Open the window Turn down the thermostat in the hall Take off some clothing! Turn down/off the radiator in your room
3	If your room was too cold what would you do first?	Switch on the radiator in your room Turn up the thermostat in the hall Plug in some other heating like a fan heater Put on more clothes

4	Without looking, what temperature do you think the thermostat in the hall is set at?	……..degrees C or ……..degrees F
5	What do you think the average, winter day time temperature in the kitchen/living room is?	……..degrees C or ……..degrees F
6	Do you know how much energy a low energy light bulb uses **compared** to a standard 100 watt light bulb of the same brightness?	10% of the energy of a 100W bulb 20% ‘’ etc 30% 40% 50% 60%
7	If a TV is switched from being **on** to being on **standby**, what percentage of energy is it using?	5% of the energy it uses when on. 10% ‘’ etc. 20% 30% 40% 60%
8	If a computer and monitor switches to **standby mode**, what percentage of energy is it using?	5% of the energy it uses when on. 10% ‘’ etc. 20% 30% 40% 60%
9	If a video is switched from being **on** to being on **standby**, what percentage of energy is it using?	5% of the energy it uses when on 10% ‘’ etc. 20% 30% 40% 60%
10	How much of your weekly rent do you think goes to cover the cost of gas and electricity?	£……….

<table>
<tr><td>11</td><td colspan="2">


The graph above shows the annual emissions from fossil fuels for Central America, Africa, Oceania, South America, Africa, North America, Europe and Asia. The left hand column in each pair shows the total emissions for the continent and the right hand columns show the emissions per person.

Which column (A to G) do you think represents Europe?</td></tr>
<tr><td>13</td><td>If Sanford was to invest money in improving the houses and flats which of the options shown should be the priority? (Please rank the following in order of priority).</td><td>No:…..Reducing fuel bills
No:……Reducing carbon dioxide emissions
No:…..A better heating system in your home
No: ….Better ventilation
No:…..Making use of renewable energy</td></tr>
</table>

Thank you for taking the time to complete the questionnaire.

Please return it to Amanda by Monday 9th June 2003.

Why are we doing this survey?

We are looking at ways of **refurbishing the houses and flats** to make them cheaper to run.

We are also looking at ways of using **renewable energy** to provide heat, hot water and electricity.

By doing this we can **reduce** the use of **fossil fuels** and emissions of **carbon dioxide**, which is one of the gases, associated with **global warming**.

To enter the prize draw

Please write you name and house number below. If you don't want to give enter the draw and give us your name we still want to hear from you.

Name:

House/Flat No:

To find out more about CSE visit our web-site at www.cse.org.uk

Thank you.

Appendix 3

Summary of questionnaire results

Awareness Questionnaire Results and Analysis			
Question	**Answers**	**Numerical Results**	**% Results**
1. In general do you find your house….	Too hot	43	**62%**
	Too cold	1	1%
	About right	25	37%
1a. What about the kitchen?	Too hot	36	**54%**
	Too cold	1	1%
	About right	30	45%
1b. And the first floor?	Too hot	31	**51%**
	Too cold	0	0%
	About right	30	49%
1c. And the top floor(s)?	Too hot	33	**54%**
	Too cold	2	3%
	About right	26	43%
2. Imagine your room is too hot,what would you do first?	Open the window	28	**41%**
	Turn down the thermostat in the hall	7	10%
	Take off some clothing	7	10%
	Turn down/off the radiator in the room	26	39%
3. If your room was too cold what would you do first?	Switch on the radiator in your room	28	41%
	Turn up the thermostat in the hall	1	1%
	Plug in some other heating like a fan heater	2	3%
	Put on more clothes	37	**55%**
4. Without looking, what temperature do you think the thermostat in the hall is set at?		Average 20.7	
5. What do you think the average,winter day time temperature in the kitchen/living room is?		Average 21.2	
6. Do you know how much energy a low energy light bulb uses compared to a standard 100 watt light bulb of the same brightness?	10%	17	**27%** correct
	20%	17	
	30%	13	
	40%	8	
	50%	5	
	60%	4	
7. If a TV is switched from being on stand-by, what percentage of energy is it using?	5%	8	
	10%	10	
	20%	13	
	30%	8	
	40%	12	
	60%	14	**22%**

			correct
8. If a computer and monitor switches to stand-by mode, what percentage of energy is it using?	5% 10% 20% 30% 40% 60%	4 10 14 13 10 10	**7%** correct
9. If a video is switched from being on to being on stand-by, what percentage of energy is it using?	5% 10% 20% 30% 40% 60%	12 11 11 12 8 6	**10%** correct
10. How much of your weekly rent do you think goes to cover the cost of gas and electricity?		£7.2	
11. Which bar in the graph represents the carbon dioxide emissions of Europe? Answer -	Correct Incorrect	32 25	**56%** correct
12. If Sanford was to invest money in improving the houses and flats which of the options shown should be the priority?	Reducing Fuel Bills Reducing Carbon Dioxide Emissions A better heating system in your home Better Ventilation Making use of renewable energy	3 2 4 5 1	**3rd** most important **2nd** most important **4th** most important **Least** Important **Most** important

Appendix 4

Sources of further information

Trade Associations

Wood Fuelled Boiler Systems :-
British Biogen
16 Belgrave Square
London
SW1X 8PQ
UK

Tel: 020 7235 8474
info@britishbiogen.co.uk

Ground Source Heat Pumps :-
The International Ground Source Heat Pump Association
Oklahoma State University
499 Cordell South
Stillwater
OK 74078

Tel: 1-800-626-4747
Fax: (405) 744-5283
E mail: laus@okstate.edu

Photovoltaic Panels:-
The British Photovoltaic Association
National Energy Centre
Davy Avenue
Knowlhill
Milton Keynes
MK5 8NG

Tel: 01908 442291
Fax: 08700 529193
E-mail: enquiries@pv-uk.org.uk
Web: www.pv-uk.org.uk

Solar Thermal:-
Solar Thermal Association
The National Energy Centre
Davy Avenue
Knowlhill
Milton Keynes
MK5 8NG

Tel: 01908 442290
Fax: 0870 0529194

E-mail: enquiries@solartradeassociation.org.uk
Website: www.solartradeassociation.org.uk

Accredited Installers

Clear Skies

For a list of accredited Wood-fuelled Boiler Systems, Solar Thermal and GSHP installers go to www.clearskies.org.uk

Solar Trade Association Installers

For a list of accredited PV installers go to www.greenenergy.org.uk/sta