National Energy Services Ltd.

Alternative Measures for HEES

Welsh Assembly Government

Final Report

April 2002

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1. Introduction

1.1 Background

It is estimated that there are approximately 41,000 households in Wales that are eligible and capable of benefiting from HEES+. Of these, an estimated 6,000 properties do not have access to the mains gas network. Additionally, many properties have solid walls and consequently are not suitable for the fitting of cavity wall insulation. There is little that HEES+ can do for these 'difficult to heat' properties in terms of alleviating fuel poverty since only minimal insulation and relatively expensive to run heating systems can be offered.

The Welsh Assembly Government is concerned that electric heating is an inadequate heating method for some households in locations with no mains gas supply, particularly where cavity wall insulation is not an option. Therefore assistance under the HEES is often insufficient to lift such households out of fuel poverty. Under the HEES, the Assembly would like to be able to offer the same benefits to all properties, regardless of whether they are connected to the gas network or not.

Commissioned by the Welsh Assembly Government, National Energy Services Ltd has derived a number of alternatives that the HEES could offer to difficult to heat properties. These recommendations consider capital costs, running costs, installation issues, environmental concerns, and operability. Where an alternative fuel is susceptible to price fluctuations, the prospect of increased prices has also been considered.

1.2 Current Home Energy Efficiency Scheme

The current Home Energy Efficiency Scheme, although recently revised to provide a more comprehensive package of energy efficiency measures, remains limited for solid walled properties that do not have access to the mains gas network. The current HEES provides a number of predetermined packages that are dependent on the construction of the property and the existing arrangements for heating and hot water.

The HEES scheme currently offers a range of energy efficiency measures, of which only some are capable of being installed in difficult to heat properties (Table 1.1)

Table 1.1 Measures capable of being installed in difficult to heat properties

Available measures	Capable of being installed in difficult to heat properties
Loft insulation	✓
Draught proofing of windows and doors	✓
Cavity wall insulation	×
Hot water tank jacket	✓
Two compact fluorescent lamps	✓
Gas room heaters with thermostatic controls	×
Three electric storage heaters	✓
Closed solid fire fuel cassette	✓
Electric dual immersion water heater with foam insulated tank	✓
Timer controls for electric space and water heaters	✓
Gas condensing combination boiler system	×

For the HEES in Wales a grant maximum of £1,500 is available, however, if a household falls under any of the following categories, a HEES+ grant of up to £2,700 may be awarded:

- Low-income householders aged over 60
- Lone parent households
- Chronically sick and disabled households

2. Methodology

The Assembly wishes to offer the same benefits to dwellings with no gas supply as it does to those with a gas supply. For the purpose of this study, this has been measured in terms of the annual running costs for the property, however SAP, measure life span, maintenance costs, and CO_2 emissions have also been considered.

The overall energy efficiency of a property is determined by a combination of the insulation of the fabric of the house and the costs of providing heat in the property. For off-gas properties no realistic amount of insulation can compensate for an expensive heating system, so the analysis has to examine both suitable insulation measures and lower cost heating systems.

Numerous alternatives to the existing HEES measures have been identified, including new heating systems, insulation options, and alternative energy sources such as photovoltaics and solar heating. In addition, the possibility of using alternative fuels such as oil, LPG, coal, and wood has been investigated.

Houses of differing sizes, but almost identical in all other respects have different running costs, and so four archetype properties have been defined ranging from a small terraced to a large detached property (Table 4.1). These properties have poor thermal characteristics, no gas supply, and poor heating systems.

A series of references have been calculated for each property type, against which the merits of different measures can be compared.

- Baseline - a property with minimal insulation and a poor heating system has been used as a baseline.
- Benchmark - defined as the baseline property with the currently applicable HEES measures applied.
- Target - a baseline property with current HEES measures applied but assuming it has a connection to the mains gas supply

Measures or combinations of measures have been simulated using NHER Evaluator to determine their running costs etc. This software is based on BREDEM-12, which is BRE's preferred method of calculating running costs. It enables a model of a property to be built up incorporating the building fabric, the heating system, the occupancy pattern, site details, and domestic appliances. NHER Evaluator also allows the adjustment of fuel costs to reflect current conditions or to model the effects of fuel cost changes.

The measure packages were finally assessed in terms of the following:

- Money and CO_2 savings – how much money and CO_2 savings can be expected with the installation of measures?
- Installation cost – how much does a measure cost to install, including labour?
- Suitability for different properties – some measures are more suited to one property than others, for example terraced properties may be too small for some technologies.
- Availability – emerging technologies may only be available in a limited supply.
- Longevity – how long before the measure should be replaced?
- Ease of use – are there any issues that would affect how easy a technology is to use, for example manual moving of heavy solid fuels?
- Infrastructure requirements – are there any situations where the infrastructure is lacking?

The assessment resulted in the selection of recommended measures.

3. Alternative measures

Alternative measures can be split into those that alter the fabric of the building, those that involve the heating system, and those that provide additional energy to the property.

3.1 Building fabric measures

The main adjustments that can be easily made to the fabric of buildings lie in the application of insulation. It is possible to insulate all surfaces of a property: walls, roof, and floor.

Insulation can be applied to either face of a wall. Two external wall insulation systems have been considered:

- Conventional external wall insulation: mineral wool slabs, or similar, are fixed to the outside of the wall and covered in reinforced render. Using this technique, it is possible to produce a brick effect finish.
- **Wallreform:** a 'trowel on' product comprising render and small polystyrene beads that can be applied to the outside or inside of the walls.

Two internal wall insulation systems are considered:

- Standard dry lining using insulated plasterboard mounted on battens; a small air gap is left behind the insulation
- **Sempatap:** an insulated wall-covering product that is supplied in rolls and glued to the existing wall in a similar fashion to wallpaper. The surface can then be painted or papered as required. **Sempatap** comes in thicknesses of 5mm and 10mm, but only the thicker product has been considered.

Where little or no insulation is fitted in the loft, the current HEES offers loft insulation top up to a thickness of 200mm, and insulation of this thickness has been modelled. Solid floors can be insulated with a layer of solid insulation beneath floorboards and carpets.

3.2 Heating system measures

The most effective way of improving the efficiency, and hence the running costs, of a domestic property is to install a new highly efficient heating system. There are numerous systems available, running on a variety of fuels.

Under the HEES, eligible properties are fitted with three storage heaters operating from an Economy-7 electricity tariff. The heaters use cheap off-peak electricity to heat up, then during the day when the heat is required and electricity is more expensive, the heaters release the stored up heat.

Boiler systems burning oil or Liquefied Petroleum Gas (LPG - a generic term applied to propane and butane; gases which are easily compressed into a liquid) have been considered. Both these systems require a storage tank located outside the property that is periodically filled by a delivery lorry. Most properties are accessible by lorry and so such systems are suited to properties with no access to the mains gas supply.

Wood pellet burning boilers feeding conventional radiators are being considered that incorporate an automatic feed system. A single unit comprises the boiler and a hopper, which is located within the property. Wood pellets are manually loaded into the hopper as required and the pellets are automatically fed into the boiler as necessary. In the summer months the hopper may require filling once a fortnight, rising to twice a week in the winter. Pellets are denser than solid wood so less frequent feeding is required than traditional wood burner/boiler systems.

Coal fired boilers that operate in a similar way to wood fired boilers are being modelled. These have a hopper that is periodically filled, and the coal is fed into the boiler as required. As with wood pellets, the coal hopper would require more filling in winter than during the summer.

The implementation of micro-CHP (combined heat and power) into housing is at present not commonplace. Accurate information on the impact on the energy consumption is therefore not freely available and a number of assumptions have been made in order to estimate the effects of micro-CHP (see section 10.9).

The development of Micro-CHP is focused primarily on gas-fuelled systems, which, while being of benefit to properties connected to the mains gas supply, is not appropriate for this study. However, LPG- and oil-fuelled CHP systems are emerging technologies and will form the basis for analysis of this measure.

The seasonal efficiency of ground source heat pumps is considerably higher than the equivalent water or air source heat pump. An algorithm to model ground source heat pumps in residential properties is currently being introduced into the standard SAP in which a ground to water heat pump has an assumed coefficient of performance (COP) of 3.2, i.e. for every kW of electricity used, it will deliver 3.2 kW heat.

Mechanical ventilation has been considered whereby a series of air ducts are installed in the property and an extractor fan draws out air. Some systems use heat recovery – warm air being expelled is used to heat cold air coming in.

3.3 Other measures

In addition to heating and insulation systems that effectively increase the efficiency of a property, it is possible to look at alternatives that provide extra energy into the property from the outside environment.

Solar energy can be used to heat water or to directly generate electricity through the use of photovoltaic (PV) cells. The outputs of both systems are dependant primarily on the area and therefore, when fitted to existing HEES eligible properties, space and cost will be important issues.

4. Archetypes

Before any simulations could be performed, a standard set of conditions was defined. These conditions take into account property details, occupancy patterns, and fuel costs.

4.1 Property types

Four main property archetypes that are representative of Welsh households with no access to the gas network have been defined using data from a variety of sources:

- Welsh House Condition Survey (1998)
- HEES surveys carried out on properties with no access to mains gas
- Estate agent websites
- Local NHER assessors

The archetypes are built to the same specification, with the main difference being the property size and built form (Table 4.1). Wall areas and perimeters have been calculated from the floor areas using simple geometric models, and the wall and roof areas, and the exposed perimeters vary from one archetype to the next. The heating system and wall, floor and roof construction remain the same. Consequently, the four properties all have a SAP of one.

Table 4.1 Typical property characteristics

Characteristic	Terrace	Semi-detached	Detached	Large detached
Total floor area	60	70	80	110
Ground floor area	33.3	35	40	55
First floor area	26.7	35	40	55
Exposed perimeter	11.8	16.9	25.5	30
Wall	Solid wall, U value = 2.1			
Total exposed wall area	64	81	122.4	144
Total wall area – windows	51	66	106	127
Zone 1 wall area	8.4	32	30.6	41.6
Zone 1 area	25	11.5	20	27.5
Window type	Single glazed wood frame			
Window orientation	All 4 directions*			
Large windows	5	6	7	7
Small windows	1	1	1	2
Chimneys	1	1	2	2
Main roof	Pitched – 25mm loft insulation			
Main roof area	26.7	35	40	55
Secondary roof	Flat – no insulation	NA	NA	N/A
Secondary roof area	12	NA	NA	N/A
Heating	Coal fire with no controls			
Hot water	Single off peak immersion heater, 80 litres, 25mm jacket			

*Although it is only possible to have windows on two sides of a terraced property, not all terraces in Wales are oriented the same way, and so the window orientation has been averaged out over all four sides of the property.

For the purpose of this study it has been assumed that coal fires heat the properties, but in reality such properties could be heated by a variety of systems including wood fires, storage heaters, and other electric heaters. A coal fire has been assumed as a poor case scenario. Similarly, solid walls and just 25mm loft insulation are poor case situations and have been assumed to form the fabric of the base property.

4.2 Occupancy types

In assessing running costs three occupancy patterns have been used within Evaluator (Table 4.2).

Table 4.2 Occupancy patterns used in analysis

Occupancy pattern	Heating use	Adults	Children	Heating hours	Zone 2 heating	Demand temp
Standard	Standard	2	2	2 hours per morning and 7 hours per evening during the week, 16 hours per day during the weekend	100%	21°C
Extended	High	2	2	16 hours heating every day	100%	21°C
Sheltered	High	2	0	16 hours heating every day	100%	21°C

The standard occupancy pattern is designed to reflect the heating regime that may be typical of a family of four with both adults working during the day, and both children at school. The extended occupancy regime differs in that it assumes that one adult is at home during the day, with one or both of the children. These two patterns are set within NHER Evaluator. The sheltered regime is what would be expected if the property were occupied by a retired couple who spend a large proportion of every day in the property. In line with the UK Fuel Poverty Strategy, all demand temperatures have been set to 21°C.

4.3 Fuel types

Fuel costs are essential for calculating the running costs of properties. Due to market forces and taxation policy, fuel costs do not remain static and the impact of possible variations in fuel costs has been considered.

4.3.1 Local fuel costs

The costs of all fuels involved in the analysis have been researched to obtain the most up to date prices possible (Table 4.3). The costs for the fuels in Wales have been sought, but where none could be found, national averages have been used.

The fuel costs have been entered into NHER Evaluator and are directly used by the software to calculate running costs.

Table 4.3 Fuel costs used in analysis (all prices include VAT at 5%

Fuel	Standing charge (£)	Cost (£/GJ)	Cost (pence/unit)	Unit used
Mains gas†	39.27	3.54	1.275	kWh
Bulk LPG**	57.10	10.38	26.61	Litre
35 sec oil††	0	4.46	16.5	Litre
28 sec oil††	0	4.32	16.0	Litre
Coal***	0	4.7	14.0	kg
Wood***	0	5.71	10	kg
On peak electricity*	44.36	20.22	7.28	kWh
Economy 7(off peak)*	27.9	8.11	2.92	kWh
Economy 7(on peak)*	27.9	21.53	7.75	kWh

† Gas prices taken from EnergyWatch website using Scottish Power / Manweb December 2001 figures for region T3

†† Oil prices obtained from oil distributors

* Electricity prices taken from EnergyWatch website, using SWALEC December 2001 figures.

** LPG price obtained from Sutherland Associates Comparative Domestic Heating Costs – UK and the Republic of Ireland

*** Distributors in Wales have been used to acquire prices for coal and wood

Evaluator assumes a calorific value for wood that is different from the information obtained from suppliers. Although the two values for wood in Table 4.1 (£/GJ and pence/unit) cannot be simultaneously entered into Evaluator, cost and CO_2 figures generated in the simulations are based on the pounds per giga-joule figure.

Concessionary coal continues to be issued to many households that have been associated with the coal industry, even if the mines have since been decommissioned. However, it is very difficult to find any information on the distribution of concessionary coal and there is no necessary correlation with those eligible for the HEES. As a worst-case scenario, it is assumed that households pay for coal at the current rate.

4.3.2 Community LPG supply

A submission by Calor Gas Ltd for the UK Fuel Poverty Strategy details a scheme whereby a number of properties are connected to a large communal storage tank rather than having their own tanks on site. Economies of scale enable a reduction in the price of LPG delivered to the properties. A delivery system serving 10 properties could be established at a cost of £1,200 per property. In addition to this would be the cost of installing the individual heating systems in the properties.

Calor Gas suggests a price of £0.20 per litre of LPG (2.81 p/kWh) and it has been assumed that the standing charge of £57.10 would be equally split between the ten properties.

4.3.3 Fuel price variation

A fuel may be considered unsuitable if it were thought that its price would increase rapidly in the near future thus rendering a previously affordable heating system, no longer affordable. Alternatively, a fuel showing a decreasing trend in its price may be more appealing. By plotting fuel prices over recent years (Fig 4.1), an indication of the any trends can be identified.

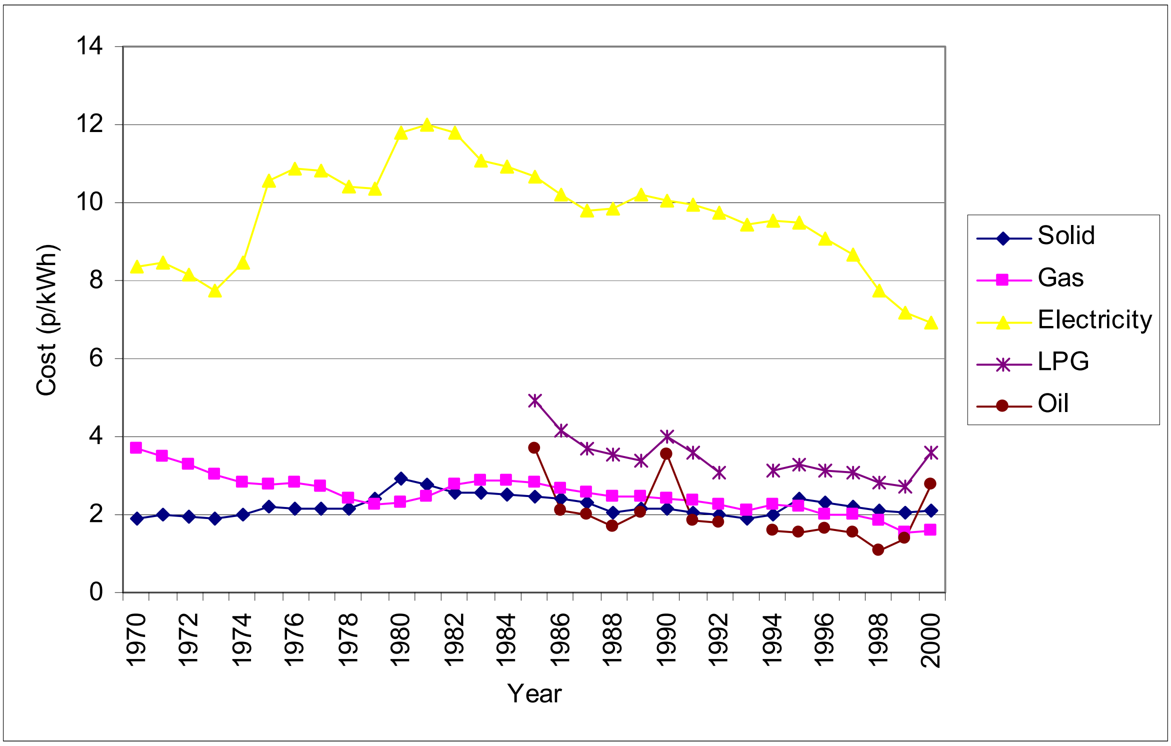


Fig 4.1 Variation in fuel costs, figures are national averages (Solid fuel, gas and electricity prices from DUKES 2001, LPG and oil prices from J Willoughby's Domestic Fuel Price Guide). Oil and LPG data for 1993 are missing. Data are shown in real terms at 2002 prices.

In the past few years the price of oil has shown a high rate of growth following a short period of falling prices. A similar pattern applies to the price of LPG, although LPG is more susceptible to local fluctuations.

Between 1970 and about 1980, the price of electricity increased rapidly.. From then on, the price has been trending downwards and there is a visible continuing trend for a decrease in the cost of electricity.

Solid fuels prices showed a slow increase between 1970 and 1980, and then have been slowly declining to roughly the 1970 level. Gas prices decreased slowly to 1980, then for a short period they increased slightly, followed by a long period of steady decline. Gas is now the cheapest fuel on a kWh basis, but unfortunately, gas is the one fuel that this study is aiming to find alternatives for.

Over the coming years, fuel prices are expected to change as follows:

- Gas - The wholesale price has already risen and is expected to rise higher over the next decade as the UK imports more gas from Europe.
- Electricity - Prices have recently come down as a result of NETA and Ofgem constraints. However over the next decade they will rise as gas prices increase and as the Renewables Obligation bites.
- Oil - Prices will continue to fluctuate significantly. It is expected that the oil price will stabilise around 20 $/barrel steadily rise roughly in line with gas prices over the next decade. After about 2010 the rate of increase will depend significantly on developments in the transport market.
- LPG - Prices will follow the same general trend as oil prices (since LPG is derived from oil). However, as LPG use for transport grows, the price of domestic LPG could increase due to limited supply.
- Coal – Prices are expected to be fairly stable due to the very large resource base and the move away from coal as CO_2 emission constraints are increased.

4.3.4 Payment methods

How fuel is paid for may change from one fuel type to another, and it may be difficult for some properties to accommodate this change. For example, a household may be used to making frequent payments for electricity, and hence being able to budget for their fuel. In the case of changing to using oil or LPG, a large delivery would be made maybe once or twice a year, and paying large amounts of money in this way may not be feasible.

When buying oil it is possible to spread payments over the year. The size of each payment is based on an estimated consumption, and at the end of the year the situation is reviewed. Similar payment options exist for LPG deliveries.

Electricity tariffs are available where the customer pays a fixed low fee. Regular payments can be made weekly, monthly or even annually; whichever suits the customer best. The fee is based on the property and the number of residents. Such tariffs may become more widely available in the near future.

Deliveries of wood pellets and coal take place more frequently than for oil or LPG (e.g. six to eight times a year) because they are more bulky, and so the cost of the fuel is spread more evenly throughout the year.

5. Modelling

5.1 References

NHER Evaluator has been used to evaluate the three sets of references (baseline, benchmark, and target) for the different archetype properties. Numerous outputs are available from the software, but this study considers the annual running costs, the SAP, and the CO_2 emissions of the properties.

It should be noted that running costs are the total fuel costs for the property under the specified occupancy conditions, i.e. they include cooking, lights and appliances, and standing / fixed charges.

5.1.1 Baseline

The baseline properties have been designed to have low efficiencies and high running costs. They also have low SAP scores and produce large amounts of CO_2 (Table 5.1).

Table 5.1 Baseline figures

	Terrace	Semi-detached	Detached	Large detached
SAP*	1	1	1	1
Running cost (£/y)				
Standard	1,224	1,356	1,727	2,078
Extended	1,270	1,408	1,816	2,179
Sheltered	1,198	1,331	1,734	2,082
CO_2 emissions (Tonnes/y)				
Standard	13.3	15.1	20.4	25.1
Extended	14.0	15.9	21.7	26.6
Sheltered	14.1	15.9	21.7	26.6

* Note that SAP is not defined below 1, for most of these properties it was certainly below the minimum figure.

It would be expected that when changing from standard to sheltered occupancy, the changes in running costs and CO_2 would be in the same direction. Table 5.1 shows otherwise, but this is explained by changes in the electricity / gas mixture that are associated with the occupancy changes.

5.1.2 Benchmark

Assuming the four archetype houses were eligible for HEES, they would receive:

- Two compact fluorescent lamps
- Three storage heaters
- Loft insulation top up to 200mm
- Draught proofing of windows and doors.
- Hot water cylinder jacket

The HEES will provide up to 200mm of mineral fibre loft insulation. If a property has loft insulation already, as in the case of the archetype properties, then this will be topped up to 200mm. The fitting of storage heaters would accompany the switching from standard electricity rate to an Economy-7 tariff, thus exploiting cheaper electricity available during off-peak times. On-peak electricity is a little more expensive under Economy-7, but constitutes a smaller proportion of energy used.

The costs of different measures increase as the property size increases; this is most noticeable when installing area-dependent measures (e.g. loft insulation). Under HEES all four archetype properties would be fitted with the same number of storage heaters.

Table 5.2 Costs of installing HEES measures in archetype properties

Measure	Cost (£)			
	Terrace	Semi-detached	Detached	Large detached
Compact fluorescent lamps	10	10	10	10
Storage heaters	1,340*	1,340*	1,340*	1,340*
Loft insulation	200	250	300	300
Draught proofing windows and doors	60	66	72	78
Hot water cylinder Jacket	10	10	10	10
Total	1,620	1,676	1,432	1,438

*Note that although the houses are different sizes, under HEES they would be fitted with the same number of storage heaters

Applying the above measures to the baseline houses results in the figures shown in Table 5.3.

Table 5.3 Effects of HEES measures on archetype properties

	Terrace	Semi-detached	Detached	Large detached
SAP	21	30	20	26
Running cost (£/y)				
Standard	957	975	1,218	1,419
Extended	921	992	1,247	1,451
Sheltered	823	887	1,137	1,324
CO_2 emissions (Tonnes/y)				
Standard	10.6	10.7	14.8	17.8
Extended	10.0	11.0	15.3	18.4
Sheltered	9.8	10.9	15.1	18.2

5.1.3 Target

If the four archetype houses were connected to the gas network and were eligible for HEES+, they would receive a gas condensing combination boiler instead of the three storage heaters, and since there would be no hot water tank, a jacket could not be included in the package. Under the HEES the four archetype properties would receive different sized boiler systems; the smallest and cheapest being fitted to the terraced property, and the largest and most expensive being fitted to the detached properties.

The gas heating system installed under HEES consists of a boiler operating through five radiators. The boiler has an interlock, a permanent pilot, and a fan-assisted flue. Controls include a programmer, four TRVs (one radiator is left without a TRV in order to keep the system open), and a room thermostat.

Table 5.4 Costs of installing HEES measures in archetype properties connected to the gas network

Measure	Cost (£)			
	Terrace	Semi-detached	Detached	Large detached
Compact fluorescent lamps	10	10	10	10
Gas condensing combination boiler	1,800	1,900	2,000	2,000
Loft insulation	200	250	300	300
Draught proofing windows and doors	60	66	72	78
Total	2,070	2,226	2,382	2,388

When these measures are applied to the archetype houses, running costs and CO_2 emissions decrease and the SAP scores increase (Table 5.5).

Table 5.5 Effects of HEES measures on archetype properties connected to the gas network

Improvement	Terrace	Semi-detached	Detached	Large detached
SAP	49	54	45	50
Running cost (£/y)				
Standard	574	627	769	916
Extended	596	653	813	966
Sheltered	541	589	742	873
CO_2 emissions (Tonnes/y)				
Standard	5.8	6.5	8.6	10.4
Extended	6.1	6.9	9.3	11.2
Sheltered	5.9	6.6	9.0	10.8

5.2 Simulations

5.2.1 Excluded measures

A few measures have been excluded from further analysis because initial investigations showed that they were not workable solutions:

- Floor insulation has not been considered because it involves too much upheaval, i.e. removing and replacing of carpet (or other flooring), refitting of skirting boards, and adjustment of doorways. It may be practical to fit floor insulation where there is access via basement voids, but such a case may be quite rare.

- Mechanical ventilation systems are often installed to combat condensation; they do not increase SAP or save energy and hence are unlikely to affect fuel poverty. They have not been considered in this report.

- While installing loft insulation, it may seem worthwhile to fit more than 200mm, maybe increasing this up to 300mm. However, in the context of this study, given the high U-values of the walls the extra savings associated with thicker insulation are not significant, installing more than 200mm loft insulation has not therefore been considered

5.2.2 Measures simulated

Numerous simulations have been run on the base properties with various combinations of energy efficiency measures applied (Table 5.6). For some simulations, the effect of increased, or decreased fuel prices has also been studied (see Appendix I for assumptions used in the simulation of different heating systems).

Table 5.6 Summary of simulations

Simulation	Measures applied
1	Base property
2	Benchmark (measures offered by HEES to archetype house – three storage heaters, 200mm loft insulation, two CFLs, and draught proofing, and hot water cylinder jacket)
3	Target (measures offered by HEES to archetype house on gas network - condensing combination gas boiler + radiators, 200mm loft insulation, 2 CFLs, and draught proofing)
4	28 sec oil condensing combination boiler + radiators
5	35 sec oil condensing combination boiler + radiators
6	50mm external wall insulation
7	70mm external wall insulation
8	10mm **Sempatap** internal wall insulation
9	Auto feed wood burning boiler + radiators
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation

Simulation	Measures applied
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation
15	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation (cost of oil is 24 p / litre)
16	50mm **Wallreform**
17	LPG condensing combination boiler + radiators
18	Three storage heaters
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**
20	$3m^2$ solar heating
21	LPG heating based on a community gas supply
22	Communal LPG + combination boiler + 200mm loft insulation
23	Communal LPG + combination boiler + 200mm loft insulation + 70mm external wall insulation
24	$6m^2$ solar heating
25	$1m^2$ solar heating
26	$10m^2$ solar heating
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating
28	Dry lining
29	Wood burning boiler + radiators + 200mm loft insulation
30	Wood burning boiler + radiators + 200mm loft insulation + 10mm *Sempatap*
31	Wood burning boiler + radiators + 200mm loft insulation + 50mm external wall insulation
32	Oil fired CHP + radiators
33	LPG fired CHP + radiators
34	Package 29 but ½ price wood pellets
35	Package 29 but ¾ price wood pellets
36	2 storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity reduced by 25%)
37	Ground source heat pump + radiators
38	Ground source heat pump + radiators + 200mm loft insulation
39	Coal fired boiler + radiators

5.3 General findings

5.3.1 Measure costs

A major consideration in the viability of a certain measure is its cost, and how this compares to the savings that it could generate. The costs of some measures vary between different properties, but the figures in Table 5.7 provide an indication of what these costs are for a semi-detached property (see Appendix II for details of measure costs). Almost all the simulated measure packages cost more than the exiting HEES+ grant maximum of £2,700.

The cost of a measure is dependent on the size of the property in which it is being installed. Area dependent measures vary more from one property type to the next than heating systems. The price of external wall insulation is about £50 per square metre. On a small terraced property this equates to an installation cost of £2,550, but on a large detached house costs total £6,350. By comparison, an oil boiler system would cost £2,400 for a terraced property, and only £200 more for a large detached property.

Costs are based on quotes from manufacturers/distributors. . With economies of scale, lower prices may be achievable particularly with the new forms of wall insulation.

When internal wall insulation is installed, the resulting surface would require redecorating to fit in with the rest of the room. In the case of installing **Sempatap** the existing wall may require a degree of preparation before the **Sempatap** can be fitted. The costs involved with these processes would vary greatly from one property to another, and have not been included in Table 5.7.

Table 5.7 Measure costs

Measure	Cost	Cost for archetype semi-detached property
Oil boiler system	£2,400 to £2,600	£2,500
External wall insulation	£40 m^2 to £60 m^2	£3,300
Wallreform	£20 m^2	£1,320
Dry lining	*c.* £15m^2	£990
Sempatap	£25 m^2	£1,650
Solar panels	£125 m^2 + £1850	
Photovoltaic panel	£700 m^2 to £800 m^2	
Ground source heat pump system	*c.* £4,500	£4,765
Micro CHP system	*c.* £3,000	*c.* £3,000
LPG boiler system	£2,400 to £2,600	£2,500
Three storage heaters	£1,340	£1,340
Wood boiler system	£4,000 to £4,500	£4,000
Coal fired boiler system	£5,000 to £6,000	£5,500

Due to the relative infancy of micro-CHP technology, there is a need to establish reliable installation and maintenance costs. By way of an estimate, a micro-CHP unit would cost a similar amount to a highly specified condensing boiler. Due to the high number of moving parts, regular servicing and maintenance would be required and could be quite costly.

Since not all measures installed in a property will necessarily last for the same length of time, the component lifespan needs to be taken into account. In addition, the cost of maintaining the measure also needs consideration (Table 5.8).

Table 5.8 Expected lifespan of measure components

Measure	Expected lifespan (years)	Maintenance frequency (years)	Maintenance cost each time (£)	Maintenance cost throughout lifespan (£)
Oil boiler	15	1	50	750
Wall insulation	30	-	-	0
Loft insulation	30	-	-	0
Storage heater	15	-	-	0
Wood/Coal boiler	15	1	50	750
LPG boiler	15	1	50	750
Photovoltaic panel	50	-	-	0
Solar panel	20	-	-	0
Micro CHP	NA	NA	NA	NA
Heat pump	15	-	-	0
Coal boiler	15	1	50	750

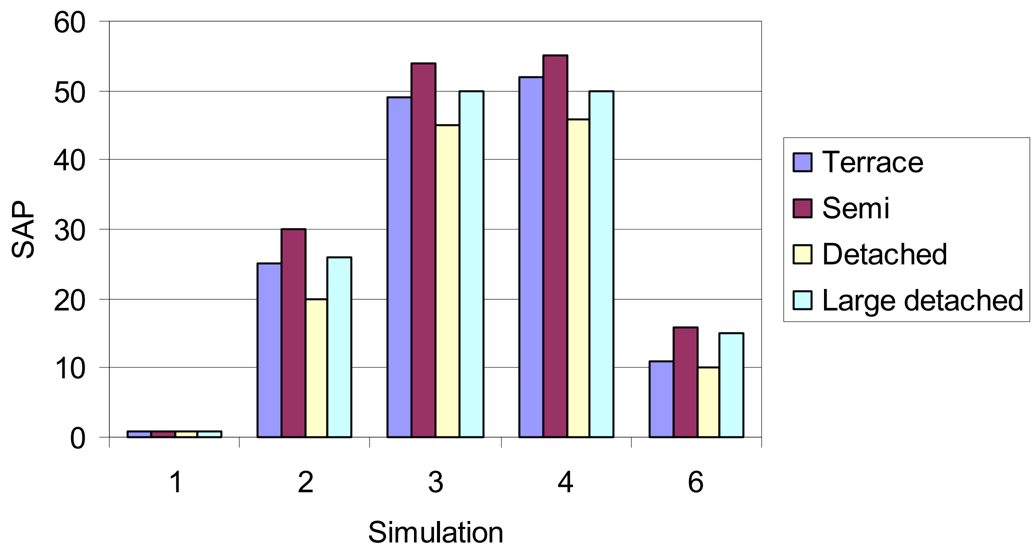
The longest life span of any of the measures is 50 years. As a means of comparing the costs of the different measures packages, a 50-year timescale has been adopted. The cost of installing a measure, maintaining it, and installing a replacement when its lifespan has lapsed, has been calculated for the period of 50 years (see Appendix III).

With their short lifespan and high maintenance requirements, heating systems generally cost more over a 50-year period than insulation measures.

5.3.2 SAP

The SAP rating of a property is independent of its floor area, i.e. a large property will have a similar SAP as a smaller property built to a similar specification (Fig 5.1), although the running costs will be different. A large property may have a high SAP, but also have high running costs due to its large size and as such may not be affordable to low income groups. A smaller property with the same SAP, built to the same specification will have lower running costs and consequently will be more affordable to these groups. It is for this reason that the SAP takes a secondary consideration.

The SAP values change from one property type to another, and the majority of this difference is probably due to the proportion of walls that are exposed. For example, in a simplified model, a terraced property would have just two exposed walls, while a detached would have four.



Key:
1
Baseline

2
Benchmark

3
Target (Measures offered by HEES to solid walled house on gas network i.e. condensing combination gas boiler, 200mm loft insulation, 2 CFLs, and draught proofing)

4
28 sec oil condensing combination boiler + radiators

6
50mm external wall insulation

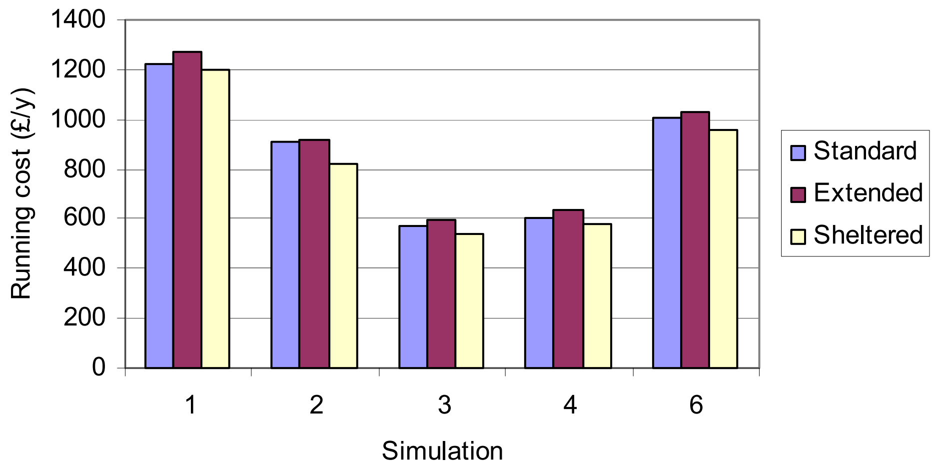
Fig 5.1 SAP scores modified by the application of measures under standard occupancy (Simulations selected = references, one heating package, and one insulation package)

Generally, semi-detached properties have the highest SAP, and detached properties the lowest . Terraced and large detached properties usually come somewhere between. There are occasions when this pattern varies slightly (for example Simulation 6 in Fig 5.1), and these depend on the combination of wall insulation and heating measures applied (a full set of SAP ratings can be found in Appendix IV).

5.3.3 Impacts of occupancy

The different occupancy scenarios have very little impact on the running costs (Fig 5.2) and carbon dioxide emissions, but as would be expected, the extended occupancy pattern generates the highest running costs and sheltered the lowest. Almost by definition, standard occupancy generates intermediate running costs.

The proportional reduction in running costs from the base property due to the application of measures does not change much from one occupancy pattern to another. The absolute figures change between occupancy types, but the relative impact of each occupancy type remains more or less the same.



Key:
1
Baseline

2
Benchmark

3
Target (Measures offered by HEES to solid walled house on gas network i.e. condensing combination gas boiler, 200mm loft insulation, 2 CFLs, and draught proofing)

4
28 sec oil condensing combination boiler + radiators

6
50mm external wall insulation

Fig 5.2 Running costs of a semi-detached property under different occupancy conditions (Simulations selected = references, one heating package, and one insulation package)

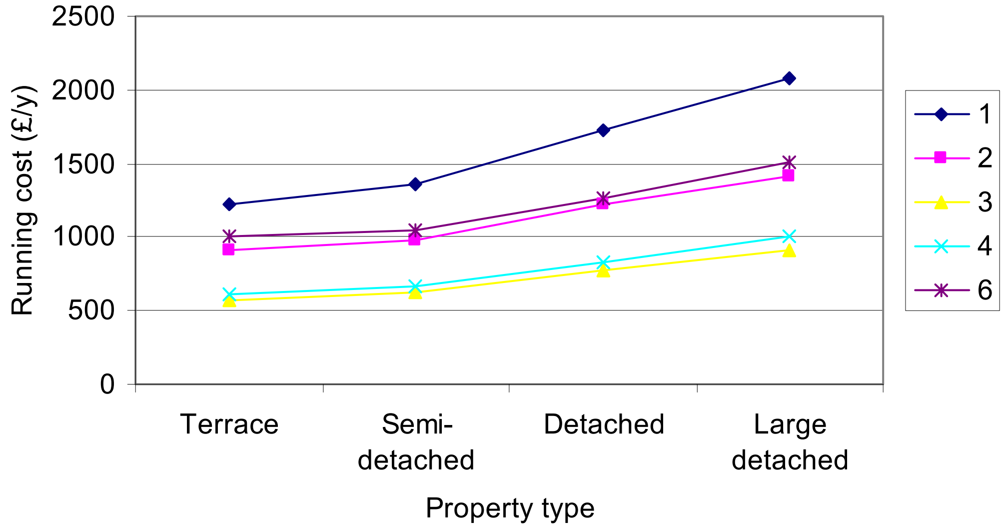
To avoid over-complication with the analysis of the various options, the standard occupancy has been applied in the remainder of this report. The alternative occupancy scenarios do not change the conclusions that can be drawn from the analysis.

5.3.4 Property types

As would be expected, the running costs increase from the small terraced property through to the large detached property (Fig 5.3). The proportional increase is roughly the same for all measure packages in the four properties although there is a slight variation between insulation measures and those that involve a heating system. Subsequent variation is introduced when insulation is fitted in conjunction with heating system changes.

The increase between the terraced property and the semi-detached property is less than the increases between semi-detached and detached, and detached and large detached.

The proportional impact of a measure is therefore similar for each property type and hence in the rest of this report, only the figures for the semi-detached property are shown unless otherwise stated (all results are shown in Appendices IV, V, and VI).



Key:
1
Baseline

2
Benchmark

3
Target (Measures offered by HEES to solid walled house on gas network i.e. condensing combination gas boiler, 200mm loft insulation, 2 CFLs, and draught proofing)

4
28 sec oil condensing combination boiler + radiators

6
50mm external wall insulation

Fig 5.3 Running cost variation across property types through the application of measures (Simulations selected = references, one heating package, and one insulation package)

5.4 Measure specific findings

The figures in this section demonstrate how the applications of measures compare to the baseline, benchmark and the target running costs. The base running costs are those for the archetypes (Table 5.1), the benchmark costs are those for the base property with HEES measures (Table 5.3), and the target running costs are those for the same houses but on the gas network (Table 5.5), with measures applied under the HEES.

Before the application of measures all properties had very high running costs. Through the installation of HEES measures to the archetype house on the gas network, target savings of around 50% were achieved.

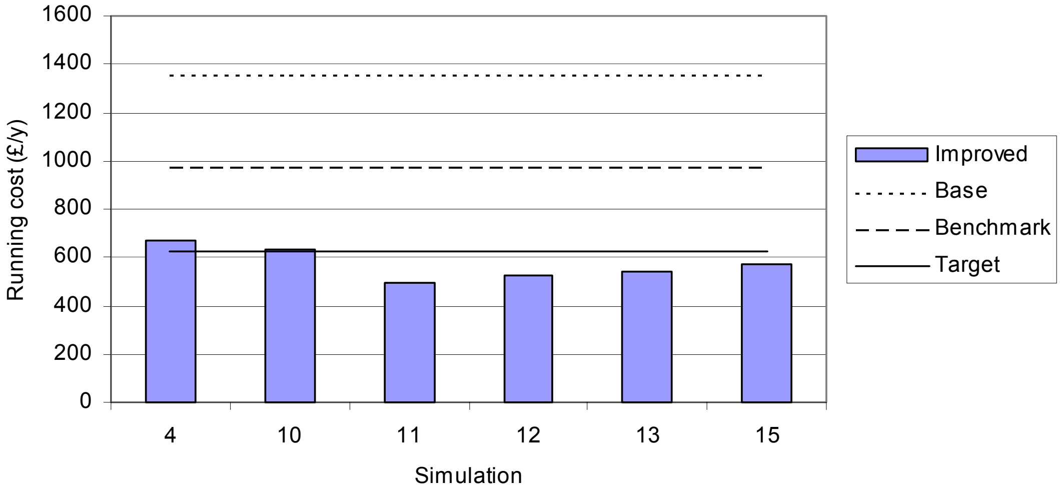
There is a roughly constant relationship between different occupancy types, and between different property types. To avoid unnecessary repetition, most subsequent figures represented are those for standard occupancy in a semi-detached property (see Appendix V for a full set of running costs).

After calculating the 50-year cost for the different measures, the result can be converted to an annual cost and deducted from the annual savings associated with the particular measure (see Appendix VII). This produces the net annual monetary savings.

Many of the alternatives discussed would require the installers to become familiar with the technologies involved, and a general expansion of the HEES skill base and support infrastructure.

5.4.1 Oil heating

The installation of an oil condensing combination boiler and radiators makes a large contribution towards meeting the target running costs, and in conjunction with the installation of loft insulation and / or external wall insulation can even exceed the targets.



Key:
4
28 sec oil condensing combination boiler + radiators (cost of oil is 16p / litre)

10
28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up (cost of oil is 16p / litre)

11
28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation (cost of oil is 16p / litre)

12
28 sec oil condensing combination boiler + radiators + 70mm external wall insulation (cost of oil is 16p / litre)

13
28 sec oil condensing combination boiler + radiators + 50mm external wall insulation (cost of oil is 16p / litre)

15
28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p / litre)

Fig 5.4 Running costs for oil boiler packages in a semi-detached property under standard occupancy

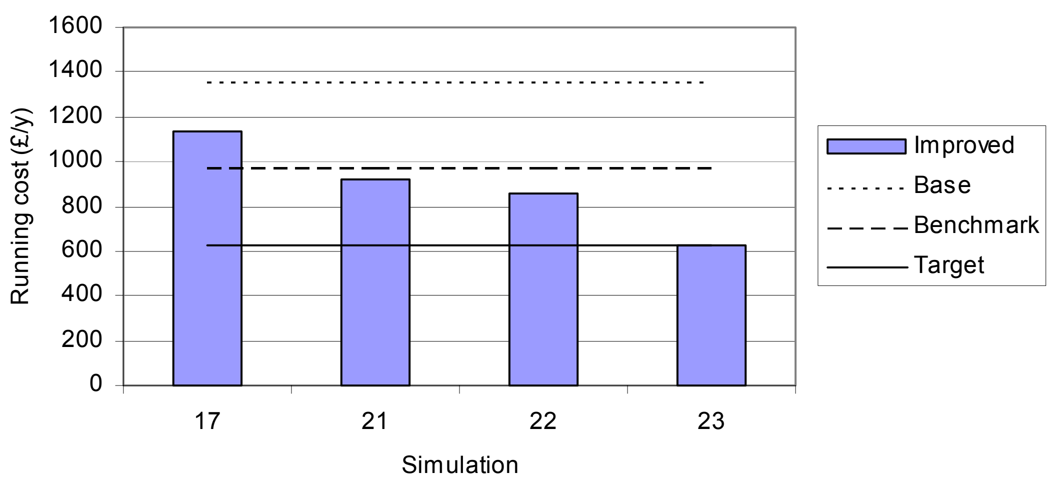
If a property is reasonably insulated and has an oil system fitted, then the running cost targets will be met (simulations 11, 12 and 13 above). Even if there was a dramatic increase of 50% in the price of oil, the running cost targets could still be met (simulation 13 above). However, if a measure package were chosen which only just met the targets, then a subsequent rise in the price of oil would result in the target running costs not being achieved. Over their lifespan, oil boilers can save more than three times their capital cost.

Oil produces more CO_2 than gas, and so with an oil heating system the carbon dioxide emissions are higher than the target emissions (A full set of CO_2 emissions levels can be found in Appendix VI.).

An oil boiler would require an external storage tank that should be built on a hard base and be accessible by a delivery lorry. It does not however, need to be close to the property since the fuel is delivered by a small pipeline to the boiler. Oil systems may be less suited to terraced properties because they may not provide sufficient space for a tank, or access for the oil delivery lorry.

5.4.2 Liquefied petroleum gas

LPG is more expensive than oil per unit volume, and the energy provided by a unit volume is less, resulting in a lower SAP rating. The running costs for a property fuelled by LPG are approximately 70% more than an oil fuel property. The carbon emissions associated with an LPG heating system are slightly larger than those associated with an oil system.



Key:
17
LPG condensing combination boiler + radiators

21
Communal LPG + condensing combination boiler

22
Communal LPG + condensing combination boiler + 200mm loft insulation

23
Communal LPG + condensing combination boiler + 200mm loft insulation + 70mm EWI

Fig 5.5 Running costs for LPG boiler packages in a semi-detached property under standard occupancy

If a scheme were set up similar to the Calor Gas submission (see section 4.3), then reduced LPG prices could be achieved giving LPG increased appeal. However, a good deal of insulation is required before the target running costs are reached. Through the installation of 200mm loft insulation and 70mm external wall insulation, the target running costs can be achieved in semi-detached and detached properties, however in a terraced property the running costs fall short of the target.

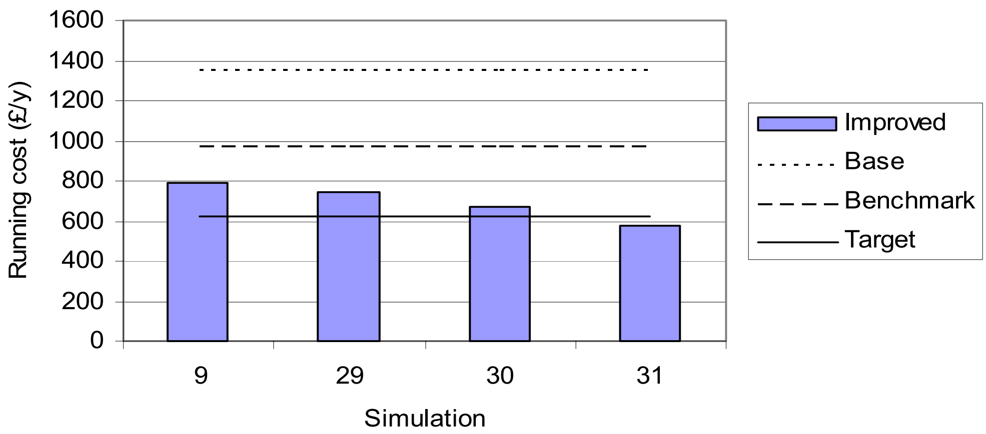
In the same manner as an oil system, LPG would be stored in an external tank that is periodically filled by a delivery lorry. Similarly, LPG may not be suited to terraced properties.

5.4.3 Wood pellet boiler

There is only one known commercial distributor of wood pellets in Wales. They are based in Bridgend and will deliver free within a 30-mile radius. A degree of risk is inherent in depending on one supplier. Should that supplier be unable to meet the demand for wood pellets there would be serious consequence for properties which have had wood fired boilers installed. However several boiler suppliers also act as fuel distributors, some importing pellets from Canada. The wood pellet industry in the UK is still in its infancy and as demand grows more suppliers are likely to appear.

The supplier in Bridgend suggests a minimum cost of £0.10 per kilogram. The software currently assumes a boiler efficiency of roughly 60%, but even with a 90% efficient boiler (as is suggested by wood boiler suppliers) the running costs are still high compared to the targets (Fig 5.6). The figure of 90% appears a little high, and it is not certain whether it is net or gross efficiency, nevertheless, the 90% figure has been modelled in the simulations. Decreasing the efficiency to 80%, only increases running costs by about 5%

To bring the running costs of a wood fuelled property to within the target running costs (assuming a 90% efficient boiler) loft insulation and at least the equivalent of 50mm external wall insulation are also required (Simulation 31 in Fig 5.6). With a 25% reduction in the price of wood pellets and the fitting of 200mm loft insulation, the running costs for all four archetypes fall within 10% of the target. If the wood pellet price were to be halved the targets would be easily met.



Key:
9
Auto feed wood burning boiler

29
Wood burning boiler + 200mm loft insulation

30
Wood burning boiler + 200mm loft insulation + 10mm **Sempatap**

31
Wood burning boiler + 200mm loft insulation + 50mm external wall insulation

Fig 5.6 Running costs in a semi-detached property with wood pellet boiler under standard occupancy

The combustion of wood produces small quantities of CO_2 compared to gas, oil, LPG and coal. Moreover, wood may be considered as a carbon-neutral fuel since it consumes CO_2 during its growth. This is only true however if the wood comes from a properly managed source.

Installation costs are between £4,000 and £4,500. Wood would ideally be stored close to the boiler to facilitate filling the hopper, but should also to located to enable re-stocking by a delivery lorry. Terrace houses often do not have the necessary combination of space and access.

It should be noted that some areas are designated Smoke Control Areas, in which wood burning is restricted.

5.4.4 Ground source heat pumps

The cost of a ground source heat pump largely depends on the type of ground source. Boreholes are more expensive to install than pipes laid in a trench, and a complete system can range from about £3,900 to £7,000.

By extracting heat from the environment, and concentrating it in a property, heat pumps are able to achieve high thermal outputs with relatively little electrical input (For completeness, all properties are shown in Fig 5.7). The costs involved are 'pumping' the heat from the ground to the property and heating by the immersion heater. Running costs comparable to those for a similar property on the gas network are achievable.

Ground source heat pumps have been modelled as per the SAP 2001 using a Beta test version of NHER Evaluator. For water heating, the SAP calculation assumes that the heat pump raises water up to 45°C, and that the immersion heater performs any subsequent heating. It is assumed that 50% of the domestic hot water is heated by the heat pump, and the remainder is heated using off-peak electricity by the immersion heater. Space heating is handled differently from water heating; it is assumed that the heat pump uses 70% on-peak electricity, and 30% off-peak electricity.

The installation of ground source heat pumps alone is almost sufficient to achieve the target running costs in most cases. A similar pattern is shown by the CO_2 emissions. The proportional savings generated by installing a ground source heat pump are larger in a smaller property.

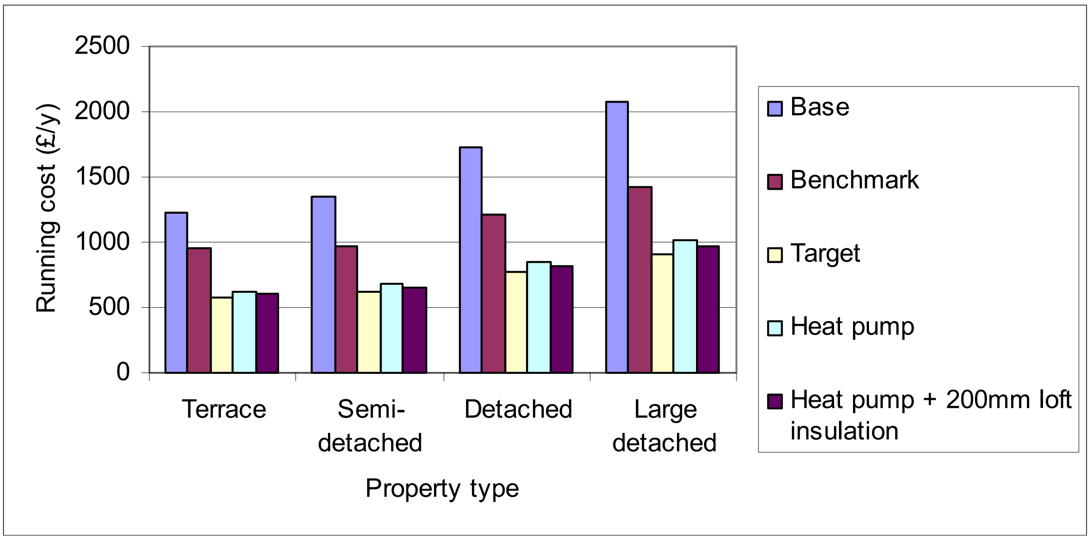


Fig 5.7 Running costs with the installation of a ground source heat pump.

With the installation of 200mm loft insulation in conjunction with a ground source heat pump, the running cost targets are almost met. The CO_2 emissions are well below those associated with the target running costs.

Ground source heat pumps can use two different means of accessing the energy in the ground – a deep borehole or shallow trench under the garden. The borehole is more efficient but is also more expensive. If space is limited then a deep trench solution is not suitable because a great length of piping under the ground is required. Both systems generate the same savings. The drilling rig required for a heat pump is not huge so the space required for the installation is not big, although sufficient access is required. For systems requiring more than one borehole, a minimum distance of 5m is suggested between holes.

Generally there are no geological issues associated with boreholes. If the ground is hard, then drilling will be more complex, but then the sides of the hole are less likely to collapse. If it is deemed too difficult to drill one deep hole, then two shallow holes can be used.

5.4.5 Wall insulation

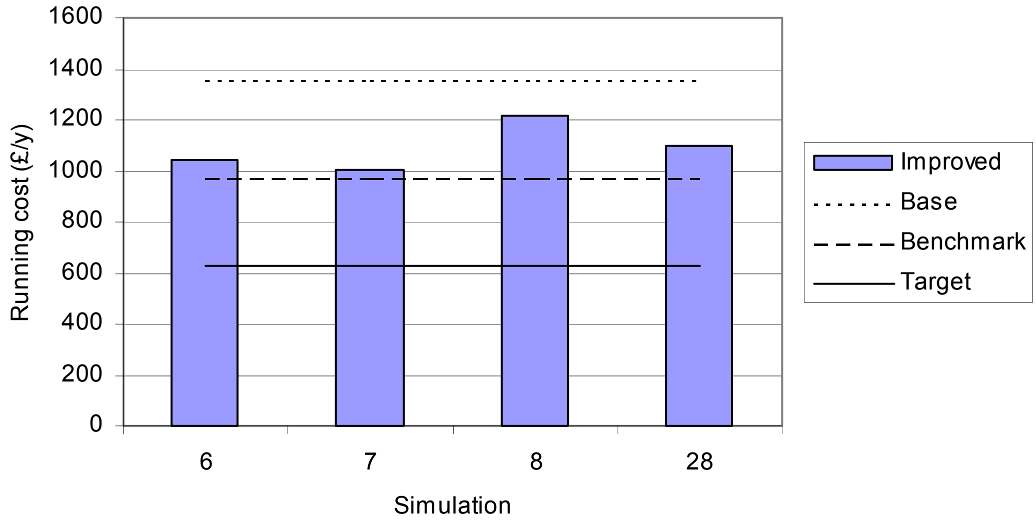
Two types of external wall insulation have been simulated: conventional external wall insulation and a trowel on render based product called **Wallreform.** According to the supplied literature, the application of **Wallreform** results in a reduction in the wall's U-value from 2.1 W/m^2K to 0.7 W/m^2K. The running costs for the two techniques are comparable for a given thickness of insulation. Where Wallreform has been simulated, a thickness of 50mm has been used. If external wall insulation is to be considered, then the deciding factors will be the costs and ease of installation, product lifespan, and also the aesthetics of the finished surface.

The cost of wall insulation is best expressed in terms of cost per square metre including installation. **Sempatap** is the easiest to fit, and is also the thinnest and achieves an installation cost of £25 per square metre, 50mm of **Wallreform** costs a similar amount. External cladding is comparatively expensive at a cost of £40 to £60 per square metre. The £20 difference is due to the differing costs of the various available finishes. A large variety of dry-lining products are available, but an approximate figure of £15 per square metre is suggested. Hence dry-lining is the cheapest of all the wall insulation options.

Generally internal wall insulation does not save the same amount of money as external wall insulation. The energy savings from **Sempatap** are reasonable when it is fitted to an otherwise non-insulated wall, however, the savings are small when it is used in conjunction with other wall insulation systems.

Conventional dry lining generates greater savings than **Sempatap,** but it is thicker and not as easy to fit. Condensation problems may not be alleviated with dry lining, since there is an air gap behind the insulation in which condensation would still form. Any fittings such as light switches, sockets and skirting boards will have to be refitted after the dry lining has been installed.

Sempatap wall covering is easy to install, and can be decorated as required. As well as reducing running costs, it also combats condensation problems and provides a degree of soundproofing. Problems may be encountered when trying to fit it around objects such as light switches and plug sockets, but generally these require removing and re-fitting over the **Sempatap**. This work is simple and could be easily done by the installer, so there should not normally be any additional cost required for electrical work. The product does not interfere with skirting boards and doorframes. The disruption associated with fitting **Sempatap** is small when compared to that associated with conventional dry lining.



Key:
6
50mm external wall insulation

7
70mm external wall insulation

8
10mm **Sempatap** internal wall insulation

28
Dry lining

Fig 5.8 Reduction in running cost due to installation of wall insulation in a semi-detached property

Since internal wall insulation saves less energy than external wall insulation, it would only be suitable when the budget is not large enough to fund external wall insulation, or for properties for which external insulation is not desirable:

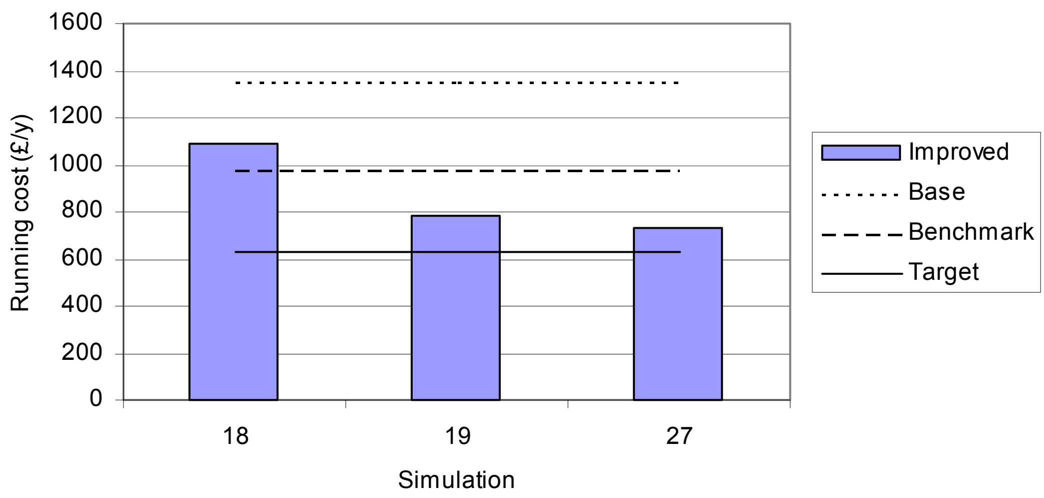
- Some properties may have exposed brickwork, timbers etc. that the occupants want retained.
- The fitting of a thick layer of insulation may mean that the new surface extends beyond the eaves of the house.
- The means of accommodating doors and windows may not be desirable.

While wall insulation would generate some savings, not all properties would be suitable for its installation, not only in terms of practicality, but also in terms of the occupants' desirability for the new surface.

5.4.6 Storage heaters

In terms of both initial cost and cost over a 50-year period, the cheapest form of heating system to install would be one based around storage heaters. For all the four archetypes storage heaters cost £1,340 including installation. While they may ultimately last longer than a boiler system, it has been assumed that after 15 years they would be replaced. They also require virtually nothing in the way of maintenance since the only moving parts are the controls and vents.

The targets cannot be achieved through the installation of three electric storage heaters, even with large amounts of insulation. In terms of proportional savings in running costs and SAP, this option is slightly more suitable for larger detached houses, though the practicality of having just three storage heaters in a large detached house is questionable (In such situations the heaters would probably lose all the stored heat before the end of the evening).



Key:
18
3 storage heaters, one of which is fitted in Zone 1, the other in Zone 2

19
3 storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm *Sempatap*

27
3 storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating

Fig 5.9 Running costs in a semi-detached property with storage heaters under standard occupancy

By installing storage heaters and reducing the cost of electricity, the target running costs could be met, but the price of electricity would have to be reduced a long way before this would happen. Even if such a decrease were to occur, it is not likely to be in the near future. In conjunction with a few other measures however, the price reduction does not need to be so large.

By fitting modern electric storage heaters alone, the price of electricity would need to be reduced by around 50% before the target running costs are met. A reduction of around 25% is required if storage heaters were installed in conjunction with 200mm loft insulation and 70mm external wall insulation. Such a price reduction is not likely in the short term. In addition, the amount of electricity is not reduced, and consequently neither is the quantity of carbon dioxide produced.

5.4.7 Photovoltaics

There are several photovoltaic (PV) products available ranging from small roof tile effect panels to large panels mounted on the roof that automatically track the sun. They typically cost £700 to £800 per square metre. There are no moving parts in PV panels and so they can last for up to 50 years, with the only maintenance being an occasional cleaning of the surface. This would often be carried out by the occupants, but may also require the services of a contractor. This, however, needn't be more than a local window cleaner.
The efficiency, and hence the output, of the panel is affected by the amount of light falling on it, and so a build up of dirt reduces efficiency. Since PV panels do not require any maintenance, over a period of 50 years they would cost £14 to £16 per square metre per year.

As a rough guide, a $1m^2$ PV panel will generate about 0.1kW of electricity, over a year this equates to approximately 76 kWh (This value will vary depending on the geographic location. Houses further north may expect less than this, and houses further south may expect more.). Assuming the electricity costs in Table 4.3, we can expect savings of approximately £5 per year per square metre of PV panel (Table 5.8).

Table 5.8 Annual savings associated with photovoltaic panels

Panel area	Electricity type	
	Standard electricity (7.28 p/kWh)	Economy 7 (on peak) (7.75 p/kWh)
$1m^2$	£5.53	£5.89
$10m^2$	£55.33	£58.90
$20m^2$	£110.66	£117.80

These savings are the same regardless of the size of the property and of any other energy efficiency measures already installed. Given that PV costs £14 to £16 per year, they cost more than they save.

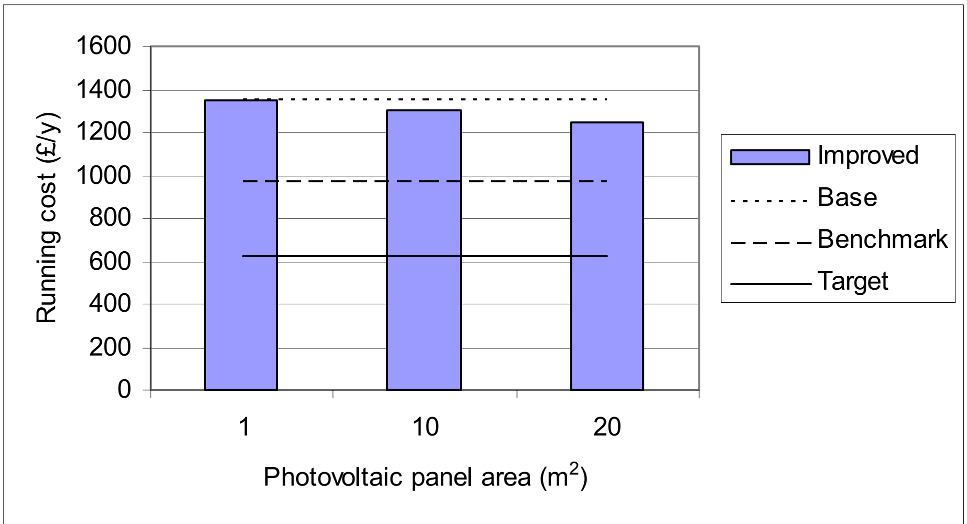


Fig 5.10 Running costs for base semi-detached property with photovoltaic panels installed

The use of PV panels only contributes towards the electricity consumption of the property, so if the heating is fuelled by gas or oil etc, then the panels will not contribute toward the heating costs. The panels convert sunlight directly into electricity so there are no associated CO_2 emissions. Each square metre of PV panel could save about 32kg CO_2 per year.

Photovoltaic panels will not be suited to all properties, since there are a number of factors that contribute to their location:

- The roof should not be shaded by other buildings or trees
- South facing roofs with an inclination of 30° to 40° will generate the most power
- Planning permission is not usually required for PV panels unless the building is listed or is in a conservation area.

Photovoltaic cells use toxic metals in their construction and therefore pose a risk if they are not disposed of properly. They are easily available, but the costs and savings involved are not suitable. PV may be an option in the future if efficiencies increase and costs decrease.

5.4.8 Solar heating

Although it is now feasible that solar energy could be used to pre-heat water entering a combination boiler, Evaluator will not allow solar water heating to be specified in conjunction with a combination boiler system (this is derived from the SAP). Therefore solar water heating contributes only to domestic hot water, (i.e. not space heating). In all properties with an electric immersion heater (using on-peak electricity), the fitting of 3m^2 of solar heating panels will result in the saving of about £50 per year (Fig 5.11). The savings generated through solar panels are related to the number of occupants in the property, and so the same savings will be seen under standard and extended occupancy patterns.

Solar panels cost £1,850 plus £125 per m^2 of panel installed. Due to the high fixed cost, the larger the area installed, the more cost effective they will be. A panel with an area of 1m^2 would cost more money than it saves, but with more than 3m^2, solar panels generate a net saving. There are no CO_2 emissions associated with solar water heating. A solar hot water heating system could save up to 200 kg CO_2 per year for each square metre of panel installed.

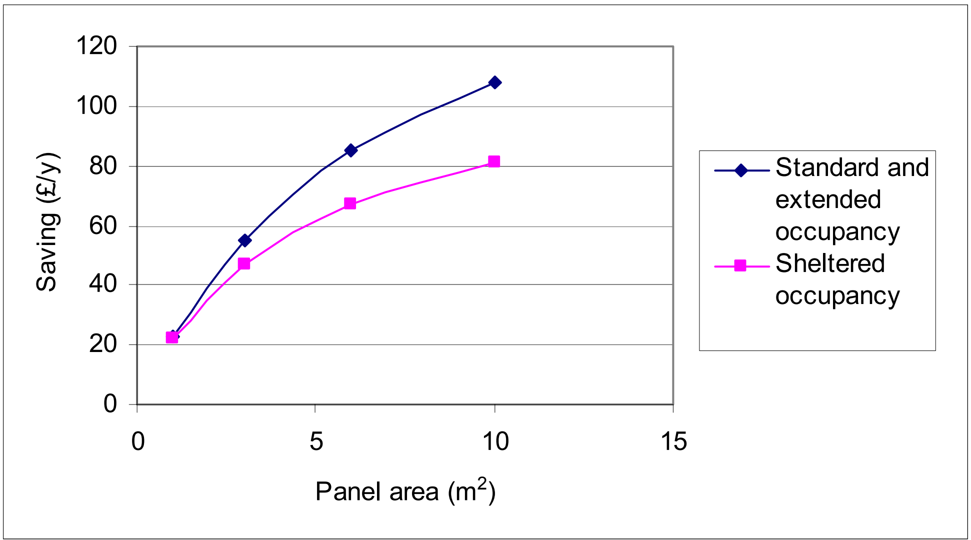


Fig 5.11 Savings associated with solar panels for properties with immersion heater.

There is only so much hot water that can be used at one time in a property. As the panel area increases, the rate at which savings (both monetary and CO_2 emissions) are generated decreases. Solar heating could be used in combination with storage heaters, but large amounts of wall and loft insulation are still required if the target running costs are to be met.

5.4.9 Micro-CHP

The application of micro combined heat and power (Micro-CHP) to domestic properties is still in its infancy. CHP is the production of heat and the electricity is a by-product. The CHP engine is used to provide heating in the same manner as a conventional boiler; it just produces electricity as well. If the property needs more electricity than the CHP engine is providing then it will draw from the local distribution network. However, if the electricity is not required by the property it could be fed into the local distribution network.

The required infrastructure, which would enable this to happen on a micro scale, is not yet developed. Current two-way electricity metres are large, expensive, and only suitable for more industrial applications or commercial premises. In addition, more research is required into how to price electricity fed into the distribution network. An alternative to a two-way metre is to price the exported electricity based upon a profile for a given house type. For example, a two-bedroom terraced property with three occupants may export electricity at *x* p/kWh, while a four-bedroom detached property with four occupants may export it at *y* p/kWh.

NHER Evaluator does not allow precise evaluation of micro CHP since field trials have not been sufficient to model it, so a work around has been used. Unfortunately, this means that it is not possible to calculate a SAP score or CO_2 emissions. It is assumed that functioning as a condensing boiler, the micro-CHP unit runs at 78% efficiency and functioning as a generator it is 15% efficient. The micro-CHP unit thus has an overall efficiency of 93%.

The amount of electricity generated is calculated as follows:

$$\text{Electricity generated} = \text{Space and water heating energy requirement} \times \frac{0.15}{0.78}$$

Unfortunately, electricity is not always required at the same time as heat, and the ratio of heat requirement to electricity requirement is not always constant. It is assumed that at best the electricity generated can substitute for 80% of the electricity required, the remainder being imported. If the electricity generated exceeds 80% of the electricity used, then the household will be exporting some electricity. Evaluator allows the differentiation of energy used for heating and that used for lights and appliances. Consequently the amount of electricity imported and exported can be calculated (Table 5.9).

By using micro-CHP, the cost of electricity forms only a small part of the total running costs for a property. It is worth noting that in all four property types, the standing charge of £44.36 exceeds the total spent on electricity.

Table 5.9 Electricity use

	Terrace	Semi-detached	Detached	Large detached
Electricity generated (kWh)	2804.5	3167.8	4209.4	5149.6
Electricity used (kWh)	3194.5	3444.5	3722.3	4500.0
Amount of electricity exported (kWh)	248.9	412.2	1231.6	1549.6
Amount of electricity imported (kWh)	638.9	688.9	744.5	900.0

It is assumed that electricity from the local distribution network would remain at 7.28 p / kWh, and that exported would be sold at about 3p / kWh (The resale price would be somewhere between the wholesale price of 2p/kWh and the bulk business purchase cost of about 4 p/kWh). Assuming these prices and the balance of imported and exported electricity from Table 5.9, the total running costs for the archetype properties can be calculated (Fig 5.12).

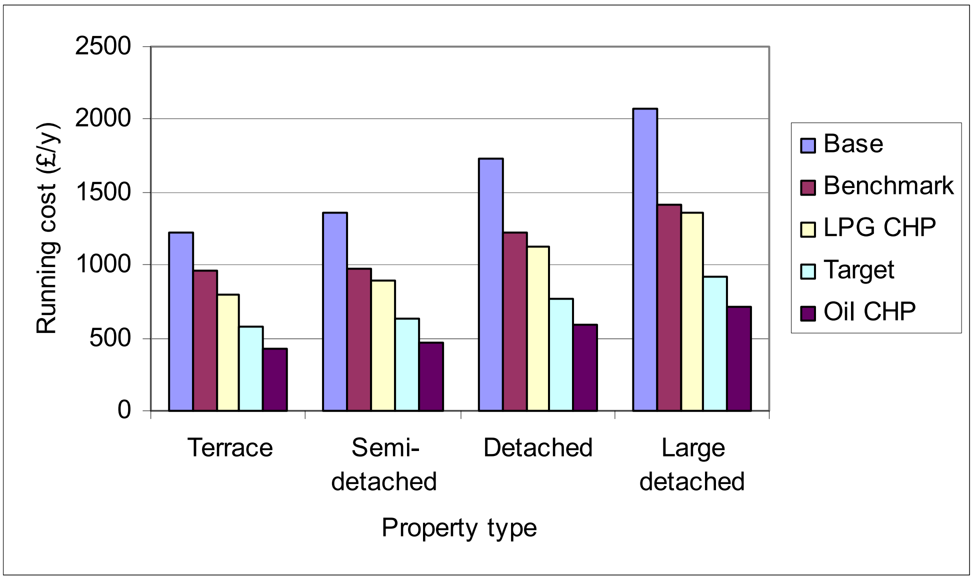


Fig 5.12 Running costs with micro CHP under standard occupancy

It is not possible to calculate the CO_2 emissions associated with micro-CHP, but it can be assumed that they are relatively low since the units operate extremely efficiently. Additional CO_2 reductions are linked with micro-CHP since the transmission losses associated with mains electricity are effectively reduced.

Gas powered domestic micro-CHP is the closest to being commercially available and units are a similar size to conventional boilers meaning they can be either floor-standing or wall-mounted. They are based around a Stirling engine and consequently produce very little noise.

Micro-CHP units currently only exist for natural gas, but since the Stirling engines used are external combustion units, there is no reason why they could not be adapted to LPG and even oil. If oil is used as a fuel, then the large decrease in the amount of electricity purchased results in properties with running costs that meet the targets. With LPG being considerably more expensive than oil the targets are not met if LPG is used and so large amounts of insulation would also be required.

Diesel and oil fired micro-CHP units currently use internal combustion engines and go down to a minimum size of about 5 kWe (i.e. too large for a single domestic property). They are also a little too noisy to be used in a domestic situation. These units are suited to larger establishments such as farms and blocks of flats. It would be a few years yet before oil fired micro-CHP will be suitable for domestic applications, and solid fuelled engines are a long way off (they probably won't be seen in the next ten years).

As a method of stimulating the market for micro CHP, it has been proposed that a household would lease a unit from an Energy Services Company.

5.4.10 Coal Fired System

By installing a coal-fired central heating system with a hopper, the running costs are still a long way from the target. In fact, running costs are closer to the benchmarks. To bring running costs in line with the targets, large amounts of insulation would also be required. Coal fired systems cost both more to install and more to run than wood pellet fired boilers.

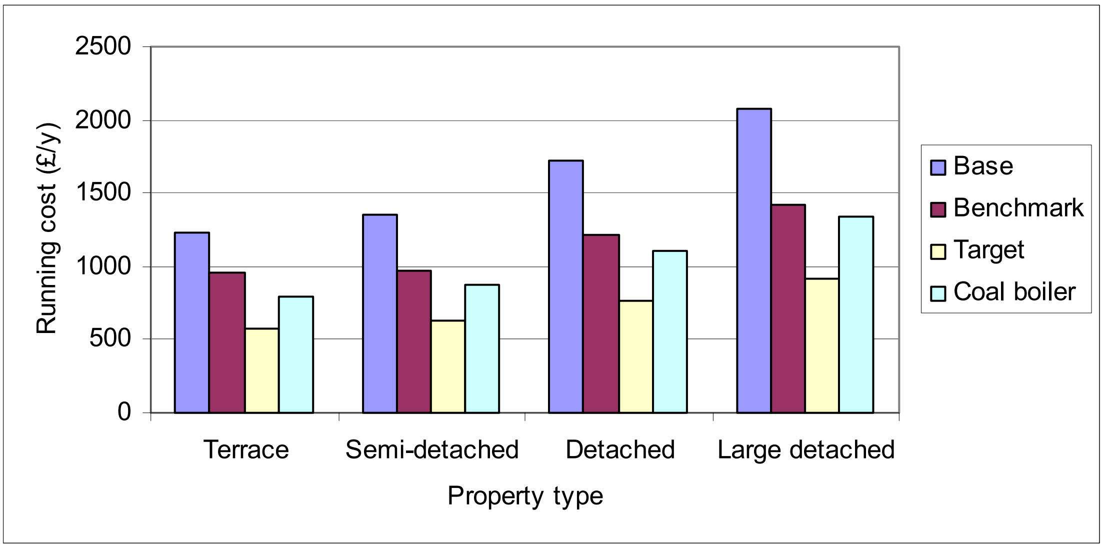


Fig 5.13 Running costs with a coal-fired system under standard occupancy

Coal suffers from similar handling and storage problems as wood pellets, but it is also dirtier, although the costs quoted include a hopper fed system. On the plus side, coal is more widely and easily available than wood pellets, and is well suited to properties with no mains gas supply. In terms of availability coal is the most suitable fuel for the archetype properties since they already use coal for heating (see Table 4.1).

The largest downfall of coal-fired boilers is the large quantities of CO_2 that they produce. The amount of CO_2 produced is only 20% to 25% less than the baseline property, and roughly twice the quantity produced by the target property. Coal burning is restricted in Smoke Control Areas, which may affect its widespread use.

6. Conclusions

By simply installing large amounts of insulation alone, it is not possible to meet the target running costs for a property. For example, by installing 70mm external wall insulation, 200mm loft insulation, and 10mm *Sempatap* insulation, the running costs are approximately 40% higher than those achievable through the HEES for a house on the gas network. Even by adding a large area of photovoltaic panels, the running costs for the property are significantly higher than the target. Consequently any package of measures has to include the installation of some form of heating system.

There are four distinct ‘themes’ that have emerged from the study. These are the main options available to the National Assembly for meeting the target running costs, as well as reducing carbon dioxide emissions. The most promising systems are oil boilers, wood boilers, ground source heat pumps, and communal LPG supply.

6.1 Oil boiler system

By itself, an oil condensing boiler is able to come within sight of the target running costs. Even with a 50% increase in oil price, the oil condensing boiler with insulation meets the target running costs. Historically oil has been the lowest cost heating fuel and although prices rose to 2000 there is evidence that the price has since fallen. Whilst the price of oil will always be volatile, it offers a good long-term low cost solution.

Installed in conjunction with 200mm loft insulation, an oil boiler system is able to either meet or come very close to the target running costs, without excessive cost.

Oil boilers produce a little more than half of the CO_2 emissions of the base property. Combined with insulation measures the target CO_2 emissions can be met and even exceeded.

The infrastructure to support oil boilers already exists since oil has been used for many years all over the country.

6.2 Wood pellet boiler system

Wood burning boilers are able to meet the running cost targets with modest levels of insulation providing the cost of wood can be reduced through economies of scale. Assuming the wood boiler is installed in conjunction with 200mm loft insulation, a reduction in the price of wood pellets of roughly 35% would be needed to achieve the targets.

From a CO_2 emissions approach, a heating system using wood boilers is the most encouraging option. A proportion of the wood used for the boilers would otherwise go to landfill, but this proportion may decrease as demand for wood pellets increases. Assuming this is the case, pellet fired boilers can be considered as an almost carbon neutral technology, and, providing the wood is sourced from waste and sustainable forests, could also be considered a sustainable technology.

The main issues when considering wood pellet boilers are the price and availability of the pellets. If wood fired boilers are to be used, then normal market forces would be relied upon to reduce price and increase geographical coverage.

With the current wood pellet price, insulation must be installed in conjunction with the boiler, thus increasing the installation cost, and resulting in this being one of the more expensive options.

6.3 Ground source heat pump

One of the most promising heating systems in terms of running cost is a ground source heat pump. By itself, a ground source heat pump is almost sufficient to meet the running cost targets. Although heat pumps are able to meet the requirements of larger properties (i.e. large detached), the proportional savings they generate are smaller. As such, they are less suited to large properties.

By extracting heat from the ground, a heat pump uses very little electricity, and hence the CO_2 emissions associated with heat pumps are comparable to those coming from gas condensing boilers.

Many homes in other European countries have heat pumps installed, but on a domestic scale in the UK they are still quite rare and consequently the market may not be able to supply the required numbers. Some properties may not have a sufficient area of land into which a borehole could be sunk or a pipe laid, others may have enough land but without access for the necessary plant. This may not cause too much of a problem since a large proportion of the houses with no gas supply would be in rural locations and so likely to have sufficient land and access.

Heat pumps are more expensive to install than conventional boilers, but they should last longer, and achieve lower running costs. Little insulation is required to meet the target running costs, so a heat pump could be installed with little else, resulting in the cheapest option. With just 200mm loft insulation a ground source heat pump comes very close to meeting the running cost targets.

6.4 Communal LPG boiler

Of the four options, the cheapest heating systems to install are oil and LPG boilers. However, if LPG is used large amounts of insulation are required to meet the running cost targets, and an extra £1,200 is needed for the communal LPG supply. Given their short life span, LPG boilers work out at an intermediate cost.

The current prices of LPG are too high to produce running costs that meet the targets, however in a scheme such as the Calor Gas proposal it is possible to meet the targets using large amounts of insulation. If the cost of LPG could be reduced further, then this may be a viable option, but the success of a communal LPG scheme, such as that proposed by Calor Gas would depend on the availability of clusters of HEES eligible properties.

7. Recommendations

Based on improved running costs, reduced CO_2 emissions, and installation cost, the analysis has identified four possible options available to the non-gas solid walled property in Wales. Taking the other issues into consideration, the three most favourable options are ground source heat pumps, wood pellet fired boilers, and oil boilers. These three measures should be installed in conjunction with 200mm loft insulation if running costs in the region of the targets are to be achieved.

Wood pellet fired boilers with hoppers are less suited to smaller properties (e.g. terrace) since they would probably be too take up too much room and there may be insufficient space and access for storing the pellets. Similar storage issues are associated with oil boiler and so these too would be less suited to terraced properties. The returns from heat pumps are not so good in larger properties, and so are more suited to smaller properties. Although the wood pellet industry in the UK is still in it's infancy, and to date Bridgend is the only commercial supplier, several boiler suppliers also provide and deliver pellets, some imported from abroad, and as demand grows the network is likely to expand.

The existing HEES offers two CFLs and draught proofing to eligible properties. While these result in only small CO_2 and monetary savings and negligible improvements in the SAP when compared to loft insulation and new heating systems, it is recommended that these 'low cost' measures are retained and installed if the required money is available. Fitting two CFLs may also encourage the householder to install more, in addition to raising awareness of energy efficiency. Draught proofing windows and doors may make the property more comfortable to live in since cold draughts would be eliminated.

Table 7.1 Summary of recommended measures in a semi-detached property for standard occupancy

Simulation		Property Type			
		Terrace	Semi-detached	Detached	Large detached
Baseline	Running cost (£/y)	1,224	1,356	1,727	2,078
	CO_2 (Tonnes/y)	13.3	15.1	20.4	25.1
	SAP	1	1	1	1
Benchmark	Running cost (£/y)	957	975	1,218	1,419
	CO_2 (Tonnes/y)	10.6	10.7	14.8	17.8
	SAP	21	30	20	26
Target	Running cost (£/y)	574	627	769	916
	CO_2 (Tonnes/y)	5.8	6.5	8.6	10.4
	SAP	49	54	45	50
Oil boiler system with 200mm loft insulation	Running cost (£/y)	574	632	789	949
	CO_2 (Tonnes/y)	6.8	7.6	10.1	12.4
	SAP	57	61	50	53
Wood pellet boiler system with 200mm loft insulation	Running cost (£/y)	674	741	939	1122
	CO_2 (Tonnes/y)	3.9	4.4	5.8	7.1
	SAP	34	38	28	33
Ground source heat pump with 200mm loft insulation	Running cost (£/y)	599	656	811	968
	CO_2 (Tonnes/y)	5.5	6.1	7.9	9.5
	SAP	46	49	39	40

It is suggested that this report is followed by the setting up of small pilot schemes looking into the feasibility of the three most favourable of the four options – ground source heat pumps, wood pellet fired boilers, and oil boilers. This should tend towards looking at heat pumps in the small to mid-sized properties, and wood and oil heating in the mid-sized to large properties. The pilot schemes should involve energy and temperature monitoring before and after the fitting of measures, and be followed up with customer questionnaires.

Appendix I

Assumptions used in the application of measures

Oil / LPG condensing boiler
- The pump is in heated space
- Controls include room thermostat, programmer, and TRV's
- The boiler has an interlock
- There would be 4 radiators in Zone 2, one of which has no TRV
- The secondary heating is the coal fire

Storage heaters
- Modern storage heaters
- Automatic charge control
- One heater in Zone 2
- The secondary heating is the coal fire

Wood boiler
- Automatic feed
- Controls include room thermostat, programmer, and TRV's
- There would be 4 radiators in Zone 2, one of which has no TRV
- Boiler has no interlock
- The secondary heating is the coal fire

Heat pump
- Operates through radiators
- Controls include room thermostat, programmer, and TRV's
- There would be 4 radiators in Zone 2, one of which has no TRV
- The secondary heating is the coal fire

Micro CHP
- Operates through radiators
- Controls include room thermostat, programmer, and TRV's
- There would be 4 radiators in Zone 2, one of which has no TRV

Coal boiler
- Automatic feed
- Controls include room thermostat, programmer, and TRV's
- There would be 4 radiators in Zone 2, one of which has no TRV
- Boiler has no interlock
- The secondary heating is the coal fire

Appendix II

Summary of initial installation costs

Simulation	Description	Installation cost (£)			
		Terrace	Semi-detached	Detached	Large detached
1	Baseline property	0	0	0	0
2	Benchmark property	1,620	1,676	1,732	1,738
3	Target property	2,070	2,226	2,382	2,388
4	28 sec oil condensing combination boiler + radiators	2,400	2,500	2,500	2,600
5	35 sec oil condensing combination boiler + radiators	NA	NA	NA	NA
6	50mm external wall insulation	2,550	3,300	5,300	6,350
7	70mm external wall insulation	2,550	3,300	5,300	6,350
8	10mm *Sempatap* internal wall insulation	1,275	1,650	2,650	3,175
9	Auto feed wood burning boiler + radiators	4,000	4,000	4,000	4,500
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up	2,600	2,750	2,800	2,900
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation	5,150	6,050	8,100	9,250
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation	4,950	5,800	7,800	8,950
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation	4,950	5,800	7,800	8,950
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation	4,025	5,250	8,200	9,825
15	28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p/kWh)	5,150	6,050	8,100	9,250
16	50mm **Wallreform**	1,020	1,320	2,120	2,540
17	LPG condensing combination boiler + radiators	2,400	2,500	2,500	2,600
18	Three storage heaters	1,340	1,340	1,340	1,340
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**	5,365	6,540	9,590	11,165
20	3m^2 solar heating	2,225	2,225	2,225	2,225
21	Communal LPG + combination boiler + radiators	3,600	3,700	3,700	3,800
22	Communal LPG + combination boiler + radiators + 200mm loft insulation	3,800	3,950	4,000	4,100
23	Communal LPG + combination boiler + radiators + 200mm loft insulation + 70mm external wall insulation	6,350	7,250	9,300	10,450

Simulation	Description	Installation cost (£)			
		Terrace	Semi-detached	Detached	Large detached
24	6m^2 solar heating	2,600	2,600	2,600	2,600
25	1m^2 solar heating	1,975	1,975	1,975	1,975
26	10m^2 solar heating	3,100	3,100	3,100	3,100
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating	6,690	7,490	9,540	10,590
28	Dry lining	765	990	1,590	1,905
29	Wood pellet boiler + radiators + 200mm loft insulation	4,200	4,250	4,300	4,800
30	Wood pellet boiler + radiators + 200mm loft insulation + 10mm *Sempatap*	5,475	5,900	6,950	7,975
31	Wood pellet boiler + radiators + 200mm loft insulation + 50mm external wall insulation	6,750	7,550	9,600	11,150
32	Oil fired CHP + radiators	NA	NA	NA	NA
33	LPG fired CHP + radiators	NA	NA	NA	NA
34	Package 29 but ½ price wood pellets	4,200	4,250	4,300	4,800
35	Package 29 but ¾ price wood pellets	4,200	4,250	4,300	4,800
36	Three storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity price reduced by 25%)	4,090	4,890	6,890	7,990
37	Ground source heat pump + radiators	4,120	4,765	4,765	5,010
38	Ground source heat pump + radiators + 200mm loft insulation	4,320	5,015	5,065	5,310
39	Coal boiler + radiators	5,000	5,500	6,000	6,000

Appendix III

Summary of installation costs distributed over a period of 50 years. These include initial installation costs, maintenance costs, and replacement costs.

Simulation	Description	50-year cost (£ / 50y)			
		Terrace	Semi-detached	Detached	Large detached
1	Baseline property	0	0	0	0
2	Benchmark property	4,920	5,009	5,098	5,104
3	Target property	8,935	9,357	9,782	9,788
4	28 sec oil condensing combination boiler + radiators	10,497	10,833	10,833	11,166
5	35 sec oil condensing combination boiler + radiators	NA	NA	NA	NA
6	50mm external wall insulation	4,250	5,500	8,834	10,584
7	70mm external wall insulation	4,250	5,500	8,834	10,584
8	10mm **Sempatap** internal wall insulation	2,125	2,750	4,417	5,292
9	Auto feed wood burning boiler + radiators	14,083	15,833	15,831	17,500
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up	10,831	11,333	11,250	11,666
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation	15,081	16,833	20,083	22,250
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation	14,748	16,333	19,667	21,750
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation	14,748	16,333	19,667	21,750
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation	6,708	8,750	13,667	16,375
15	28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p/kWh)	15,081	16,833	20,083	22,250
16	50mm **Wallreform**	1,700	2,200	3,534	4,234
17	LPG condensing combination boiler + radiators	10,500	10,831	10,833	11,166
18	Three storage heaters	4,466	4,466	4,466	4,466
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**	11,175	13,216	18,133	20,675
20	3m^2 solar heating	2,225	2,225	2,225	2,225
21	Communal LPG + combination boiler + radiators	11,700	12,031	12,033	12,366
22	Communal LPG + combination boiler + radiators + 200mm loft insulation	12,033	12,531	12,450	12,866

Simulation	Description	50-year cost (£ / 50y)			
		Terrace	Semi-detached	Detached	Large detached
23	Communal LPG + combination boiler + radiators + 200mm loft insulation + 70mm external wall insulation	16,283	18,031	21,283	23,450
24	6m^2 solar heating	2,600	2,600	2,600	2,600
25	1m^2 solar heating	1,975	1,975	1,975	1,975
26	10m^2 solar heating	3,100	3,100	3,100	3,100
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating	11,650	12,983	16,316	17,983
28	Dry lining	1,275	1,650	2,650	3,175
29	Wood pellet boiler + radiators + 200mm loft insulation	14,417	16,333	16,247	18,000
30	Wood pellet boiler + radiators + 200mm loft insulation + 10mm **Sempata***p*	16,542	19,083	20,664	23,291
31	Wood pellet boiler + radiators + 200mm loft insulation + 50mm external wall insulation	18,667	21,833	25,081	28,583
32	Oil fired CHP + radiators	NA	NA	NA	NA
33	LPG fired CHP + radiators	NA	NA	NA	NA
34	Package 29 but ½ price wood pellets	14,417	16,333	16,247	18,000
35	Package 29 but ¾ price wood pellets	14,417	16,333	16,247	18,000
36	Three storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity price reduced by 25%)	9,050	10,466	13,716	15,550
37	Ground source heat pump + radiators	13,732	15,867	15,867	16,683
38	Ground source heat pump + radiators + 200mm loft insulation	14,065	16,284	16,368	17,183
39	Coal boiler + radiators	16,665	18,332	19,998	19,998

Appendix IV

Summary of SAP scores for under different simulations.

Simulation	Description	SAP			
		Terrace	Semi-detached	Detached	Large detached
1	Baseline property	1	1	1	1
2	Benchmark property	21	30	20	26
3	Target property	49	54	45	50
4	28 sec oil condensing combination boiler + radiators	52	55	46	50
5	35 sec oil condensing combination boiler + radiators	52	55	46	50
6	50mm external wall insulation	11	16	10	15
7	70mm external wall insulation	12	18	13	18
8	10mm **Sempatap** internal wall insulation	3	7	1	4
9	Auto feed wood burning boiler + radiators	30	33	24	29
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up	57	61	50	53
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation	74	81	72	78
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation	69	75	68	72
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation	67	72	64	69
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation	20	27	21	28
15	28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p/kWh)	74	81	72	78
16	50mm **Wallreform**	10	16	9	15
17	LPG condensing combination boiler + radiators	21	24	17	21
18	Three storage heaters	18	22	14	20
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**	37	45	40	46
20	$3m^2$ solar heating	1	2	1	1
21	Communal LPG + combination boiler + radiators	21	24	17	21
22	Communal LPG + combination boiler + radiators + 200mm loft insulation	24	29	20	26
23	Communal LPG + combination boiler + radiators + 200mm loft insulation + 70mm external wall insulation	40	48	42	49

Simulation	Description	SAP			
		Terrace	Semi-detached	Detached	Large detached
24	$6m^2$ solar heating	1	3	1	1
25	$1m^2$ solar heating	1	1	1	1
26	$10m^2$ solar heating	1	4	1	1
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating	41	49	43	49
28	Dry lining	8	13	6	11
29	Wood pellet boiler + radiators + 200mm loft insulation	34	38	28	33
30	Wood pellet boiler + radiators + 200mm loft insulation + 10mm *Sempatap*	40	45	36	42
31	Wood pellet boiler + radiators + 200mm loft insulation + 50mm external wall insulation	49	57	49	55
32	Oil fired CHP + radiators	NA	NA	NA	NA
33	LPG fired CHP + radiators	NA	NA	NA	NA
34	Package 29 but ½ price wood pellets	34	38	28	33
35	Package 29 but ¾ price wood pellets	34	38	28	33
36	Three storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity price reduced by 25%)	37	38	33	38
37	Ground source heat pump + radiators	43	46	36	36
38	Ground source heat pump + radiators + 200mm loft insulation	46	49	39	40
39	Coal boiler + radiators	29	33	24	29

* Note that in these simulations, very little change is seen in the SAP due to solar heating being fitted to the baseline properties. The properties have very low SAP (the SAP scale ranges from 1 to 100), and by fitting solar heating, the improvements are often not sufficient to raise the SAP above 1.

Appendix V

Summary of annual running costs. These include the costs for heating, domestic hot water, cooking, and lights and appliances, and any fixed / standing charges.

Simulation	Description	Annual running cost (£ / y)			
		Terrace	Semi-detached	Detached	Large detached
1	Baseline property	1,224	1,356	1,727	2,078
2	Benchmark property	957	975	1218	1,419
3	Target property	574	627	769	916
4	28 sec oil condensing combination boiler + radiators	605	671	828	1,008
5	35 sec oil condensing combination boiler + radiators	612	679	839	1,021
6	50mm external wall insulation	1,002	1,040	1,269	1,503
7	70mm external wall insulation	975	1,002	1,211	1,432
8	10mm **Sempatap** internal wall insulation	1,126	1,216	1,527	1,825
9	Auto feed wood burning boiler + radiators	713	792	994	1201
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up	574	632	789	949
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation	481	499	598	707
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation	504	528	624	747
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation	515	543	647	776
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation	885	884	1073	1241
15	28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p/kWh)	554	572	694	819
16	50mm **Wallreform**	1,007	1,047	1,279	1,516
17	LPG condensing combination boiler + radiators	1,019	1,132	1,422	1,721
18	Three storage heaters	1,007	1,091	1,345	1,581
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**	783	786	911	1,032
20	$3m^2$ solar heating	1,169	1,301	1,672	2,023
21	Communal LPG + combination boiler + radiators	826	920	1,157	1,408
22	Communal LPG + combination boiler + radiators + 200mm loft insulation	779	858	1095	1,315

Simulation	Description	Annual running cost (£ / y)			
		Terrace	Semi-detached	Detached	Large detached
23	Communal LPG + combination boiler + radiators + 200mm loft insulation + 70mm external wall insulation	614	624	756	887
24	6m^2 solar heating	1,139	1,272	1,643	1,993
25	1m^2 solar heating	1,201	1,333	1,704	2,055
26	10m^2 solar heating	1,116	1,249	1,619	1,970
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating	730	735	864	987
28	Dry lining	1,044	1,099	1,357	1,612
29	Wood pellet boiler + radiators + 200mm loft insulation	674	741	939	1,122
30	Wood pellet boiler + radiators + 200mm loft insulation + 10mm **Sempatap**	621	666	831	985
31	Wood pellet boiler + radiators + 200mm loft insulation + 50mm external wall insulation	555	573	691	812
32	Oil fired CHP + radiators	454	508	667	814
33	LPG fired CHP + radiators	891	996	1,298	1,573
34	Package 29 but ½ price wood pellets	524	575	715	857
35	Package 29 but ¾ price wood pellets	599	658	828	990
36	Three storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity price reduced by 25%)	621	679	794	917
37	Ground source heat pump + radiators	624	689	843	1,017
38	Ground source heat pump + radiators + 200mm loft insulation	599	656	811	968
39	Coal boiler + radiators	789	877	1,106	1,337

Appendix VI

Summary of CO_2 emissions, including cooking, lights, and appliances.

Simulation	Description	Annual CO_2 emissions (Tonnes / y)			
		Terrace	Semi-detached	Detached	Large detached
1	Baseline property	13.3	15.1	20.4	25.1
2	Benchmark property	10.6	10.7	14.8	17.8
3	Target property	5.8	6.5	8.6	10.4
4	28 sec oil condensing combination boiler + radiators	7.3	8.3	10.8	13.3
5	35 sec oil condensing combination boiler + radiators	7.3	8.3	10.8	13.3
6	50mm external wall insulation	10.1	10.5	13.7	16.7
7	70mm external wall insulation	9.7	9.9	12.8	15.6
8	10mm **Sempatap** internal wall insulation	11.9	13	17.5	21.4
9	Auto feed wood burning boiler + radiators	4.2	4.7	6.2	7.7
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up	6.8	7.6	10.1	12.4
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation	5.2	5.3	6.8	8.1
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation	5.6	5.8	7.3	8.8
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation	5.8	6.1	7.7	9.3
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation	8.3	8.2	10.8	12.9
15	28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p/kWh)	5.2	5.3	6.8	8.1
16	50mm **Wallreform**	10.1	10.6	13.8	16.9
17	LPG condensing combination boiler + radiators	7.4	8.3	10.9	13.4
18	Three storage heaters	11	12.3	16.5	20.1
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**	7.1	6.9	9.0	10.6
20	3m^2 solar heating	12.9	14.7	20.0	24.7
21	Communal LPG + combination boiler + radiators	7.4	8.3	10.9	13.4
22	Communal LPG + combination boiler + radiators + 200mm loft insulation	6.8	7.6	10.2	12.4
23	Communal LPG + combination boiler + radiators + 200mm loft insulation + 70mm external wall insulation	5.0	5.1	6.5	7.7

Simulation	Description	Annual CO_2 emissions (Tonnes / y)			
		Terrace	Semi-detached	Detached	Large detached
24	6m^2 solar heating	12.7	14.5	19.8	24.5
25	1m^2 solar heating	13.1	14.9	20.2	24.9
26	10m^2 solar heating	12.5	14.3	19.6	24.3
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating	6.8	6.7	8.8	10.4
28	Dry lining	10.7	11.3	15.0	18.3
29	Wood pellet boiler + radiators + 200mm loft insulation	3.9	4.4	5.8	7.1
30	Wood pellet boiler + radiators + 200mm loft insulation + 10mm **Sempatap**	3.5	3.8	5.0	6.1
31	Wood pellet boiler + radiators + 200mm loft insulation + 50mm external wall insulation	3.0	3.2	4.0	4.9
32	Oil fired CHP + radiators	NA	NA	NA	NA
33	LPG fired CHP + radiators	NA	NA	NA	NA
34	Package 29 but ½ price wood pellets	3.9	4.4	5.8	7.1
35	Package 29 but ¾ price wood pellets	3.9	4.4	5.8	7.1
36	Three storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity price reduced by 25%)	7.2	8.2	10.5	12.7
37	Ground source heat pump + radiators	5.8	6.5	8.3	10.1
38	Ground source heat pump + radiators + 200mm loft insulation	5.5	6.1	7.9	9.5
39	Coal boiler + radiators	105	11.8	15.5	18.9

Appendix VII

Summary of net annual monetary benefit over the baseline property. A positive figure indicates that a measure saves more money than it costs to install and maintain, while a negative figure shows that a measure costs more money than it saves.

Simulation	Description	Net benefit (£/y)			
		Terrace	Semi-detached	Detached	Large detached
1	Baseline property	0	0	0	0
2	Benchmark property	169	281	407	557
3	Target property	471	542	762	966
4	28 sec oil condensing combination boiler + radiators	409	468	682	847
5	35 sec oil condensing combination boiler + radiators	612	677	888	1,057
6	50mm external wall insulation	137	206	281	363
7	70mm external wall insulation	164	244	339	434
8	10mm **Sempatap** internal wall insulation	55	85	112	147
9	Auto feed wood burning boiler + radiators	229	247	416	527
10	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up	433	497	713	896
11	28 sec oil condensing combination boiler + radiators + 200mm loft insulation top up + 50mm external wall insulation	441	520	727	926
12	28 sec oil condensing combination boiler + radiators + 70mm external wall insulation	425	501	710	896
13	28 sec oil condensing combination boiler + radiators + 50mm external wall insulation	414	486	687	867
14	200mm loft insulation top up + 70mm external wall insulation + 10mm **Sempatap** internal wall insulation	205	297	381	509
15	28 sec oil condensing combination boiler + radiators + 200mmloft insulation top up + 50mm external wall insulation (cost of oil is 24 p/kWh)	368	447	631	814
16	50mm **Wallreform**	183	265	377	477
17	LPG condensing combination boiler + radiators	-5	7	88	134
18	Three storage heaters	128	176	293	408
19	Three storage heaters, 200mm loft insulation, 70mm external wall insulation, and 10mm **Sempatap**	218	306	453	633
20	3m^2 solar heating	11	11	11	11
21	Communal LPG + combination boiler + radiators	164	195	329	423

Simulation	Description	Net benefit (£/y)			
		Terrace	Semi-detached	Detached	Large detached
22	Communal LPG + combination boiler + radiators + 200mm loft insulation	204	247	383	506
23	Communal LPG + combination boiler + radiators + 200mm loft insulation + 70mm external wall insulation	284	371	545	722
24	6m^2 solar heating	33	32	32	33
25	1m^2 solar heating	-17	-17	-17	-17
26	10m^2 solar heating	46	45	46	46
27	Three storage heaters + 70mm EWI + 200mm loft insulation + 6m2 solar heating	261	361	537	731
28	Dry lining	154	224	317	402
29	Wood pellet boiler + radiators + 200mm loft insulation	262	288	463	596
30	Wood pellet boiler + radiators + 200mm loft insulation + 10mm *Sempatap*	272	308	483	627
31	Wood pellet boiler + radiators + 200mm loft insulation + 50mm external wall insulation	296	346	534	694
32	Oil fired CHP + radiators	770	848	1,060	1,264
33	LPG fired CHP + radiators	333	360	429	505
34	Package 29 but ½ price wood pellets	412	454	687	861
35	Package 29 but ¾ price wood pellets	337	371	574	728
36	Three storage heaters + 70mm external wall insulation + 200mm loft insulation (electricity price reduced by 25%)	422	468	659	850
37	Ground source heat pump + radiators	325	350	567	727
38	Ground source heat pump + radiators + 200mm loft insulation	344	374	589	766
39	Coal boiler + radiators	333	367	400	400