Home Energy Efficiency Group

Sustainable Design Practice

Theory and Practice of Sustainable Design

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Executive summary

This report presents research conducted over six months by four graduate students studying on the Theory and Practice of Sustainable Design MSc course at the Welsh School of Architecture, Cardiff University. The research explored energy consumption and efficiency in domestic buildings. These issues were examined in the context of Penarth, a town of 23,000 people several miles outside of Cardiff, Wales.

This research was comprised of three distinct phases. The first phase of research, conducted by all members of the MSc course, explored a range of topics related to sustainability. It sought also to investigate these topics in relation to Penarth. The results of the first phase of the research have been presented in a separate document. A brief summary of the first phase of research is provided in Chapter 2 of this report; however, reviewing this research in greater detail will provide useful background to what is presented in this report.

During the second phase, issues specific to energy consumption and efficiency were examined. It was recognised that a change in behaviour as well as in physical infrastructure must be manifested in order to effect the reduction in energy consumption necessary to mitigate and adapt to climate change. Several obstacles to this change were identified. These include a lack of understanding of the importance of reducing energy use, a lack of access to tools and knowledge to make change, indifference to the issue, and a feeling of powerlessness to effect change. This report presents concepts for addressing these obstacles. These include developing practical methods of conveying technical information, which are described in Chapter 3, and strategies for the development of awareness campaigns which are described in Chapter 4.

During the final phase of the research, strengths and weaknesses of the strategies identified were examined. Building on this examination, opportunities for the development of campaigns and education tools are presented. The discussion of this phase will benefit the educator, activist, and campaigner in effecting change in domestic energy consumption. This discussion is presented throughout Chapters 3, 4, and 5.

It is the intent of the authors of this report that it serve not only to present the work undertaken during the period of research, but that it be a useful guide for the citizens of Penarth who are endeavouring to reduce the consumption of energy associated with their built environment. As such, effort has been made to highlight significant points that will be of interest to environmental activists, educators and homeowners as they engage themselves in this effort. Key points are presented in the column at the side of each page. The casual reader may choose to use the table of contents to select topics of specific interest and may find the highlighted key points a useful guide while reading.

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Chapter 1 – Introduction

1 Introduction

1.1 Context

The UK Climate Change Act of 2008 is a legally binding act that aims to transition the UK to a low carbon society while being exemplar amongst the European Union. One of the key aims of the act is to reduce emissions by 34% by 2020 and 80% by 2050. Both of these targets are based on 1990 levels. Emissions from housing in the UK are estimated to be in the region of 27% of the total carbon footprint (Boardman, 2007). Reduction in emissions through improvements in the building stock offers one of the single largest opportunities for the UK to reach its targets. It also presents the opportunity to educate and change behaviour at a large scale.

Despite changes in policy and increased rhetoric from government officials, emission levels from housing have actually risen by more than 5% since 1997 (Boardman 2007). This can partly be attributed to increased levels of ownership of electrical appliances and also the increased comfort requirements of occupants.

The knowledge and skills required to make the improvements necessary to improve building stock are increasingly available and yet the uptake of these measures has been slow. The rate of uptake in improvements, although increasing, is largely dependent on the initiative of householders. "*A total of 17 million homes have cavity walls, but over half are still unfilled, despite this being an inexpensive measure that makes the home much more comfortable"* (Boardman 2007 pg 5). The Government reported in 2007 (DTI 2007b), that 8 million homes were in existence with un-insulated cavities. It estimated that cavity insulation pays for itself in reduced

The UK Climate Change Act sets out policy governing carbon emissions.

Housing accounts for ~27% of UK carbon emissions

National emissions are rising, in the domestic sector; this is largely attributable to lifestyle changes

Despite knowledge and resources being available, improvement in efficiency is slow.

energy bills in less than three years. Facilitating the improvement of efficiency in homes is a vitally important effort to reducing carbon emissions. Estimates by the Government indicate loft and cavity insulation and boiler replacement schemes could reduce carbon emissions by up to 9 MtC per year by 2020 (DTI 2007b).

It has been determined that an estimated 26 million houses in the UK today will still be in existence by 2050, comprising 60 per cent of housing stock in that year (CCC 2010). The role of domestic energy efficiency retrofitting therefore is critical to ensuring that carbon emission targets can be reached. Improving efficiency, increasing comfort, and lifting householders out of fuel poverty[1] are all possible through appropriate retrofit strategies.

The relationship between fuel mix and domestic energy consumption and their impact on emissions cannot be ignored. Meeting emissions reduction targets requires addressing the emissions associated with our heating and electricity fuels. Equally important, however, is that this change in generation is met with a dramatic increase in energy efficiency. Within the domestic sector, reducing energy demand can be achieved through fabric improvements like insulating and airtightness detailing and through behavioural changes.

1.1.1 Energy Performance of Buildings Directive (EPBD)

Published in 2002, this legislation is the principle driver in the requirement for all member states to develop a methodology for the calculation of the energy performance of buildings (with some exceptions such as

Roughly half of homes with uninsulated cavity walls in the UK have not been retrofitted with insulation.

Loft and cavity insulation, coupled with boiler replacement schemes could save up to 9MtC per year by 2020

60% of homes in 2050 are estimated to already exist today.

The Energy Performance of Building Directive (EPBD) was published in 2002.

[1] Although alternative definitions exist, for the purpose of this report households that spend more than 10% of total household income on fuel for heating are considered to be in fuel poverty.

religious buildings) and forms part of European member states' commitments to the Kyoto Protocol. The four key points of the directive are (Europa 2007):

1. Member states must develop a methodology for predicting the energy performance of buildings (in the UK, this is the Standard Assessment Procedure (SAP) methodology)
2. Member states must define minimum standards for the energy performance of buildings (In the UK, this is approved guidance document; Part L)
3. Certificates of energy performance are mandatory and must be made available; in the case of public buildings over 1,000 m^2, they must be on display.
4. Regular inspection of boilers and air conditioning systems in buildings are required. Heating systems are with boilers more than 15 years old must be assessed.

The EPBD forms part of the European member states' commitments to the Kyoto Protocol.

1.1.2 Sustainability

This report strives to place domestic energy use against a wider context of sustainability. The concept of sustainability underpins the research presented in this report, and it is necessary to discuss our definition of sustainability in order to present more clearly the relationship between energy efficiency and sustainability.

There are many ways of understanding sustainability. Perhaps the most famous wording used to describe sustainable development was provided by The World Commission on Environment and Development (the Brundtland Commission), in 1987:"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In the Declaration of Rio on Environment and Development, made in 1992,

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

-Brundtland Commission

the three pillars of environmental, economic, and social sustainability were described. This described the inter-connected relationship of these three realms and posited that consideration of sustainability must acknowledge the importance of all three (Figure 1). Economic vitality and social fabric should be recognised as being just as central to sustainability as environmental protection. This represents a form of systems thinking. By recognising that economic, social, and environmental considerations are part of a unified whole, we can see that each plays an equally integral role in defining sustainability. In the context of energy efficiency of homes, these three elements of sustainability are equally relevant.

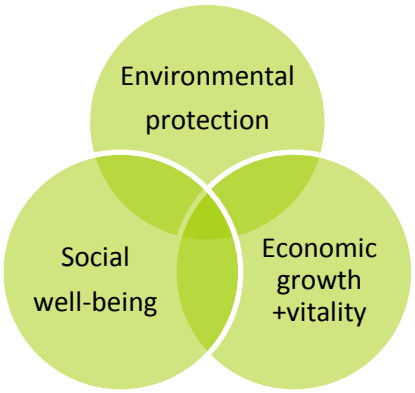


Figure 1: The three 'pillars' of sustainability

Environmental, social, and economic factors must be balanced to achieve sustainability

1.1.2.1 Environmental Sustainability

Perhaps most obviously, environmental protection is a direct outcome of improving energy efficiency. This is relevant beyond avoidance of atmospheric pollution and the contribution of greenhouse gas production to climate change, as energy use has direct impact on resource consumption and the conservation of ecological habitats. Especially in the building industry, the processes of extraction of materials, processing, building of homes, deconstruction, and disposal, all release great amounts of CO_2 and create waste that can be harmful to the environment. Therefore, as much as is reasonably

Energy and environmental sustainability:

-Atmospheric pollution

-Greenhouse gas production

-Resource consumption

-Habitat loss

practicable is being done in legislation to ensure mandatory requirements that reduce the impact of these processes on the environment. The earth's resources are finite and so, our reliance on the way that materials are used, and energy is sourced has been brought to public attention. Even the amount of CO_2 that is produced by buildings when in use is at a level of urgency. Hence, methods of reducing consumption, such as improving the level of efficiency of buildings, have been developed in an attempt to reduce this impact.

Addressing energy use in buildings is vital to ensuring environmental sustainability

1.1.2.2 Economic Sustainability

The contribution to economic vitality that is made by conserving energy likewise extends beyond the obvious direct effect of conserving household income. Energy conservation also plays a role in stemming the flow of economic resources outside of a local community to pay for consumed fossil fuels and other sources of gas and electrical energy. This in turn supports the development of local economies. By transitioning the energy budget of buildings and communities first to "energy lean" and eventually to "net energy neutral" we will enable a great proportion of individual income to be spent locally. This also translates to resilience to the economic effects of climate change and of Peak Oil. The support of new and existing supply chains in support of energy efficient building and retrofitting is another contribution to economic vitality made by the move to energy efficiency.

Energy conservation:

-stems the flow of economic resources outside of local communities

-supports resilience to climate change and to Peak oil

-promotes the development of new and supply chains.

1.1.2.3 Social Sustainability

In the context of social sustainability, energy efficiency has a multitude of implications. The implications of reducing pollution for a healthier ecological environment as well as for individual health can be seen as an overarching benefit to quality of life. At a basic level, energy efficient homes

should be recognised as potentially more comfortable environments to live in. Efficiency retrofitting may also entail the regeneration of existing structures or communities. The creation of more energy efficient homes – whether new-built or retrofitted or simply through adapted behaviour – can have positive effects beyond physical comfort. It can be seen as a platform for new knowledge and technical industries, which bolster societal fabric in addition to providing economic stimulus. In this sense, it contributes to the development of new skills, education and workplace training across broad sections of society, as well as knowledge exchange between individuals. By bringing people to new trades, employment opportunities and industries, social fabric is improved. This positive effect on social fabric is also visible wherever efficiency upgrading translates to an increase in interpersonal exchanges, community workshops, or other forms of knowledge exchange.

1.1.3 Climate change

Anthropogenic climate change is the disruption of climate patterns associated with human activity from the latter half of the Nineteenth Century to today. There is a clear record of a global warming trend over this period coupled with an increase in disruption of weather patterns and an increase in severe weather events (CCC 2010) (Figure 2 [CCC2010, data from MOHC & CRU, NASA GISS, and NOAA NCDC]).

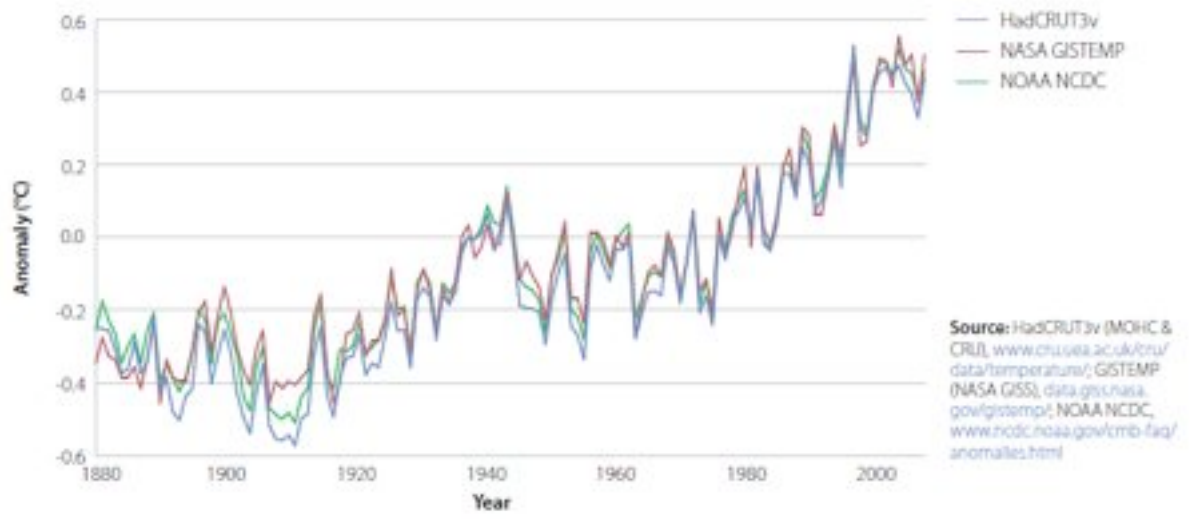


Figure 2: Global average surface temperatures since 1880 as calculated by three different research centres).

The UK Committee on Climate Change (CCC 2010) has underscored conclusions drawn by the IPCC (2007), stating that in order to ensure a best-case projection of a 2 degree rise in global mean temperature by 2100 is not exceeded, greenhouse gas emissions must be reduced relative to 1990 levels by 80 per cent by 2050. The Committee has recommended a reduction of 60 per cent be reached by 2030. This builds on recommendations in the 2007 Energy White Paper that UK

emissions be reduced by this same amount by 2050. Further, the Committee on Climate Change has recommended that the currently legislated 34 per cent cut by 2020 dictated by the Climate Change Act, be changed to 37 per cent and advised that the reduction could be moved to 42 per cent as it is anticipated that the EU will soon adopt tighter emissions targets (CCC, 2010).

1.1.4 Rising energy consumption

Just less than half of total energy consumed in the UK and 79 per cent of energy use outside of the transport sector is used for heating (DTI 2007a). Domestic buildings account for nearly 35 per cent of national energy consumption (Ward 2008), with domestic heating accounting for 20 per cent of UK CO_2 emissions (DTI 2007a). A breakdown of 2008 greenhouse gas emissions is shown in Figure 3.

Roughly half of total UK energy consumption and 79% of UK energy outside of transport sector is used for heating.

Domestic buildings account for ~35% of UK energy consumption

Domestic heating accounts for ~20% of UK CO_2 emissions

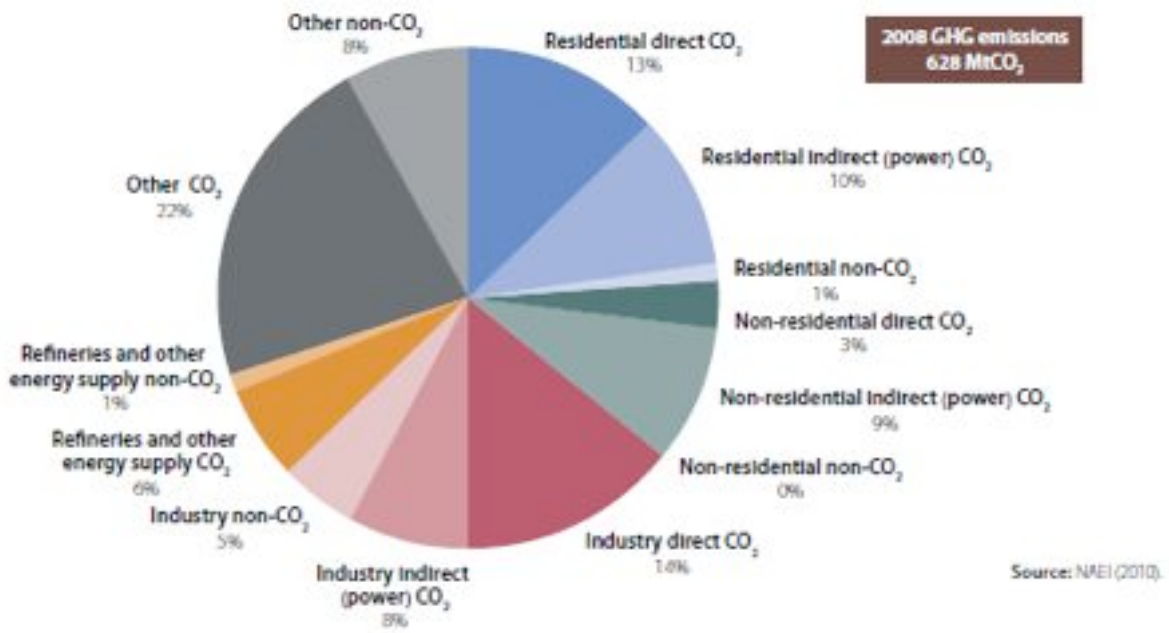


Figure 3: Greenhouse gas emissions from buildings and industry as proportion of total 2008 UK emissions (NAEI 2010, as cited by CCC 2010).

According to the DTI (2007a), 87 per cent of energy consumed in the UK domestic sector is used for heating (Table 1, overleaf). In a 2007 Energy White Paper (DTI 2007b), this proportion is given as 75 per cent. Nevertheless, there is ample evidence that heating accounts for a majority of consumed energy in the domestic sector, as seen in Appendix G (DTI, 2007a).

Table 1: Energy consumption by sector and end use. Thousand tonnes of oil equivalent. Note space heating for domestic sector comprises greatest proportion of energy use (DTI 2007a).

End use	Domestic	Services	Industrial	Transport	Total	Total excluding Transport
Space heating	29,296	9,067	3,538	-	41,901	41,901
Water heating	11,315	1,715	-	-	13,030	13,030
Process use	-	-	16,312	-	16,312	16,312
Drying/separation	-	-	3,445	-	3,445	3,445
Cooking/catering	1,299	1,969	-	-	3,268	3,268
Heat total	41,910	12,751	23,294	-	77,955	77,955
Other	6,373	5,900	8,694	59,225	80,193	20,968
Total	48,283	18,651	31,989	59,225	158,148	98,923
Percentage of total attributed to heat	87%	68%	73%	-	49%	79%

Total does not include heat sold, renewables and waste as well as blast furnace gas or coke oven gas for industrial sector

While heating as a proportion of domestic energy use has not increased, overall domestic energy use has risen by about 20 per cent between 1990 and 2005 and by 32 per cent since 1970 (DTI 2007a) (Figure 4, overleaf). This increase would have been greater were it not for changes in efficiency; a phenomenon termed the 'intensity effect.' Concurrently, the number of households in the UK has increased by 10 per cent since 1990 while population has increased by just 4 per cent. The percentage of UK households that are one-person households has risen from 17 per cent in 1971 to 32 per cent in 2000 (DTI 2007a) (Figure 5, overleaf). Meanwhile, household disposable income has risen by 30 per cent during this same period (DTI 2007a). This has been correlated with increased appliance ownership, rising indoor temperatures, and the increase in overall energy consumption delineated above.

UK domestic energy consumption rose by 20% between 1990 and 2005.

32% of households in the UK in 2000 were one-person households.

Household disposable income rose by 30% between 1971 and 2000.

Rising average indoor temperatures and increased appliance ownership are correlated with rising disposable income.

In part due to fuel switching, this has not increased carbon emissions appreciably. Conversely, carbon savings have not been realised despite an improved ratio of emissions to units consumed.

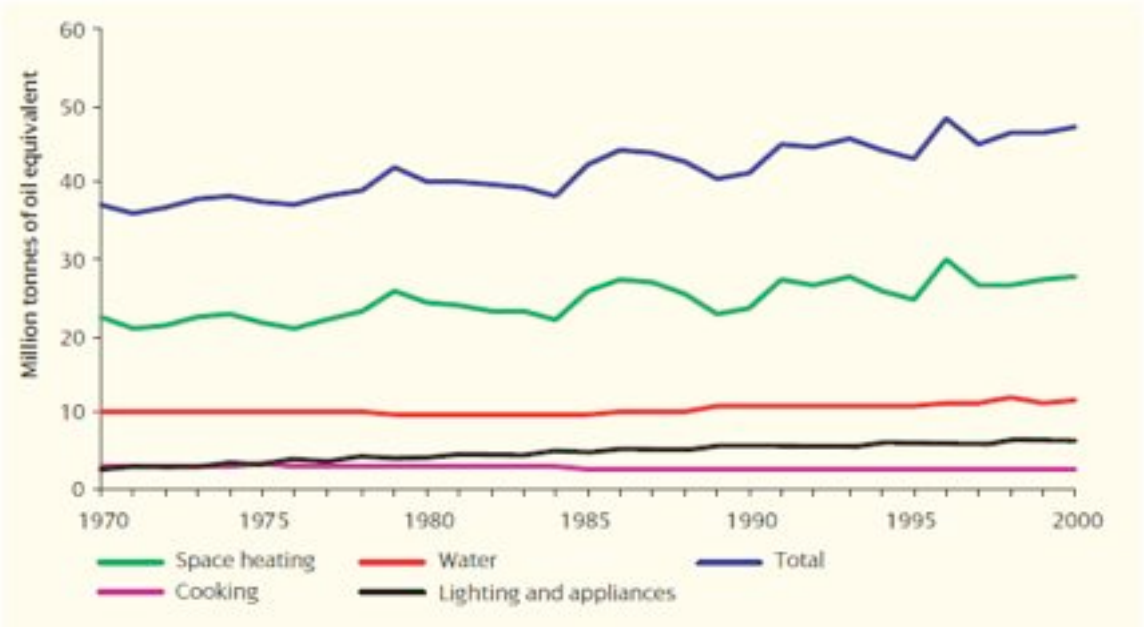


Figure 4: Domestic energy consumption by end use, 1970-2000 (DTI 2007a).

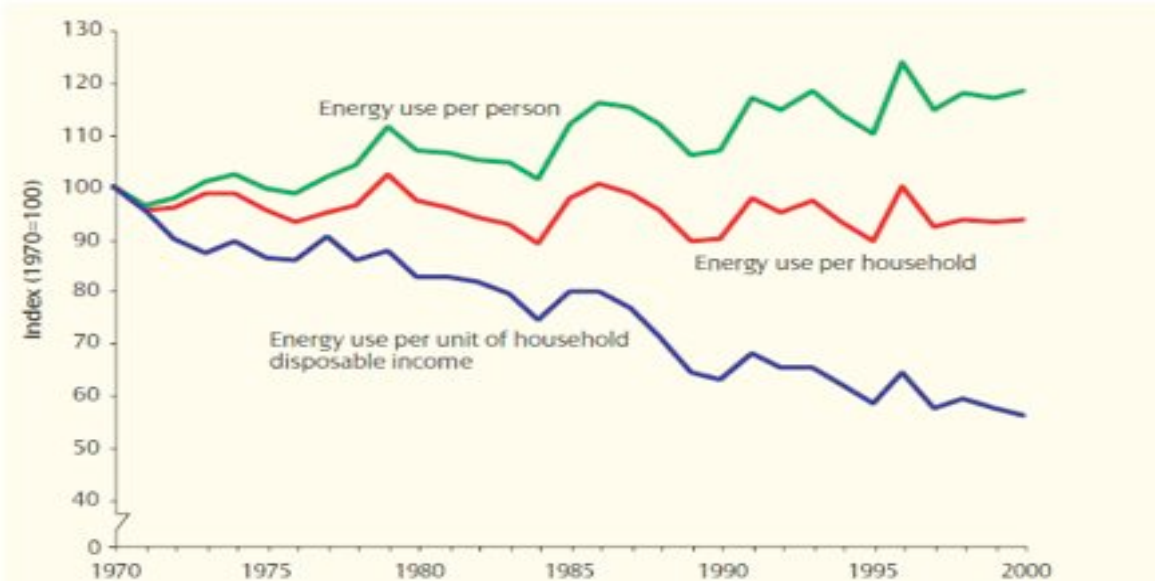


Figure 5: Domestic energy consumption per person, per household, and per unit of household income (DTI 2007a).

Energy consumption is, in part, tied to weather patterns since more energy is required to heat buildings to the same temperature during colder temperatures. A rise in average external temperature in the UK is pointed to by

Despite a rise in average external temperatures, average interior temperatures have risen from13 ° C in 1970 to 18 °C in 2000.

the DTI (2009) as increasing from 5.8° C in 1970 to 7.2° C in 2000. Data show, however, that primary consumption has risen steadily even correcting for outside temperatures. In 1970, average indoor temperatures were 13° C; by 2000, they had risen to 18° C. In 1970, 5.6 million homes were centrally heated, while by 2000 this number had risen to 21.7 million (DTI 2009).

Against a historical backdrop of rising energy consumption (Figure 6), the trend remains visible, as primary energy use rose by three per cent between 2009 and 2010 (DECC 2011c). Despite this, the rate of increasing demand has slowed over the past ten years. Looking at specific fuels, demand for gas has increased at a faster rate relative to electricity and fuel oil. Between 2009 and 2010, gas demand increased by 8.5 per cent, while electricity demand grew by just 1 per cent.

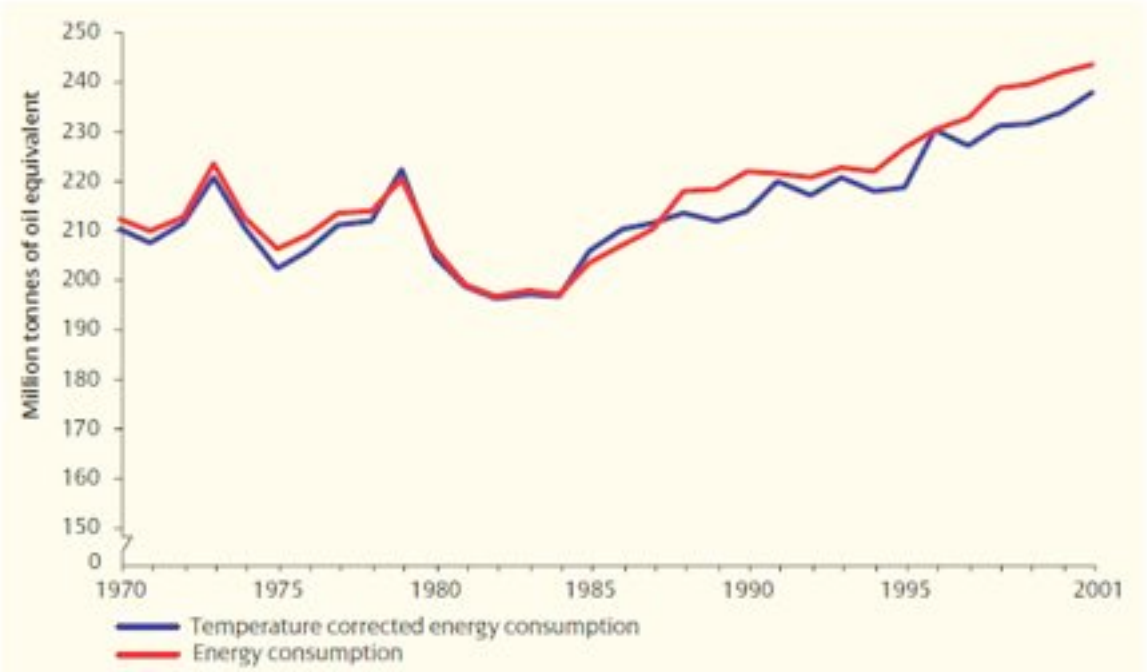


Figure 6: Total UK primary energy consumption 1971-2000, showing temperature adjustment (DTI 2007a)

Another trend correlating with increasing energy consumption is a rise in owner-occupied dwellings as a proportion of the whole (owner-occupied dwellings are associated with higher levels of energy consumption. Further context for the rise in energy consumption has been reviewed. Defra, as reported in the 2007 Energy White Paper (DTI 2007b), presents a useful analysis of the contributions of individuals to the national carbon emission rate as well as an analysis of the makeup of the average UK individual carbon footprint (Figure 7, overleaf). This describes the proportion of space heating within an individual's footprint as being 30 per cent.

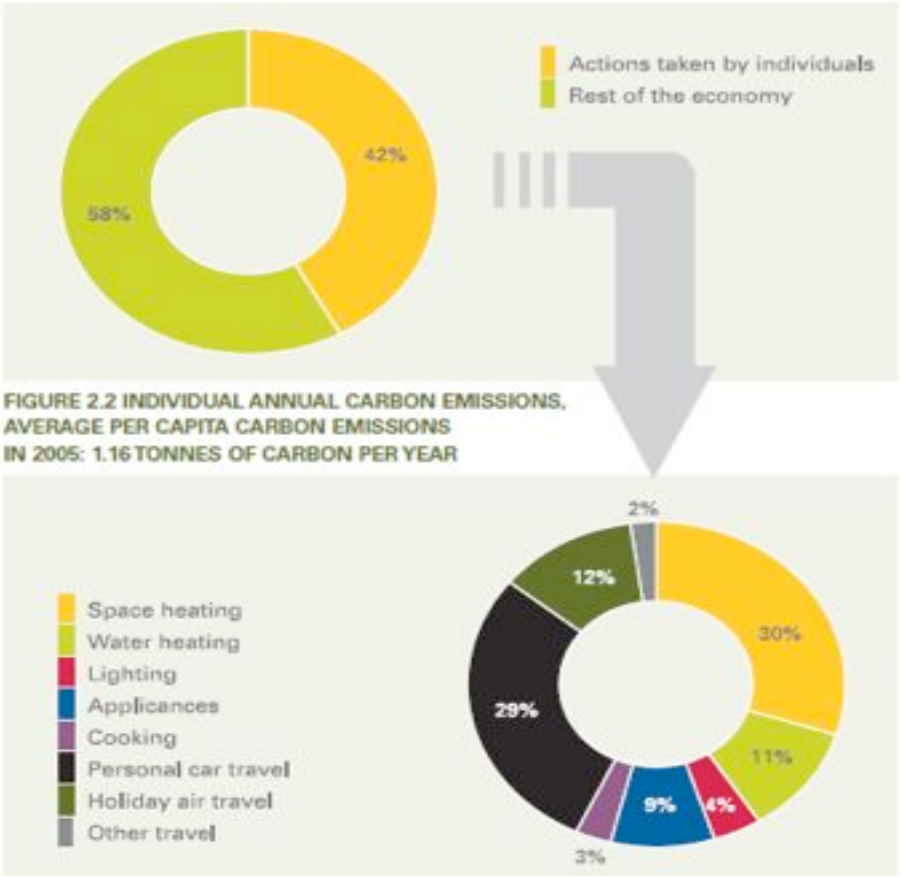


Figure 7: Figure from Defra, presented in the 2007 Energy White Paper (DTI 2007b) showing breakdown of carbon emissions. Graphic at top shows individual versus collective contribution to national emissions. A breakdown of individual emissions is shown at bottom.

Data supporting these conclusions have been provided by the Department of Trade and Industry (DTI 2007a; DTI 2009). Extensive information detailing the breakdown of energy consumption in the domestic sector is provided in Chapter 3 of 'Energy Consumption in the United Kingdom' (see DTI 2009). This is the most recent publication of comprehensive data by a Government body. Reviewing this information will serve as a helpful primer for any campaign addressing energy consumption. It has been summarised in brief in this section.

1.1.5 Energy prices

Recent hikes in energy prices, particularly in petrol prices at the pump, have given many people the impression that energy prices have increased drastically over time. In fact, prices have only exhibited dramatic change in recent time. Although often correlated with each other, prices of gas, electricity, and fuel oil need to be examined individually to understand trends in the change of prices paid by the consumer.

According to Government reports, domestic electricity prices fell in real terms in every year from 1992 and 2003 (except in 1994 when VAT was introduced at 8 per cent). This trend has been attributed to price controls set by Ofgem (DTI 2011a). Following 2004, wholesale electricity prices climbed, largely because of the increased cost for fossil fuels (primarily wholesale gas) and carbon allowances. This trend peaked in 2008. Average electricity bills for 2010 were lower than average electricity bills in 2009. Q4 prices in 2010 were 2.7 per cent lower than Q4 prices (in real terms) in 2009 (DTI 2011c). 2010 figures show that the average credit electricity bill decreased by £13, compared to 2009, to £435. Average direct debit and prepayment bills both decreased by £11 to £398 and £446 respectively (DTI 2011a).

Gas prices also fell in real terms each year from 1995 to 2000 due to competition. Between 2001 and 2009, prices then rose, largely attributed to wholesale price increases. The average 2010 gas bill across all payment types fell by £25, compared to 2009, to £658. Q4 gas prices in 2010 were 7.1 per cent lower than Q4 prices (in real terms) (DTI 2011a).

The average cost of crude oil, however, has in recent times climbed dramatically. Crude acquired by refineries in February 2011 was 33.5 per cent higher than in February 2010 (DTI 2011c). The price of heating oils increased by 24.3 per cent in real terms, whilst the price of coal and smokeless fuels fell by 2.3 per cent in real terms (Figure 8, overleaf). By comparison, petrol and oil prices during this same period rose by 13.3 per cent (DTI 2011a).

Extensive information detailing energy consumption is available through Government publications including 'Energy consumption in the United Kingdom' (DTI 2009), 'Estimates of heat use in the United Kingdom' (2007a), and 'A White Paper on Energy. Meeting the energy challenge' (2007b).

Oil prices have risen dramatically recently.

In the 1990's, electricity prices in real terms fell. In recent years, electricity costs have climbed, however, not in tandem with oil prices.

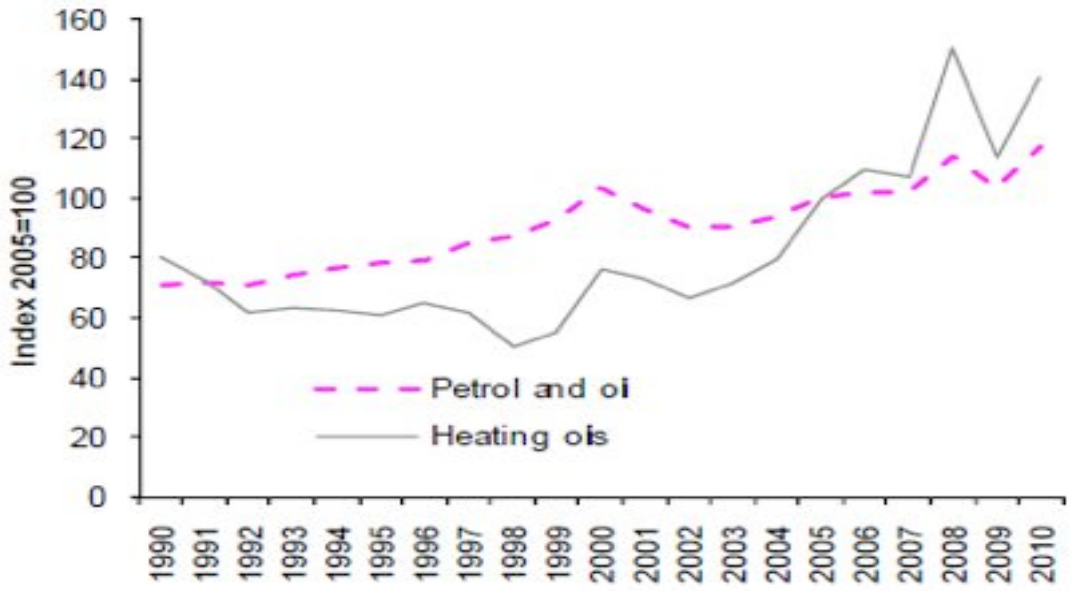


Figure 8: Fuel price indices in the domestic sector in real terms 1990 to 2010 (ONS, cited in DECC 2011a)

Between Q4 2009 and Q4 2010, the combined price for domestic heating fuel and electricity fell by 3.0 per cent. In the second half of 2010, UK domestic gas and electricity prices, including taxes, were below the EU15 median for small consumers (DTI 2011a).

It should be recognised that the overarching trend in energy prices is that a steady increase has been occurring in recent years. As all energy prices are generally correlated to crude oil prices, and crude oil prices have been increasingly at a dramatic rate over recent months, it is likely that energy prices will begin a more rapid increase soon. There is also cause to believe that some of this increase may be linked to Peak Oil. In light of this, the agenda of energy efficiency can be seen as increasingly important. Low energy prices are likely to stall development of commercial markets catering to energy efficiency. Balancing higher energy prices with a healthy economy is necessary to securing sustainability.

Between Q4 2009 and Q4 2010, the combined price for domestic heating fuel and electricity fell by 3.0%

Consider Peak Oil and the potential for energy prices to rise in relation to it.

"Balancing higher energy prices with a healthy economy is necessary to securing sustainability."

1.1.6 Energy supply

In the past year, overall energy production in the UK has fallen, while at the same time, renewable electricity generation has increased slightly and renewable electricity capacity has increased greatly.

Total energy production in the UK fell in 2010 by 6 per cent relative to 2009 production. Oil production was 7.5 per cent lower than in 2009 and gas production was 4.5 per cent lower. Provisional figures for 2010 show renewable generation increased by 0.4 per cent above 2009 levels. Renewable capacity, meanwhile, rose 12 per cent during this same time period. The majority of this is due to increases of 476 MW in onshore wind and 400 MW in offshore wind (a 42 per cent increase on 2009 capacity). Notably, solar photovoltaic capacity more than doubled in 2010, which DECC attributes to being the result of the Feed in Tariff scheme (DECC 2011c).

The potential for marked reduction in carbon emissions associated with grid electricity represented by the increase in renewable capacity was in the last year in part negated coal electricity generation increased between as nuclear supply fell by 10 per cent on 2009 levels (DTI 2011c).

At present, the proportion of UK grid electricity supplied by renewable sources remains at 7 per cent (Figure 9, overleaf) (DECC 2011c). This has important implications for understanding the carbon emissions associated with grid electricity. According to 2009 figures, grid electricity has 0.544 kg of CO_2e associated with 1 kWh. This can be compared with 0.184 $kgCO_2e$ per kWh from natural gas, and 0.266 $kgCO_2e$ per kWh from fuel oil (Carbon Trust 2010).

Total energy production in the UK fell in 2010 by 6%.

Renewable capacity rose by 12% in 2010. Renewable generation rose by 0.4%.

Photovoltaic capacity more than doubled in 2010 due to the Feed in Tariff.

7% of UK grid electricity is supplied by renewable sources.

1000 watts consumed for one hour (1kWh) of grid electricity produces 0.544 kg of CO_2e.

This can be compared with 0.184 $kgCO_2e$ per kWh from natural gas, and 0.266 $kgCO_2e$ per kWh from fuel oil.

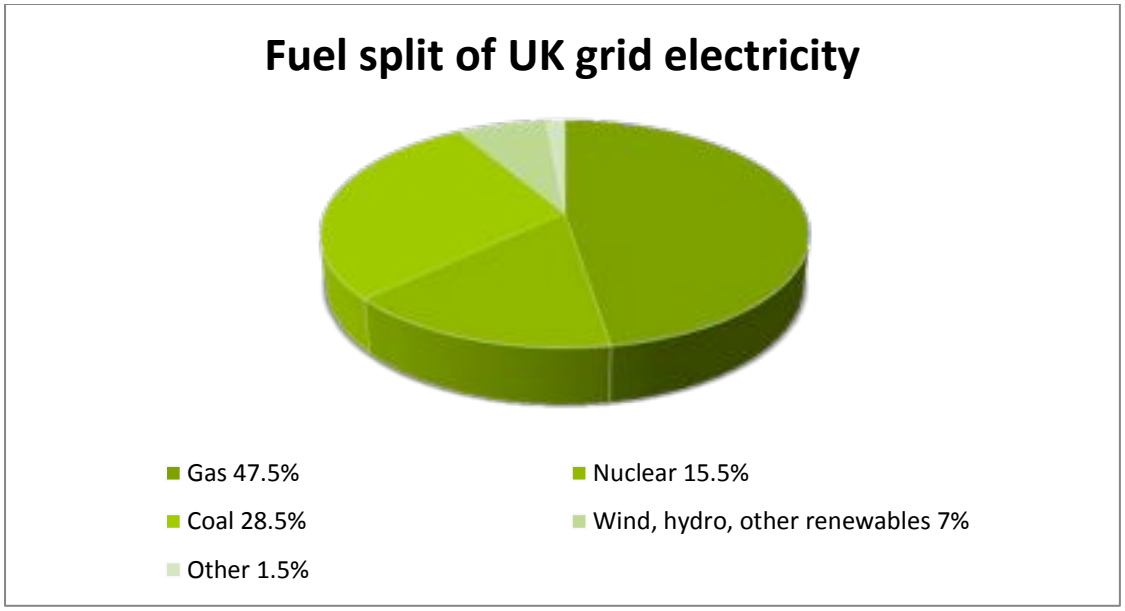


Figure 9: Fuel split associated with UK grid electricity showing 7 per cent proportion supplied by renewables (data from DECC 2011c).

1.1.7 Carbon emissions

Many new practices are appearing which are directed toward mitigation of climate change and ecological impact. Largely as a result of government policy, much of the focus of these practices is on reducing carbon emissions. In the UK, domestic buildings account for over twenty-five per cent of national carbon emissions (CCC 2008). In the context of growing societal concern about climate change and widening recognition of the contribution of anthropogenic greenhouse gas emissions to it, newly emerging government incentive programmes as well as market forces are driving homeowners to improve energy efficiency not just in new construction but also in the existing building stock.

The UK Government has set ambitious goals for improving the energy efficiency of the existing housing stock in the country. In the Department of Environment and Climate Change's 'Heat and Energy Saving Strategy Consultation'

In the UK, domestic buildings account for over 25% of national carbon emissions.

Dramatic reductions in carbon emissions are required to meet Government targets.

(DECC 2009a), the Government proposes policy that would by 2030 provide all homes access to a 'whole house' improvements package including all cost-effective energy saving measures, and by 2015 access to loft and cavity wall insulation. In this proposed programme, 400,000 homes would be upgraded for energy efficiency annually by 2015 and 1.8 million homes annually by 2020.

This reduction of emissions from the domestic built environment can be seen in the context of the 'Medium abatement scenario' given by the Committee on Climate Change showing a reduction of roughly half of CO_2e to 310 $MtCO_2e$ by 2030 (Figure 10, overleaf). Further reductions of roughly 200 $MtCO_2e$ would be required to meet 2050 emissions targets (CCC 2010). An alternate context for emissions reductions is shown in Figure 11 (overleaf), which positions reductions against the Committee's 'Medium abatement,' its 'Extended ambition' scenario, and its 2050 target reduction.

Under the Government's targets, 400,000 homes would be upgraded annually by 2015 and 1.8 million annually by 2015.

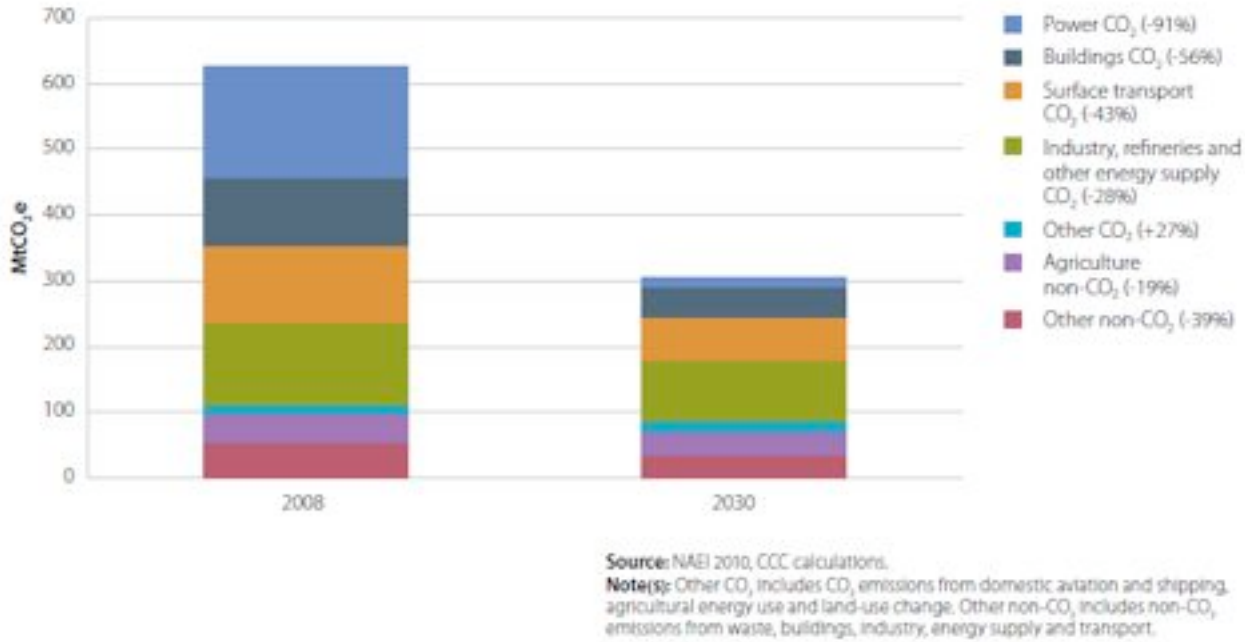


Figure 10: Medium abatement scenario: sectoral emissions reductions achieved by 2030 (NAEI 2010, as cited by CCC 2010)

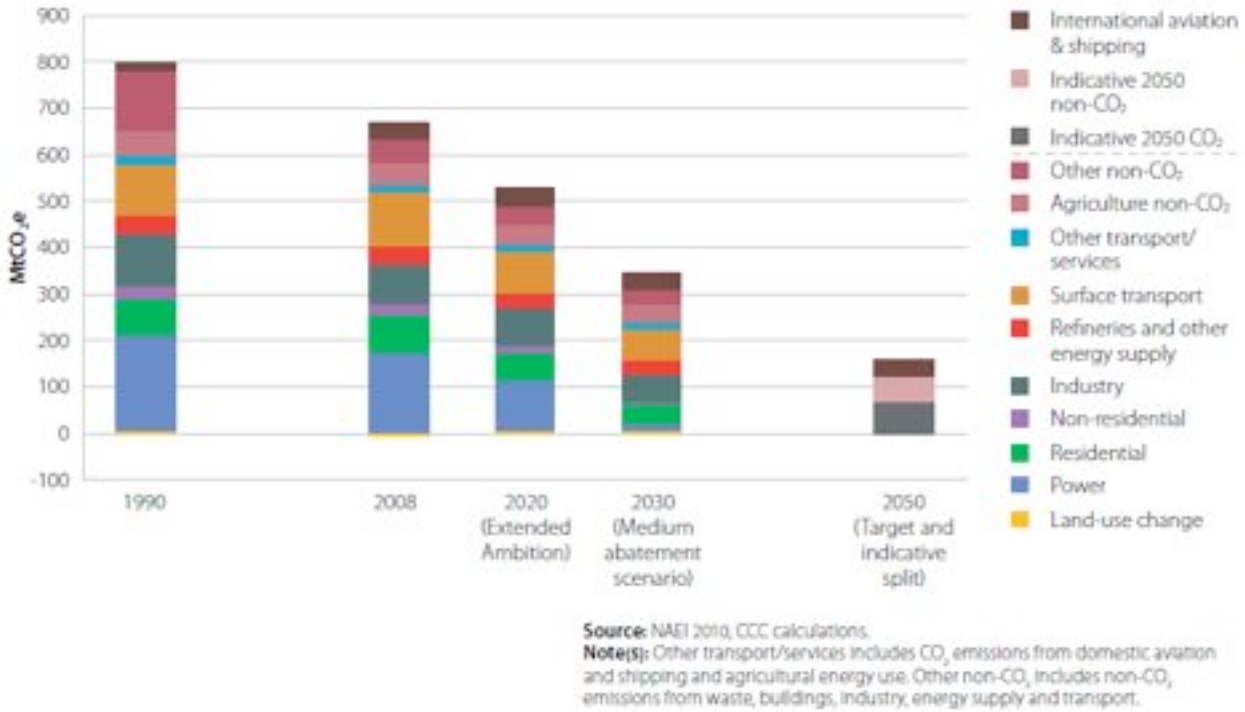


Figure 11: Scenarios for UK greenhouse gas emissions from 1990 to 2050 (NAEI 2010, as cited by CCC 2010).

1.1.8 A hierarchy for reducing building-associated CO_2

So many approaches are available for reducing the CO_2 associated with a building that it is often difficult to pick the most sensible approach. By adopting a pragmatic view as to what can realistically be achieved with available resources, and by making decisions which are informed by an educated perspective, an appropriate strategy for reducing CO_2 and energy use can be selected.

One very useful hierarchy for the decision making process is the often-cited "lean, clean, green" maxim. This describes a strategy which aims to reduce energy use as a first approach, followed by ensuring that energy use is efficient, and finally by introducing new green technologies.

It is important that interventions are carefully planned and designed. In many cases, the simplest and lowest-cost solution may have a net effect equal to or better than complicated and expensive solutions. For instance, reducing temperature set-points in homes or causes of energy waste will generally be preferable to installing photovoltaic panels or a new boiler. By evaluating the energy use of a home against this hierarchy, CO_2 savings can be made in a logical order starting with the most cost-effective and lowest impact solutions.

Consider the "lean-clean-green" hierarchy when making decisions about energy efficiency.

"...reducing temperature set-points in homes or causes of energy waste will generally be preferable to installing photovoltaic panels or a new boiler."

1.2 Heat Losses & Gains in a Dwelling

Heat is lost from a dwelling via a number of mechanisms. The principle multiplier of all losses is the temperature difference between internal and external air temperature. The rate at which it is lost is largely dependent on the following factors

- The amount of air entering the building either

The principle factor of heat less in a dwelling is the difference between internal and external air temperatures.

through ventilation or infiltration via gaps in the building fabric

- The difference between internal and external temperatures - Since winter conditions usually govern the design of dwellings in the UK, it is normal to assume the temperature difference is positive
- The insulating properties of the building fabric elements; walls, windows, doors, roof and floors.

1.2.1 Ventilation

Building regulations require that a certain volume of fresh air must enter a dwelling each hour in order to help maintain a healthy indoor environment and to ensure adequate provision for removing moisture from a dwelling. Kitchens and bathrooms require mechanical ventilation because of the high vapour content from cooking and showering etc. Most dwellings will have vents in the walls or windows in every other room.

The losses due to this ventilation is dependent on

- The volume of the dwelling
- The air change rate; the number of times per hour that the air in the dwelling is replaced by fresh air
- The difference between internal and external temperatures
- The specific heat capacity of air

Ventilation losses can be calculated using the following formula

$H_v = Cp*\rho*q_v*\Delta t$ **Equation 1**

Where:
H_v = Ventilation Heat Loss (W)
Cp = Specific Heat Capacity of air (J/kg/K)
ρ = Density of air (kg/m^3)
q_v = Rate of air changes (m^3/sec)

The rate of heat loss from a building is controlled by the insulating properties of the building, the amount of air entering the buildings, and principally, the difference between internal and external temperatures.

Adequate ventilation is necessary, but also results in heat loss

Mechanical ventilation with heat recovery (MVHR) systems can be used to prevent heat loss.

MVHR systems must be considered against actual energy savings in use.

Δt = Difference in outside and inside temperature (Creaney 2008).

Some of the heat energy can be recovered using mechanical ventilation with heat recovery. This works by recovering heat from the exhausted stale air and using it to pre-heat the incoming fresh air. Discussion of the various types and operation of mechanical ventilation are outside the scope of this paper but may warrant further investigation from the reader, should they wish to know more.

While ventilation represents a large heat loss, it is essential to the health of the occupants and often to the structural health of the building and as such is necessary and must never be mitigated by blocking vents or any such similar actions.

1.2.2 Infiltration

Infiltration losses, not to be confused with ventilation, are also from fresh colder air entering a building but the difference being, they are uncontrolled and unwanted. They can be in part because of poor workmanship, materials or aging. Examples of areas where there might be problematic infiltration include

- Poorly fitting doors and windows
- Attic access hatches
- Cat-flaps

Infiltration losses can be calculated using the following formula

$H_i = Cp*\rho*n*V*\Delta t$ **Equation 2**

Where:
H_i = Heat loss due to air Infiltration
n = No. of air shifts (1/sec)

'Infiltration' is the uncontrolled flow of air into a building.

Many homes have high levels of unwanted infiltration.

Infiltration can be a major source of energy loss.

V = Volume of a room (m^3) (Creaney 2008).

Infiltration can be a major energy loss, particularly in older buildings and because of this, particular attention has been paid to examining this issue during this research.

1.2.3 Fabric Losses

The building fabric can be thought of as anything which separates the inhabitants from the external environment. This can be walls, windows, doors, the roof or the ground floor. The rate at which heat is lost depends on the insulating properties of the building elements.

U-Values are a measure of the rate of heat energy transmitted through a building element and expressed in watts per square metre per degree difference ($W/m^2/K$). The lower the U-Value, the better the building element is at retaining heat energy.

'U-Values' are used to represent the rate of heat energy transmitted by an element.

U-values can easily be calculated using a simple formula and commonly-available data sources for material properties.

Fabric Losses can be calculated by using the following formula

Fabric heat loss, $Q_f = U*A*\Delta t$ **Equation 3**

Where:
Q_f = Fabric Heat Loss (W)
U = U-Value ($W/m^2/K$)
A = Area of building fabric (m^2)
Δt = Difference between outside and inside temperature

The simplest way of improving the U-Value of a building element is by adding insulation. This can be easily done in some parts of a building, such as the roof and more difficult in others, such as walls. Improving the U-Value of windows and doors usually means replacing them although sometimes, secondary glazing may be fitted. Ideas for improving the U-Value of a building element are explored in more detail in 'Solutions', Section 3.4

1.2.4 Thermal Bridging

Thermal bridging occurs when materials of poor insulating properties are used adjacent to materials with good insulating properties. This forms a path of least resistance for heat energy to escape the building. Typical thermal bridging includes window and door frames, wall ties and structural beams.

Thermal bridging can often cause large differences in surfaces temperatures and can lead to surface condensation. They can be a significant heat loss, the SAP assessment (Standard Assessment Procedure) assumes 15% of fabric losses, and understanding their effects is complicated as their effect is multi-dimensional relative to the adjacent building materials and while examination of their exact impact is not conducted here, some solutions have been provided.

Thermal bridging can be accounted for by application of the following formula

$H_{TB} = \Sigma(L*\Psi)$ **Equation 4**

Where:
H_{TB} = Transmission heat loss co-efficient for thermal bridges
L = Length of occurring bridge (m)
Ψ = Linear thermal transmittance (W/m*K)

Linear thermal transmittance is usually given as a factor per unit length of the bridge and should be added to fabric losses when calculating the overall transmission losses of a building. Exact information of values for thermal transmittance is often not readily available usually in an audit situation, such as SAP assessments it is more usual to apply a factor to the whole building to account for thermal bridging rather than calculate each of them individually

Thermal bridging is an important concept to understand when renovating.

Energy is lost through paths of low-resistance across the building fabric.

(Creaney 2008). This factor can be reduced by using accredited robust detailing.

1.2.5 Heat gains in a building

Ironically, windows which form one of the largest fabric losses in a building can also facilitate one of the largest gains. Sun entering a building can be a significant source of heat energy. The effect of solar gains can be quite high particularly in winter, when the sun is lower but is largely dependent on orientation. Southerly facing glazing is preferable in the northern hemisphere. Although changing glazing orientation is rare in refurbishment works, understanding the positive effect solar gain can have warranted its discussion here. The average solar gain per day through windows and glazed doors is given by

$G_{solar} = 0.9*Ag*S*g\infty*Z$ **Equation 5**

Where:
G_{solar} = average solar gain (kWh/m^2 day) for orientation of glazed opening
0.9 = Ratio of typical average transmittance to that at normal incidence

A_g = Area of glazing (m^2)
S = Solar radiation on a surface for relevant orientation (kWh/m_2 day)
$g\infty$ = Total solar energy transmittance factor of the glazing at normal incidence
Z = Solar access factor (% of sunlight not obstructed)

(Creaney 2008)

Gains include energy from the sun, occupants, and domestic appliances. The heating potential of these gains can be much more important than many homeowners realise.

There are other sources of internal gains that serve to reduce the heating load in a building such as the inhabitants, their activities and electrical devices. People give off heat and the amount of heat they give off increases with activity. So too do electrical devices such as computers, TV's and refrigerators. Lighting also gives off heat; modern efficient light bulbs give off less heat but the energy savings through their use is far more preferable to the heat gains that are lost. Quantifying these effects can be difficult but some average values are given in CIBSE Guide A environmental design (CiBSE 2007). Although the focus in the guide is office buildings, useful values can be found.

Chapter 2 – Background Research

2 Background research

Each of the 18 Theory and Practice of Sustainable Design students worked individually during the first episode of research to study topics covering the full gamut of issues related to sustainability related to Penarth. Much of this work has served to form a foundation for the domestic energy efficiency study presented in this report. Key facets of this work are summarised in this chapter.

In addition to this information, further background for the research in this report is presented here, covering occupant behaviour, comfort, practical issues to do with renovations, awareness campaigns, conservation and fuel poverty, with a look at available grants and incentives in Penarth.

2.1 Penarth

Penarth is a small town in the Vale of Glamorgan just 8km's to the south west of central Cardiff (Figure 12, overleaf). It is the second largest town in the Vale next to the administrative centre of Barry. Historically, a busy port for the coal industry and more recently a seaside destination, it is now largely a satellite town for commuters working in Cardiff. Despite having a good rail link to Cardiff, there is still an issue with overuse of cars in the area and traffic problems are significant, particularly at rush hour times of day.

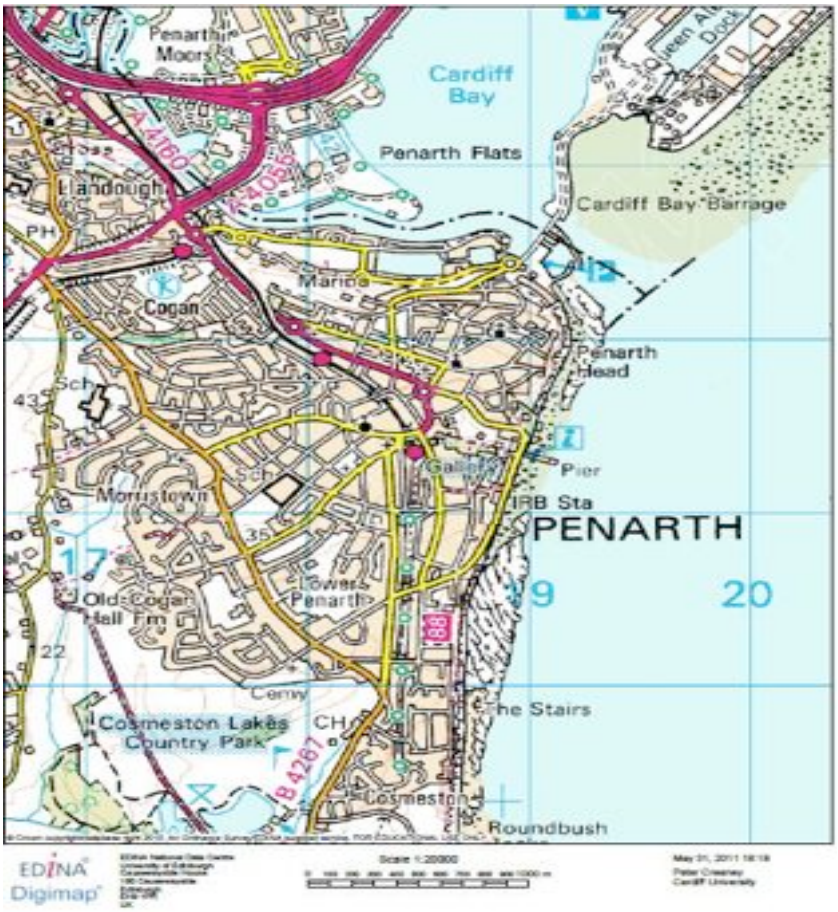


Figure 12: Map of Penarth showing proximity to city of Cardiff (Edina digimap, 2011).

During Episode 1 of the research, class members examined a number of subjects in relationship to the potential for sustainability in Penarth, including research on the physical barriers to transportation due to topography and an in depth analysis of demographics in the area. Penarth has a population of roughly 23,000 residents, comprised of 14 Lower Super Output Areas. In Figure 13 (overleaf), the percentage of each council tax band is shown for each of the LSOA. (Close, Hayes et al. 2011).

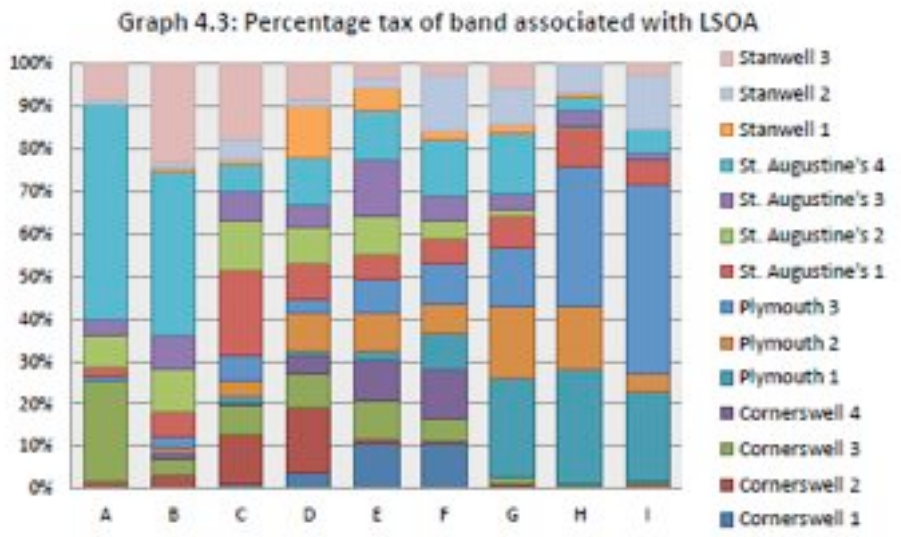


Figure 13 - Council Tax Bands versus LSOA. Source: Close, Hayes &Morris, 2011.

The town has a wide cross section of housing typologies of varying levels of operational efficiency.

The National Statistics Office reports a similar proportion of occupancy being held by owner-occupants, private renters, local authority tenants, and housing authority tenants across the Vale of Glamorgan (Appendix L). The mode council tax band for the Vale is Band C, with sizable percentages of dwellings falling into tax Bands D, E, and F (Appendix L). Episode 1 research behind this report examined housing typologies and determined a mix of dwellings, primarily of Victorian, Edward, Post-War and Late 20th Century dates. The profile of dwelling types includes large numbers of terraced and semi-detached houses, with small sections of the town comprised of detached houses and apartment buildings. Further details of the profile of dwellings in Penarth can be found in Alexander et al., 2011.

The mode council tax band for the Vale is Band C.

Understanding the profile of houses and domestic buildings in Penarth will allow effective campaign strategy. Look for ways to make messages relevant to as many people as possible.

2.2 The role of occupant behaviour

As building practices improve and the heating systems

become more and more efficient there is often still a large gap between predicted and actual performance. How much of domestic energy consumption is a direct result of behavioural influences? While the relationship continues to be examined at commercial scale, there is still relatively little known about occupant behaviour and its influence on energy consumption at a domestic scale.

(Gill, Tierney et al. 2010)(Gill, Tierney et al. 2010)Wood and Newborough suggest that *"whilst behavioral change is a major untapped route for energy savings, the varying knowledge, attitudes, and abilities of occupants presented a fundamental barrier to its implementation and optimization"* (2003, as cited by Gill, Tierney et al., 2010).

Traditionally however, the domestic construction sector rarely stipulates performance measurement (Gill, Tierney et al. 2010) and so meeting strict technical standards is not incentivised. Gill et al. go on to suggest that poor understanding of how occupant behaviour influences energy demand, means aspirations for low or zero carbon homes are unlikely to be fulfilled.

Even if a building is well insulated, has appropriate heating systems and controls and low energy lighting and appliances throughout, it is still up to people how they use their homes and whether or not they adapt low carbon lifestyles.

Further to this is the question of why some interventions are more readily adopted and why. For the purpose of this paper, we shall only consider 'interventions' as improvement works to the dwelling or its heating system. (Crosbie and Baker 2010) presented two key questions on the matter.

1. Why householders shun energy-efficiency interventions that are economically viable, simple and well understood?
2. Why expensive and difficult energy interventions can be more popular with householders than relatively cheap and simple interventions?

The authors go on to describe how
"It is vital to understand energy-efficiency interventions from the participants' perspective. It does not matter how much energy hypothetically could be saved by 'green' housing developments or energy-efficient heating and lighting systems if the energy-efficiency measures are unwanted" (Crosbie and Baker 2010 pg 71)

Their research suggested that environmental concerns played a rather minor role in the acceptance of interventions. They found that the key deciding factors were monetary savings from the interventions and how the interventions fit within their existing lifestyle expectations and tastes. They suggest that

- promoting energy-efficiency interventions in terms of abstract environmental issues is likely to be ineffective
- promoting energy-efficiency intervention in terms of the direct benefits they can bring to participants lifestyles is likely to increase participation
- energy-efficiency interventions must be aesthetically pleasing, stylish and fit with current lifestyles and practices if a significant level of participation is to be achieved

It is essential that this be considered when developing a

"Whilst behavioral change is a major untapped route for energy savings, the varying knowledge, attitudes, and abilities of occupants presented a fundamental barrier to its implementation and optimization."

(Wood and Newborough 2003)

Why are some inventions more readily adopted than others?

"It is vital to understand energy-efficiency interventions from the participants' perspective. It does not matter how much energy hypothetically could be saved by 'green' housing developments or energy-efficient heating and lighting systems if the energy-efficiency measures are unwanted."

(Crosbie and Baker 2010 pg 71)

campaign for improvements. While certain members of society will of course make improvements based on a sense of social and environmental responsibility, it would seem that the best way to frame the benefits of energy efficiency upgrades to occupants is in terms of the economic benefits. Behind closed doors it would seem; everybody is doing the sums. Energy efficient improvements can add value stability and resale value to a home and this is perhaps the best way to 'sell' the idea of energy efficiency upgrades to Penarth residents. The importance of maintaining a positive perception of the interventions is also noted, as is the importance of realising those expectations during the interventions. This may come in the form of lifestyle improvements, such as increased thermal comfort (Crosbie and Baker 2010). This idea is discussed further in the section 'Rebound Effect'. The importance of addressing the issue of user expectation was critical in ensuring that the users had a positive experience and would recommend the intervention to others. They concluded that

- Information regarding energy-efficiency interventions should contain realistic expectations and be clear, concise and easily available
- greater efforts need to be made to design domestic energy-efficiency interventions and technologies to fit the lifestyles and tastes of young adults and non-traditional family units

The way in which we receive and act on information is highly complex and outside the scope of this paper however, it can be observed that decision making is the result of a combination of experience, education and information (Schweiker and Shukuya 2011).

No matter how many sustainable strategies are integrated into a dwelling, it is up to inhabitants to adopt a low carbon lifestyle

For many the best way to frame the benefits of energy efficiency upgrades to occupants is in terms of the economic benefits.

Energy efficient improvements can add value stability and resale value to a home.

User expectation is critical in ensuring that the users have a positive experience and would recommend the intervention to others.

"…environmental concerns played a rather minor role in the acceptance of interventions."

The way in which people process information and receive messages is highly complex.

2.3 Interacting with utilities

How occupants interact with their utility bills and information provided can have a large influence on their energy consumption behaviour and emissions. At the moment, consumers get bills based on estimated usage for most of the year with a reading an adjustment once or twice a year. With most utility companies, it is possible to provide their utility company with meter readings they took themselves. The utility company will still take readings periodically but taking regular readings ensures accurate bills and a clearer understanding of the influence of their behaviour by linking experience and memory with real-time feedback about energy use. Currently, billing includes information about current consumption in kWh's but not information on how this relates to carbon or historic consumption. While this may change in the near future, we would encourage GPG and Penarth residents to consider developing a spread-sheet for collecting the information from billing to allow residents to monitor and compare bills in an aim to identify a bespoke strategy for reductions. Further to this, we would encourage all Penarth residents to contact their energy suppliers and ask questions about the carbon content or the availability of 'green' tariffs.

Being able to monitor and compare bills can have a large influence on their energy consumption behaviour and emissions, and allow for bespoke reduction strategies

Contact energy suppliers and ask questions about the carbon content of their fuel mix or the availability of 'green' tariffs. Consider asking for improved consumption breakdown on bills or smart-metering.

2.4 The Rebound Effect

An issue that requires careful consideration is the potential for rebound effects arising from improved energy efficiency. Research has shown that there is often an energy 'take back' after improvements have been made. This is sometimes referred to as 'Jevon's Paradox' (Vale and Vale 2010). Jevon argued that the efficient use

of fuel tended to result in an increase in the consumption of that fuel.

"It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth." (Jevons 1866) cited in (Vale and Vale 2010 pg 853)

It can occur that with heating system improvements or fabric upgrades, people expect a higher level of comfort and increase their energy consumption in order to provide it, thus undoing the effectiveness of the improvement works. Any subsequent campaigns from GPG about the value of improvements should include a strategy to mitigate the likelihood of this happening. In the case of the suggested 'efficiency champion' (see Section 4.4.1), we would suggest that when explaining the effective operation of the heating controls, they also take the time to explain to occupants that they with correct operation they should reduce their consumption while maintaining the *same* level of thermal comfort.

With heating system improvements or fabric upgrades, people expect a higher level of comfort and increase their energy consumption in order to provide it, thus undoing the 'efficiency' provided by the improvement works.

Teaching people about heating system operation could realise substantial energy savings.

2.5 Comfort in the home

One of the most interesting aspects of the physical testing activities in Penarth was the high average internal temperatures observed in most of the homes. We installed temperature loggers in six homes in Penarth In some cases, temperatures in bedrooms never dropped below 18°C during monitoring, and the mode of average internal temperatures was 21°C. Although these figures have not been corrected for external weather data, they do give an idea of the temperatures people have become used to in recent years. Nationwide, average internal

Nationwide, average internal temperatures are reported to have risen between 1970 and 2000 from 13℃ to 18℃.

temperatures are reported to have risen between 1970 and 2000 from 13°C to 18°C (DTI 2007a).

Comfort in the home is governed by several factors including air movement, surface temperatures, air temperatures and humidity. While it is beyond the scope of this exercise to examine them all in great detail here due to their complex relationship with both occupants and each other, the high internal temperature coupled with the majority of respondents answering that they were at a comfortable temperature is an area for examination. Turning the thermostat down by 1°C has been shown that it could save as much as 10 per cent on heating costs without having a detrimental effect on comfort.

2.6 Smart Metering & Home Energy Management Systems (HEMS)

Smart meters are devices that measure energy consumption, usually electrical energy and usually at hourly intervals and relay this information back to utility companies and convey it to occupants. An example of various methods of displaying energy feedback is shown in Figure 14: Types of feedback from HEMS. Source: Hargreaves, Nye et al. 2010. This allows suppliers to manage the grid more effectively. These devices display real-time consumption and cost figures, and there is evidence that they tend to reduce household consumption; however, the extent of this effect is debated (Stevenson and Leaman 2010).

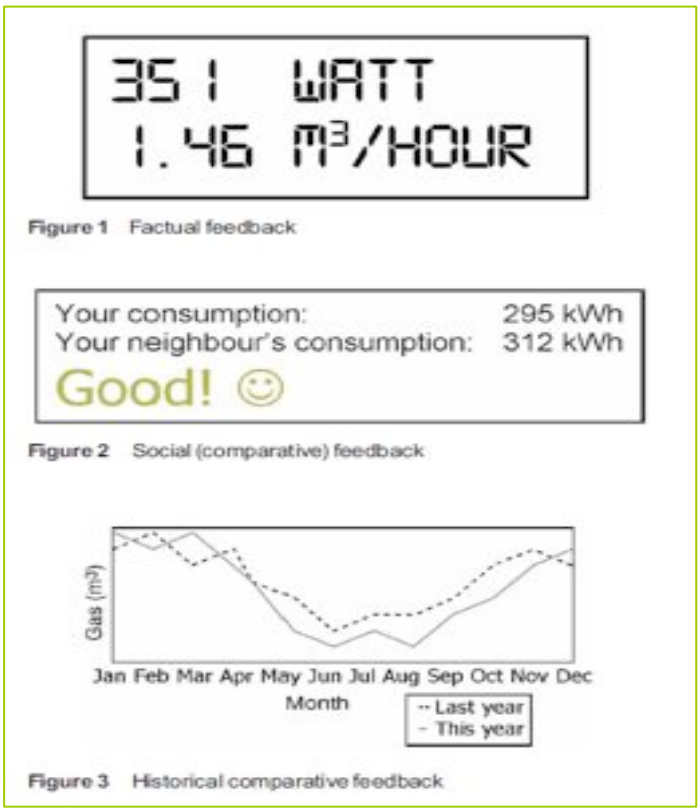


Figure 14: Types of feedback from HEMS. Source: Hargreaves, Nye et al. 2010

In December 2009, the UK Department for Energy and Climate Change (DECC) announced they would be rolling out smart metering to every household in the UK. They also announced that this would be accompanied with real time displays of consumption to each home (Hargreaves, Nye et al. 2010). This follows the statement in the 2007 Energy White Paper that, "[The Government's] expectation is that within the next 10 years, all domestic customers will have smart meters with visual displays of real-time information that allow

communication between the meter, the energy supplier and the customer" (DTI 2007b, p. 64). The document also states that,

> *We therefore propose that, from May 2008 and where technically feasible, every household having electricity meter replaced and every newly built domestic property will be given a real-time electricity display, free of charge… In addition, from as soon as possible in 2008 to March 2010, any household requesting a real-time display for their electricity meter should be given one free of charge by their energy supplier.*

In a press release dated 30 March 2011 (DECC 2011b), the Government announced the timetable for the installation of 53 million smart meters in 30 million homes and businesses in the UK; the rollout is expected to start in early 2014 and to be completed in 2019. Predictions from the Government are that this programme will deliver carbon reductions of up to 0.5 MtC (DECC 2007b).

Home Energy Management Systems (HEMS) are slightly different in that they offer both real time information and the means to manage that information. In its simplest form this is using the information to adjust the use of appliances and at its more advanced by using the interface to directly control appliances. Although less common, similar systems are available for heating systems. They may be worth installing if refurbishment works are being undertaken as they do require a level of disturbance to install; they are connected directly to the ring mains or gas supply. There are arguments for and against the use of such systems in the home and (Stevenson and Leaman 2010 pg 438) argue that, "The inflated claims made by

Turning the thermostat down by 1°C could save as much as 10 per cent on heating costs.

Smart meters measure energy consumption, relay this information back to utility companies, and visually convey it to occupants

These devices display real-time consumption and cost figures, and there is evidence that they tend to reduce household consumption.

The Government supports the installation of 53 million smart meters in 30 million homes and businesses by 2019.

Home Energy Management Systems (HEMS) offer real time information, but also the means to manage energy use.

some about smart metering and home energy-management systems leading to energy reduction have not been substantiated, so more caution is needed when advocating it."

While it remains to be seen just how effective the use of these technologies will be when they are rolled out in full, it is important to acknowledge their presence in the future of the management of the national grid and household energy alike.

2.7 Building Physics and the implications of improvement works

When designing a strategy for improvements, careful consideration needs to be given to how the occupant will experience the space after the works and the impacts on the physics of the indoor environment. As discussed in an earlier chapter, thermal comfort is the result of a complex combination of influences and their relationship should be understood at the very least, at a basic level. While a detailed analysis of the implications of every improvement scenario is beyond the scope of this work, a couple of short examples are presented to illustrate the importance of understanding building physics.

Several small less expensive measures may result in larger savings in energy use than more expensive solutions that do not pay attention to these relationships. For example, insulating the walls without replacing the windows can lead to large differences in surface temperatures which can lead to a feeling of discomfort. This, in turn usually leads to increased energy use as occupants increase set point temperatures to compensate.

Following on from this, the increase in air temperature

A strategy for improvement must consider occupancy and interaction with the physical environment.

Insulating walls without replacing windows can lead to large differences in surface temperatures which can lead to discomfort, surface condensation and damp problems.

and cold surfaces could lead to surface condensation and damp problems. To a certain extent this type of problem is not as prevalent in older buildings; usually the poor airtightness means there is sufficient air infiltration to deal with the excessive moisture.

When adding insulation to the loft area, careful detailing is required to ensure adequate ventilation is still being achieved for the roofing members. Covering up soffit vents with insulation *could* lead to a build-up of moisture in the roof structure going unnoticed until it has caused damage. While, it would be irresponsible to suggest these scenarios will always occur if said improvement works are undertaken, they serve to illustrate an important point too often ignored.

When insulating lofts, adequate ventilation of roofing members must still be provided to avoid build-up of moisture in the roof structure.

2.8 Renovation Infrastructure and Wider Economic, Social and Environmental Issues

When embarking on any renovation or improvement works, it is important to address a number of wider issues. In this section we shall attempt to give a brief summary of some of the more critical considerations.

2.8.1 Materials

All renovation works will require at some point for a decision on the type of materials to be used. Upgrading the thermal performance of a building is a relatively straightforward task, save perhaps for the disruption it can cause but understanding the wider issues is more complex. Understanding mechanical properties of a material is often the first step undertaken. In terms of insulation materials, this is usually the conductivity (the rate at which it transmits heat energy) and the density

Information showing carbon footprints of most building materials is readily available. Contact organisations like the Carbon Trust for assistance.

(has a direct influence on the 'response' to heating). Usually, potential solutions are made based on these criteria and cost. There should however be wider economic, social and environmental criteria built into the decision making process

Understanding that there are very often many choices for building materials is the first step in making more informed and sustainable decisions. The carbon footprint of an insulating material is quite complex and requires an understanding of supply chains, material properties, resource extraction processes, how they are transported to site and indeed the skills and equipment required for their correct application. Appendix F contains a report on the carbon foot-printing of two competing insulation materials should you wish to examine the issues in more detail. Any remedial works undertaken in Penarth must first consider the availability of locally sourced materials and their suitability for application. Using locally sourced materials will reduce environmental impact of these works as there is less carbon emitted in transportation. It also garners relationships within the community and improves resilience against market instabilities for local businesses. This simple decision of sourcing locally where available addresses the 'three pillars' of sustainability; economic, social and environmental. One must also consider the expected lifespan of a product and what happens with that material at the end of its use. While this is perhaps the realm of construction professionals, being conversant with the principle is an important point for the end user if Penarth is to ensure sustainability. Similar materials can vary greatly in anticipated lifespan and potential for re-use and this can impact heavily on their environmental performance.

Understanding that there are very often many choices for building materials is the first step in making more informed and sustainable decisions

The carbon footprint of an insulating material is quite complex and requires an understanding of supply chains, material properties, resource extraction processes, how they are transported to site and indeed the skills and equipment required for their correct application

Using locally sourced materials reduces environmental impact.

Consider:

- the expected lifespan of a product

- what happens with that material at the end of its use.

2.8.2 Skills

Employing local tradespeople where possible has several benefits similar to those from choosing local materials. Less travelling time for those on site means reduction in emissions. It also serves to further strengthen the economic situation in the area by encouraging the movement of funds throughout the area and improve local employment. There is also the opportunity for education in the community through these works and may encourage local young people to take up crafts based career. People may also consider a co-operative approach to some of the simpler jobs. If a member of the community is proficient at installing loft insulation for example and another in decorating, there is the chance to improve social cohesion by trading skills.

2.8.3 Waste

"No other sector of industry uses more materials and energy, produces more waste and contributes less to material recycling than the building industry"

(Hegger 2008)

The waste hierarchy is to prevent, reduce, reuse and recycle before considering sending a material to landfill (Thorpe 2010). Effective site management will mean that careful calculations of what is required are undertaken and the reuse of as much material as possible is given priority, bearing in mind a material that has reached the end of its life for its intended purpose may be fit for a new life as something else. This is sometimes known as down-cycling. For example, timber roof members may need to be replaced but the old ones could be used in garden furniture. If a material is of no use anywhere on-site then it must be recycled appropriately.

Employing local tradespeople encourages the movement of funds within the area and will increase local employment.

Encourage local young people to take up vocational enterprises as career

Less travelling time for those on site means reduction in emissions.

"No other sector of industry uses more materials and energy, produces more waste and contributes less to material recycling than the building industry"

(Hegger 2008)

The waste hierarchy (Thorpe 2010):

1. Prevent

2. Reduce

3. Reuse

4. Recycle

5. Landfill

This approach should also be taken when sourcing materials. Looking in local trade advertisements and websites such as www.gumtree.co.uk or www.preloved.co.uk for surplus and second hand materials will help close the material 'loop' and reduce environmental impact although it is important to give consideration to the carbon emissions required to get them to site as mentioned in the above section. (Thorpe 2010) outline the priority that ideally should be applied when making material selections

1. second hand/reusing;
2. recycled materials
3. renewable or local, new materials
4. new materials from further away

Reusing materials will generally use far less energy than recycled materials which usually require processing, transportation and water use.

Designing for deconstruction may also help close resource loops at the end of the buildings useful life. While it may not be an option on all refurbishment works, careful consideration of standard material sizes and fixing details can have the desired effect. Screws are more easily reused than nails for example.

In terms of waste handling and management, waste from site should be carefully separated in order to ensure it can readily be recycled and no unnecessary materials go to landfill. Try also to consider that some packaging waste such as cardboard is compostable and could be disposed of on-site (Thorpe 2010). Natural materials are by their nature biodegradable or combustible and should be given preference; assuming of course, they have been responsibly sourced.

Designing for deconstruction reduces waste over long timespans.

Priority for material selection (Thorpe 2010):

1. Second hand/reusing

2. Recycled materials

3. Renewable or local materials

4. New materials from further away

Upgrading buildings has significant implications for waste production. People should be encouraged to manage the production of waste during construction.

Encourage the selection of environmentally friendly materials during renovations.

Background information supporting this report can be found in Alexander et al., 2011.

The choice of paints and finishes should be addressed too; preference should be given to paints with low VOC content and ideally breathable where possible. Floor coverings including carpet underlay often have more environmentally friendly alternatives and preference should be given to these where possible.

2.8.4 Building regulations

Building Regulations (HM Government, 2010) are increasingly strict and although it could be argued that they have a narrow focus on energy consumption and are largely based on theoretical rules, their recent extension to existing buildings is critical in getting the building stock to an appropriate level of efficiency. As of 2006, regulations governing refurbishment of existing buildings with relation to energy conservation were introduced in 'Conservation of Heat and Power' Approved Document Part L1B; new buildings are covered under Part L1A. A number of other sections of the Building Regulations may apply to efficiency-related works including most notably Part F (Ventilation) and Part N (Glazing). Part L 1'Accredited Construction Details' (DCLG, 2007) is a document produced to support compliance with Part L1. Part L1B covers extensions, renovation of a "thermal element" (providing work affects 50% or more of the element or 25% of total building area), or change of a "control service" or "controlled fitting," or a "material change of use" (HM Government 2010).

Building Regulations L1A and L1B address 'Conservation of Heat and Power' when working in new and old buildings (respectively).

2.9 Awareness, communication, campaigns

Various forms of awareness campaign have been reviewed in the research leading to this report. A large amount of

research into communication and campaigning was undertaken in Episode 1 research and can be found in the reports written by Creaney and by Forman, in Alexander et al. (2011). This presents conclusions which are central to the foundations of the research presented in this report. Discussion in Chapter 4 of this report discusses concepts for the development of communication and campaign strategies based on the Episode 1 research. The reader may wish to review the report on this background research.

Central themes of the Episode 1 research findings included the integral nature of message framing and media strategy to successful communication. It examined approaches to motivating campaign audiences by 'outcome framing' and creating a positive and collective dialogue around campaign issues. The concept of 'opinion leaders' and critical mass development was also an important finding of the research. Discussion of the merits of bottom-up approaches to building community participation was central to the development of the research that is presented in this report. This drew attention to the vital nature of inclusion in building dialogue and in motivating people to action. Finally, the research focused on media strategies based on repeated messaging and the use of varied approaches to reach the broadest possible audience.

Looking to the successes and failures of campaign formats can provide GPG with useful guidance in carrying forward their own campaign within Penarth. There is also a great deal of academic literature which applies methods of social psychology research to understand these successes and failures. This summary of the background research

'Outcome framing' and creating a positive and collective dialogue around campaign issues are effective tactics.

Look to 'opinion leaders' and understand critical mass development will help to build a campaign.

Bottom-up approaches help to build community participation.

Repeated messaging and the use of varied approaches reach the broadest possible audience.

Look to lessons learned from past campaigns in Penarth (and elsewhere).

presented in this section is intentionally brief. Because this research has already been presented in full, this summary is designed to simply inspire the reader to examine the Episode 1 report in full (see Alexander et al. 2011).

We believe that to affect change in domestic energy efficiency within Penarth, it is important to develop considered strategies as an integral part of designing campaigns and communication approaches. Recognition of the difference of perspectives of Penarth residents will ensure information and support is delivered in formats appropriate to recipients. In light of this, it will serve campaign organisers to fully acquaint themselves with their campaign audience and appreciate the importance of bottom-up strategies of fostering community participation.

"Recognition of the difference of perspectives of Penarth residents will ensure information and support is delivered in formats appropriate to recipients."

2.10 Conservation issues

The current established Conservation Area boundary within Penarth can be found in Appendix 15. It is important to establish the parameters and constraints when advising on physical alterations to properties within a protected historic environment.

Any physical alteration to the fabric of a building to reduce its carbon emissions will have an effect on the appearance of that property. Some alterations will have a lesser effect on the 'historic character' than others, and these are judged by heritage specialists within the Government and it's advising Bodies.

Any works considered to a listed building or to a structure within the Conservation Area should be discussed and

Any works in a listed building or a structure within the Conservation Area should be discussed and approved first by the Conservation Team at the Vale of Glamorgan Council before implementation.

Most property owners will know if their property is protected under 'Listing' but many may not know if it lies within the Conservation Area and what implications this may hold.

approved first by the Conservation Team at the *Vale of Glamorgan Council* before implementation to avoid damage to Penarth's cultural heritage and potential for prosecution to property owners and/or design consultants.

2.11 Fuel Poverty

The three pillars of sustainability cover the environment, its people, and economy. In recent years, more focus has been made to design schemes that do not just effect one, but all of these issues. One of these covers the topic of fuel poverty – often defined as the concept of spending more than 10% of household income on energy costs (Boardman, 1991). Many governments have now acknowledged and are now actively trying to alleviate this issue as well as extreme fuel poverty, which increases the boundary to 20% of the household income. It is a desperate situation in some cases, but tackling the issue improves the well-being of a household, the financial situation, and also, because most of the strategy focuses on improving the building fabric of a house in order to reduce its energy demands, which also reduces its carbon emissions, it helps reduce the building's impact on the environment.

Fabric efficiency, energy prices, and the household income are the three factors that affect the potential for fuel poverty (Department of Trade and Industry, 2007).

Fabric efficiency covers passive design aspects of a building that dictate its performance. Since retrofit is the only option, strategies such as orientation and south facing windows may not be able to be implemented, but what the strategies do use are efficiency upgrades of

If a property under discussion is identified as Listed or within the Conservation Area, further information on implications of works carried out to the property can be found in the background report which accompanies this document (Alexander et al., 2011)

Fuel Poverty can be defined as spending more than 10% of household income on energy costs.

existing elements. Improving the efficiency of a wall or other building element to resist the flow of heat through insulation and draught proofing for example is a common mechanism used. In buildings built over 100 years where a common building composition was solid stone wall and single insulation, the performance can be extremely inefficient (Department of Energy & Climate Change, 2009). Upgrades, however, can be very expensive, and those in fuel poverty may not be able to afford to do these upgrades by themselves. Fuel costs combine the fuel requirements of a household and the costs of fuel at the time, as opposed to what may actually be spent on fuel. The cost per unit of fuel required uses regional data split by payment type, put against available data for fuel prices (DECC, 2010). Household income combines the total income of a household, but also any benefits received by any individuals or by the household. These include any state, or housing benefits (BERR, 2008). The level of fuel poverty is calculated using a ratio where a household is considered to be in fuel poverty if this ratio is higher than or equal to 0.1 (Welsh Assembly Government, 2010):

"Fuel poverty ratio = fuel costs (usage x price) / income"

According to the Department of Energy and Climate Change (2010), the proportion of households in fuel poverty in 2008 was considerable (Figure 15).

Tackling fuel poverty improves the well-being of a household, the financial situation, and also helps reduce the building's impact on the environment. This relates to social, economic, and environmental aspects of sustainability.

Fuel Poverty factors:

- Fabric efficiency: passive design aspects of a building

- Energy prices: fuel requirements of a household and the costs of fuel at the time

- Household Income: total income of a household, but also any benefits received by any individuals or by the household itself.

"Fuel poverty ratio = fuel costs (usage x price) / income"

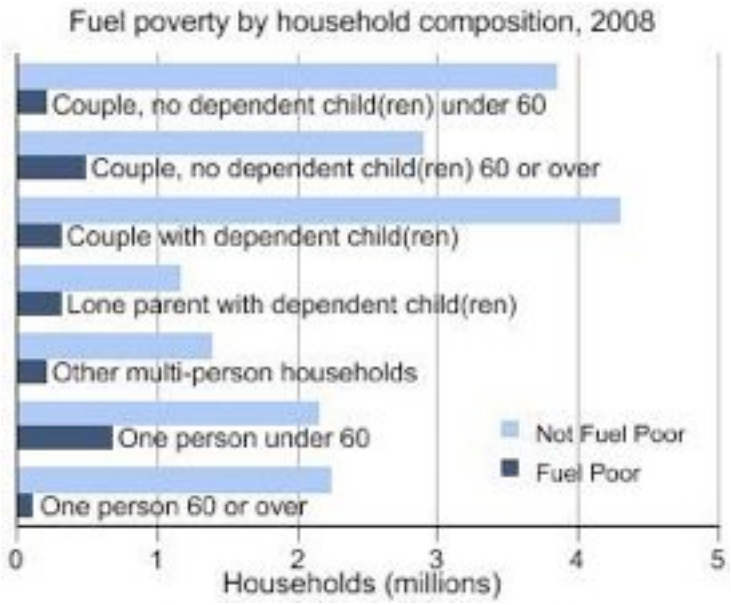


Figure 15: Annual Report on Fuel Poverty Statistics (DECC, 2010).

The Fuel Poverty Strategy sources its statistics from the "National Survey for Wales" (Welsh Assembly Government, 2011), energy price and household income information. It is similar to the strategy in England but updated less frequently. This can affect the accuracy, and thus validity of some results, which adds to the inaccuracy caused by the estimations that the surveys themselves are based on.

One of the issues with schemes such as this is awareness, and so one of the steps of the scheme is to establish a referral network with relevant information and advice centres (such as social housing providers, local Arbed businesses, the Welsh Assembly Government, and third sector organisations) to supply all information, regardless of who an individual goes to. The idea is that with more awareness comes more demand, which will put pressure on efficient supply, which in turn should help lower energy prices. Effort is made to get the information to those who need it while looking at more ways to increase efficiency, keeping household consumptions low, and doing all possible so that eligible owners claim benefits (Department of Trade and Industry, 2007).

Fuel poverty strategy:

- Two- way referral network

- Cooperation from stakeholders

- Maximise income through enterprise and benefits

- Help people pay less for energy

- Improve fabric performance of homes.

According to the Department of Trade and Industry (2007), numbers of households in fuel poverty had reduced from 6.5M in 1996 to 2M in 2004, but progress was challenged by the 35% fuel price increases that followed, putting another 1.2M households into a state of fuel poverty (Figure 16).

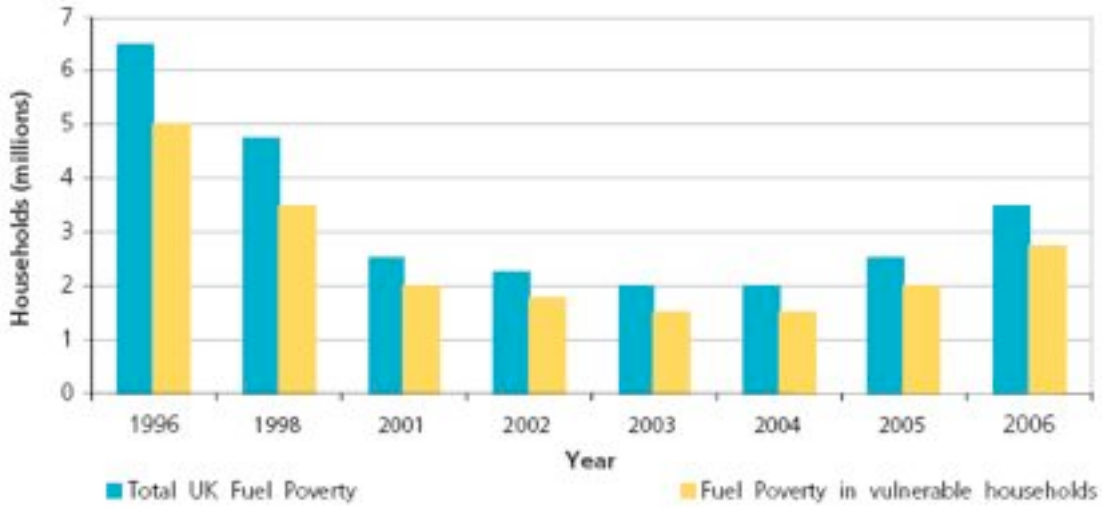


Figure 16: UK Fuel Poverty Statistics (Defra, 2008)

Effectiveness of the scheme has also been affected by those who do not take advantage of benefits, those in extreme fuel poverty (Osmond, 2011) where it is difficult to raise the energy efficiency to a sufficient level, and the fragmentation of programmes that already offer upgrades to households.

The Fuel Poverty Scheme in Wales has the target that "no household in Wales will be living in fuel poverty by 2018" (Welsh Assembly Government, 2010), and this includes Penarth. They aim is to counter fuel poverty, create green enterprise, and reduce the domestic greenhouse emission levels (Fuel Poverty Charter Wales, 2010) which directly address social, economic and environmental sustainability issues. These benefits will directly affect Penarth through two-way referral networks, having cooperation from stakeholders, maximising on income through enterprise and benefits, helping people pay less for energy, and improving fabric performance of homes in Penarth (Welsh Assembly Government, 2010).

"No household in Wales will be living in fuel poverty by 2018"

(Welsh Assembly Government, 2010)

Fuel Poverty Scheme aims:

-Counter fuel poverty

-Create green enterprise

-Reduce environmental impact

2.12 Grants and Incentives

With global warming, carbon emissions and renewable energies being high on government agendas, many grants and incentives have been implemented to promote and sustain green lifestyles in order to benefit not only the individual or community, but as part of the national and international attempt by countries to reduce the impact that people are having on the environment. In the process, they help sustain a stable economies and societies where individuals and communities live in better performing homes, and even start generating their own renewable energies. A simple place to start if looking for grants and incentives is the Energy Savings Trust Grants and Discounts Database (2011) in which one can input a postcode and follow the steps at the end of which, a list of available grants and discounts will be available.

Many grants and incentives are available to defray the costs of upgrading properties. The availability changes over time, a simple place to start looking is the Energy Savings Trust Grants and Discounts Database.

2.12.1 Feed-In Tariff (FiT)

Energy suppliers have been paying households, landlords, businesses, organisations and small communities that produce energy from renewable or low carbon energies up to 5 megawatts (DECC, 2011) since the scheme started on April 1st, 2010 (Energy Savings Trust, 2011). Coverage under the Feed-in Tariff include sources such as wind, photovoltaic, hydro and anaerobic digestion. These tariffs pay for the electricity produced, even if it is used by the household, giving a bonus for electricity given back to the grid. On top of that is a reduction on the standard electricity bill due to the energy produced by the household itself (Feed-In Tariffs Ltd, 2011).

The Feed-in Tariff (FiT) pays a premium for electricity produced from wind, photovoltaic, hydro and anaerobic digestion (in <5MW installations).

2.12.2 Renewable Heat Incentives (RHI)

This UK incentive seeks to help build a low carbon economy by phasing out the use of fossil fuels with renewable heat to help meet the UKs targets (DECC,

The Renewable Heat Incentive aims to create a low carbon economy by phasing out the use of fossil fuels with renewable heat to help meet the UKs targets (DECC, 2011e).

2011e). Figure 17 shows the small proportion of overall energy consumption in the UK represented by renewables.

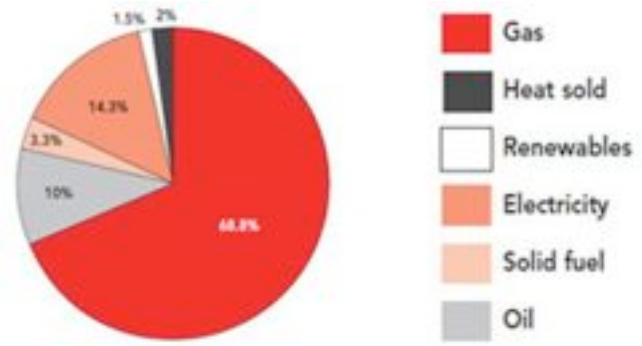


Figure 17 - Analysis of Energy Consumption UK Data. Digest of UK Energy Statistics (Department of Trade and Industry, 2008)

In the first phase, the non-domestic sector was targeted first to make the most cost effective impact, but quarterly Renewable Heat Premium Payments will be introduced in July 2011 to pay households that install renewable heating from them, who in return, are asked to give feedback on the effectiveness of the equipment. Phase 2 will begin in 2012 where all households (including Penarth) using fossil fuels to heat their homes are eligible, and will be supported by the long-term tariffs introduced in the next stage of the incentive to bridge the gap between the costs of conventional and renewable heating systems (DECC, 2011e).

2.12.3 Home Energy Savings Programme (HESP)

11million lower income and pensioner households qualify for part of the £1 billion being spent to make up to £300 of savings on bills through insulation and energy efficient devices. Also, a community energy saving programme in 100 fuel-poor areas will offer central heating, efficiency measures and benefits to those who need it (HM Government, 2008). The Energy Savings Trust offers free

The RHI will pay premiums to households who install renewable heating technologies.

The Home Energy Saving Programme (HESP) offers up to £300 of savings on bills through insulation and energy efficient devices.

"The Energy Savings Trust offers free advice, and measures for household energy efficiency improvements are paid for by energy suppliers."

advice, and measures for household energy efficiency improvements are paid for by energy suppliers under the scheme (Energy Savings Trust, 2011).

2.12.4 Carbon Emissions Reduction Target (CERT)

This responsibility for this incentive is on gas and electricity suppliers and transporters with more than 50,000 customers as part of the Climate Change and Sustainable Energy Act (2006), to save energy by helping customers to apply energy efficiency measures in their homes, and thus make lifetime CO2 savings of 293 MtCO2 by the end of 2012 and help meet UKs many energy targets as an approach to satisfy the Kyoto Agreement (United Nations, 1998). Because it is the suppliers and transporters as a whole that hold the responsibility to reach their targets, most households will qualify (DECC, 2008), and any grants or offers do not have to be from a households specific supplier. However, more attention is paid to regeneration areas such as the Penarth Central Renewal Area (Vale of Glamorgan Council, 2010). Also, as part of the CERT scheme, many companies and suppliers are now able to offer subsidized insulation; companies such as 'Wickes', 'British Gas' and 'Npower' are already involved.

2.12.5 Decent Homes Standard

This is part of a larger strategy for regeneration covering social homes, neighbourhood renewals and sustainable communities through a mixed communities approach. A decent home is one that meets minimum standards for housing, is in a reasonable state of repair, has reasonably modern facilities and services, and provides a reasonable degree of thermal comfort (Department for Communities and Local Government, 2006). Homes that do not meet these criteria are eligible for the scheme. Because social

CERT is part of the government targets to reduce carbon savings through energy efficiency measures in homes by 293 MtCO2 by the end of 2012.

More attention is paid to regeneration areas such as the Penarth Central Renewal Area.

Many companies and suppliers are now able to offer subsidised insulation.

A decent home […] meets minimum standards for housing, is in a reasonable state of repair, has reasonably modern facilities and services, and provides a reasonable degree of thermal comfort (Department for Communities and Local Government, 2006)

homes are owned by the council, they will survey the home s under their management and see what improvements may be necessary. Common upgrades may include insulation, a new bathroom or kitchen, or wiring around the home (Directgov, 2009).

2.12.6 Arbed (Wales)

This is an energy performance investment programme that addresses; environmental issues by increasing the efficiency of households to reduce CO2 emissions; social issues by tackling fuel poverty levels in Wales; and economic issues by creating jobs and opportunities for Welsh businesses in the development of energy efficiency and renewable energy technology (Welsh Government, 2007).

With regards to homes, the first phase of the project targets social housing providers for fuel poor and low income households, and so, inhabitants are often informed of what the council will be doing to the property at no cost to the tenant (Warm Wales, 2010). Deprived communities and regeneration areas are targeted and individual households owned by the council or housing associations receive a whole-house approach to identify the most appropriate measures for that specific property (Swansea Council, 2011). These measures may range from photovoltaic cells or insulation, to heat pumps or changing fuel type, but efficiency measures such as insulation come before micro-generation such as solar thermal, as part of its energy hierarchy.

2.12.7 Nest - Welsh Assembly Government Programme

Nest replaces the Home Energy Efficiency Scheme (HEES) in Wales as of April 2011 as a response to fuel poverty (Torfaen Homes, 2011). British Gas offers measures such

Arbed (Wales) aims to:

- increase the efficiency of households to reduce CO2 emissions

- tackle fuel poverty levels in Wales

- create jobs & opportunities for Welsh businesses.

Households owned by the council or housing associations receive a whole-house approach to identify the most appropriate measures for that specific property.

Nest eligibility:

- privately owned, rented

- receiving means-tested benefits

- SAP rated F or G for energy efficiency.

as draught proofing, boiler replacement and insulation, as partners to Nest. Domestic properties in Wales that are privately owned, rented, or receiving means tested benefits are eligible if SAP (Standard Assessment Procedure) rated 'F' or G'' for energy efficiency (UK Energy Saving, 2011). Buildings most likely to be 'F' or 'G' rated are those which have no central heating, un-insulated hot water cylinders, single glazed windows, little insulation, solid exterior walls and no draught proofing (DECC, 2009b). The Nest website has an advisor form that would have to be filled in, after which, an advisor will inspect the property if it qualifies (Nest Wales, 2011).

"Buildings most likely to be 'F' or 'G' rated are those which have no central heating, un-insulated hot water cylinders, single glazed windows, little insulation, solid exterior walls and no draught proofing."

2.12.8 Warm Front

April 2011 marked the re-opening of the Warm Front scheme after a brief suspension, with the aim to assist over 90,000 of the poorest households in Wales by installing heating and insulation measures worth up to £3500 (£6000 if oil central heating and alternate technologies are advised) to those that need it, over the next 2 years (DECC, 2011f). Households already receiving income-related benefits, are poorly insulated, have no central heating and owned by an individual or a private landlord are those that will qualify for the scheme (Directgov, 2009a). Applications can be made online (EagaGroup, 2011). Successful applicants will receive a technical survey by a Warm Front engineer, followed by the allocation of a Warm Front installer, who will perform the installation work. Random inspections may then be randomly performed to check the effectiveness (Directgov, 2009b).

Warm Front was recently re-launched to assist more than 90,000 of the poorest households in Wales.

The scheme will cover installing heating and insulation measures worth up to £3500 to those that need it, over the next 2 years.

Warm Front eligibility:

- Households already receiving income-related benefits

- poorly insulated

- no central heating

- owned by an individual or a private landlord.

2.12.9 Welsh Housing Quality Standard (WHQS)

This initiative has the target of bringing social housing in Wales up to the Welsh Housing Quality Standard and will

cost around £4billion by committing local authorities into the scheme. The standards were implemented to help reach the vision outlined in "Better homes for people in Wales" (2001), which cover a household's state of repair, safety and security, fuel efficiency, suitability to any disabilities and other minimum standards. The initiative affects local authorities, which are required to establish the state of housing stock, estimating the scope, assessing necessary programmes to achieve standard, do a consultation with the tenant on the proposed programme, and implement this repair or improvement (Welsh Assembly Government, 2002). The business plan is then updated to include the consultation and improvements, and then will follow, reviewing and monitoring.

The Welsh Housing Quality Standard aims to bring houses up to the "Better homes for people in Wales" standard through:

- state of repair

- safety and security

- fuel efficiency

- suitability to any disabilities

2.12.10 Welsh Declaration on Climate Change & Energy Efficiency

300 councils have already declared their commitment to fighting against climate change by committing to either the Welsh Declaration on Climate Change and Energy Efficiency, or England or Scotland's equivalents (Welsh Assembly Government, 2005). By signing, they commit to prioritising issues of climate change into community strategies, help in the drive for sustainability by supporting and encouraging awareness and implementation of environmental, social and economic sustainability, and take necessary action to rectify any current deviations from this initiative. This means that councils will actively pursue initiatives and schemes such as those mentioned here, that will help alleviate fuel poverty, and raise the quality of life of communities in Wales.

Under the Welsh Declaration on Climate Change & Energy Efficiency, councils commit to prioritise issues of climate change in community strategies and to encourage awareness and implementation based on all aspects of sustainability.

2.12.11 Boiler Scrappage Schemes

Boilers can be condensing, combination, system or open vent boilers. They have a substantial impact on a

household's consumption and CO2 emissions (Energy Savings Trust, 2011), but the efficiency is what dictates its performance. This can be influenced by age and type, so it would be advantageous to confirm this before any work is done. Old boilers over 15 years for example can be less than 70% efficient and rated G, or over 90% efficient for A rated boilers. Because of high interest, the government's boiler scrappage schemes are ending with all vouchers already allocated in England and Scotland as well as Wales. However, inquiries can be made for application for a specialist boiler scrappage expert who is matching or improving on the government scheme per area code in UK (Boiler Scrappage Scheme, 2009). Failing this, individual suppliers such as 'British Gas' (Boiler Scrappage Scheme, 2009), 'Eaga Heat', 'Npower Hometeam' and 'Swalec' are still offering their own scrappage schemes (Energy SavingsTrust, 2011), as well as Welsh Gas Heating who are also implementing a scheme for Welsh inhabitants (Welsh Gas Heating, 2011).

Boilers older than 15 years can be less than 70% efficient and rated 'G'.

New boilers over 90% efficient are 'A' rated

The Government's boiler scrappage scheme has now ended, but may be re-launched in future.

Private suppliers still offer similar schemes

Chapter 3 – Work in Penarth

3 Work in Penarth

This chapter presents the practical work carried out in Penarth. Opportunities for further development of this work as well as the obstacles to this development are discussed throughout the chapter.

One of the most significant elements of the discussion that emerged from background research for this project was the importance of communicating issues of climate change and influencing individuals to engage with it. Members of the Domestic Energy Efficiency Group felt that the Penarth community could capitalise on the research of issues of sustainability being undertaken on the course, particularly if it were communicated to them effectively. A significant amount of thought was given to how best sustainability, and more particularly energy consumption, could be communicated to the Penarth community and how members of the community as individuals and collectively could be supported in understanding the issue and inspired to act in response to it.

A key theme of the Episode 1 research investigating communication and campaigning was positive message framing. There is broad support for the concept that individuals are more likely to engage with a message and respond proactively to it if communication is made 'positive.' This approach entails underscoring the ability of message recipients to 'do something' in response to an issue. It focuses on inspiring change rather than threatening the listener or scaring them. Many reports exist which show that listeners are likely to dissociate themselves from frightening messages. Equally, they are more likely to engage with an issue if the positive

Communicating messages regarding climate change and sustainability is best done having conducted research into successful techniques and models.

Although different members of an audience will be receptive to a variety of approaches, research shows that people can most effectively be reached by framing messages in positive terms and presenting outcomes of actions, not inaction.

Stress the ability of an audience to do something in response to an issue.

People are likely to dissociate themselves from frightening messages.

outcomes of action are delineated and they are made to feel that their actions can have influence.

Episode 1 research also focused on making climate change – a truly global scale problem – relevant at a community and individual level. A common response to climate change found in reviewed research was that individuals felt incapacitated by the scale of the problem. It was the intent of the Domestic Energy Efficiency Group to delineate ways to make individuals feel engaged and capable of action in response to climate change.

At the scale of an individual and his or her house, there are many ways to improve one's sustainability. As delineated in Section 1.1.2, energy efficiency has implications for a broad number of elements of sustainability. In addition to addressing environmental sustainability, campaigns to encourage increased uptake of efficiency measures should be designed to highlight the broader context of sustainability. Additionally, in the format and design of the campaigns themselves, they should strive to support social fabric, and local and sustainable economic structures.

How can you make climate change – a truly global problem – relevant to an individual or a community?

How can you engage people? Will you use different strategies for reaching receptive audiences than disinterested ones?

Energy efficiency has implications beyond environmental decline.

Potential benefits of efficiency to local businesses and tradespeople, household budgets, and skills development are just a few examples of social and economic benefits discussed in this report.

3.1 Testing

We reviewed several concepts for how to relate the relationships between building fabric, occupant behaviour and energy efficiency to individuals. A principal obstacle to individuals taking action to improve the energy efficiency of their homes is a clear understanding of available pathways to that improvement and access to information. This sentiment is echoed by the Existing Homes Alliance (2010a) in 'Moving consumers to action:

Recommendations to Government for Creating Demand for the Green Deal':

> *Consumers themselves report a lack of clear, concise and freely available information as being a barrier to them taking action. People do not know what is being asked of them or what the appropriate actions are for their home and situation, so they are often not confident enough to take any action.*

In response to this, there is an obvious need to provide homeowners with clear guidance. One component of this guidance seems very clearly to be information which enables homeowners to quantify the 'problem' which they are facing.

Most homeowners will have easy access to figures representing their energy consumption in the form of utility bills and usage meters. What is lacking for most people, however, is an equivalent quantification of energy efficiency. It is quite easy for people to come to grips with what they are using, but difficult to understand how they are using it and how some of this use could be curtailed. Our solution to this problem was to outline various physical testing methods which can be utilised to provide quantification of energy use or 'loss' in the home.

Although benchmark data are readily available about domestic energy consumption, research in Episode 1 had shown that the effectiveness of campaigns in community development and capacity building is often strengthened by being a function of the community *"… they must originate within the community, as a function of it, and be particular to the characteristics, needs and goals of the community"* (Barton, 2000, pg 164). This was a hugely influential factor in deciding to undertake physical testing

Homeowners often report a lack of information that would enable them to improve efficiency.

"Most homeowners will have easy access to figures representing their energy consumption… What is lacking for most people, however, is an equivalent quantification of energy efficiency."

in Penarth. It was felt that residents would more closely relate to information presented about domestic energy consumption if they could relate this information to their personal experience of the area. The role of peers and opinion leaders it was felt, could play an important role in garnering the requisite interest to make a campaign effective.

Further to this, preliminary research had indicated that case studies were an extremely effective way to communicate issues and inform decision making processes and not simply knowledge for knowledge's sake. "*There is nothing better than a vivid case study to communicate lessons learned and underwrite decision making*"(Leaman, Stevenson et al. 2010 pg 567). We felt that by monitoring and targeting efficiency in Penarth homes, it would show the wider community that something *can* be done to improve the efficiency of their homes.

The combination of ideas presented above and the desire to be present in Penarth and seen so as to raise awareness by drawing attention to the research, underwrote the decision to undertake physical testing. It was felt that monitoring buildings in Penarth would send a positive message about the benefits of action focused work.

> *Building evaluation monitors performance to discover and then try to solve problems. This is not knowledge for its own sake, but knowledge with results aimed at helping designers and managers make more informed decisions to help improve the building being studied and, of course, to spread the knowledge further to improve future buildings.*
>
> -(Leaman, Stevenson et al. 2010 pg 565)

In motivating people to adopt new behaviour, it is important to recognise the importance of peers partaking in similar action, and of the positive effect of 'opinion leaders.'

Developing efficiency case studies is an extremely effective way to communicate messages and influence people.

Building evaluation not only discovers and helps solve problems; it also helps communicate lessons aimed at improving efficiency.

We examined a variety of testing methods which apply to different elements of energy use. We selected tests on the basis that they were reasonably simple to implement, that the required equipment is readily available, and that collectively they addressed a wide range of energy sinks present in the domestic built environment. These tests were selected strategically as the cross section of testing and evaluation measures examined the impact on energy use as a result of building fabric, occupant behaviour, and services efficiency.

It is important to understand the implications of conducting monitoring exercise on dwellings. It is implicit that something will be done about any shortcomings found. Excessive monitoring without action may leave participants disappointed or disenchanted. While it was beyond the scope of our research in Penarth to provide advice to individuals, although it did at times stray into this, any monitoring done by GPG or subsidiaries in the future should be mindful of what may be expected. Any subsequent monitoring exercises performed by GPG should be about solving problems, not just gaining knowledge.

The methods of testing that we employed were as follows:

- Blower Door Testing
- Thermal Transmittance Testing (Flux Plate)
- Temperature Logging & Comfort Diary
- Thermo-graphic Imaging
- Tracer Gas Decay Testing
- Visual Survey
- Utility Bill Analysis
- SAP Assessments

We selected tests that were simple to use, readily available, capable of addressing a range of energy sinks, and generally affordable.

"Excessive monitoring without action may leave participants disappointed or disenchanted."

"…subsequent monitoring exercises performed by GPG should be about solving problems, not just gaining knowledge"

Each of these methods is described in the following sections alongside discussion of their strengths and weaknesses. It should be noted that a multitude of options are available for investigating energy sinks. Testing methods such as the co-heating heat loss test, neutral buoyancy balloon infiltration tests, dew point testing, hot-wire anemometry, particle streak velocimetry, delta-q duct flow analysis and acoustic methods of testing permeability were reviewed in brief during background research but were not employed during our testing and are not presented here. These methods were deemed either inappropriate or too difficult to carry out given the limitations of equipment and time. They also represent less commonly used approaches; as our intent was to convey information about easily employed methods of investigating energy use; we chose not to use these methods.

A multitude of testing methods can be used in buildings. We employed just a few.

3.1.1 Comfort Diaries & Temperature Logging

The difference between internal and external temperatures (ΔT) in a domestic setting, is the multiplier of all energy loss in the home. The researchers wanted to explore the relationship between internal temperatures and perceived thermal comfort. Logging the temperature in a building by use of logging thermometers enables temperatures to be tracked at high resolution (we tracked at five minute intervals though any interval can be used). These temperatures were examined for trends and compared to the results of a 'comfort diary' completed by the occupant. By doing this, varying notions of thermal comfort can be documented.

Temperature logging is a simple and affordable technique that is very effective in highlighting behaviour with regard to heating.

The link between interior temperature and factors including comfort, clothing, and activity level can be shown using comfort diaries alongside temperature logging.

Thermal comfort is a complex idea influenced by many factors (Fanger, 1982) including

- Ambient air temperature
- Surface temperatures
- Speed of air movement
- Relative humidity (RH)
- Clothing resistance
- Activity level

While examination of the relationships between each factors and their influence on domestic energy consumption could warrant an entire report on its own, a short scenario is presented in an effort to demonstrate its complexity.

If surface temperatures have a difference greater or equal to 3°C of the air temperature, convection currents and air movement increase which can lead to a feeling of discomfort (Keller and Rutz 2010). This in turn can lead to energy intensive behaviour such as increasing set point temperatures. While this is a hugely simplified example, it gives an idea of the importance of user comfort and its relationship to domestic energy use.

Temperatures are generally accepted to be the biggest contributing factor in user perceptions of comfort (CiBSE 2007) and as such were chosen for examination. They are also the easiest thing to monitor as they require relatively simple equipment that is largely unobtrusive to householders under examination. In order to make a relationship between the recorded temperatures and the occupant's perceived comfort, it was decided that the participants would be asked to keep a thermal comfort diary. An example of those used is provided in Appendix B. With the use of questionnaires or surveys, there is almost

Understand the importance of temperature variation in creating draughts. Draughts can often be the result of convection currents rather than leaks in a wall or window as if often believed.

Be sure to give a great deal of attention when writing questionnaires or surveys to make sure they will reflect data accurately.

Discretion should be used and efforts should be made to ensure participants are not offended or made to feel uncomfortable. This is a commonly-encountered unintended consequence.

always the potential for criticism; they require discretion, trade-offs and judgement (Denscombe 2007)to be of any use which makes them vulnerable by their nature as a research method. The difficulty is in applying best practice whilst ensuring it is not too obtrusive or inconvenient for the participants.

A number of options were discussed including the potential for phoning participants and asking about their comfort at specific times so as to match as closely as possible the recorded temperatures with their feelings of comfort. It was decided that this was both resource intensive for the researchers and inconvenient for the participants. Asking the participants to record their feelings on diaries provided by the researchers three times a day over a short period was a sufficient exercise. While the participants were asked to record specifically the time for which they made an entry, this was not always completed. This meant using three hour averages for recorded temperatures and while this was not as robust as possible, it offered adequate data for examination.

Although the sampling was too small and the research project was too short (an average of four days in each household) for any depth of statistical analysis, the diary responses do provide a snapshot of the range of internal temperatures occupants were satisfied with. The responses also to indicate what would be possible with a great number of respondents. Research identified that the average internal temperature has been steadily rising in UK households since the 1970's (DTI 2009) and it was felt that identifying empirical evidence of this trend at play in Penarth would lend strength to any campaigns in Penarth that may focus on a strategy to reduce set point temperatures in the home.

When using comfort diaries, it is not possible to ensure forms are completed during the times stated. Consider a telephone survey instead. Although more resource intensive, it will be more precise and is likely to be more accurate.

A balance between available resources and robust data collection should be reached in determining monitoring period.

Analysis of results gives very useful information. Be careful that statistical analysis is based on legitimate data and is carried out correctly.

Be aware that many factors contributing to thermal comfort (or discomfort) are at play. Accounting for all of them may not be possible.

Figure 18 shows analysis of Question 1 of the comfort diary, completed by eight respondents over an average period of four days. Respondents were asked to complete the comfort diary between 9am-12pm, 12pm-6pm, and 6pm-9pm (whenever at home). A sum total of 44 responses to Question 1 were received from the respondents. The analysis compares responses to the question to the average temperatures recorded by temperature loggers (recording at 10 minute intervals). This is shown for demonstration purposes only. No correction is made for clothing, exertion levels, or outdoor temperature. The lack of participants in this research means that statistically representative studies in Penarth were not possible. With larger research groups, analysis such as that which appears in Figure 18 would be more statistically relevant. Notably, it would be interesting to see if the modal response for comfort (indicated by '3' on a 1-5 range) correlated with 21° C as it did in our research.

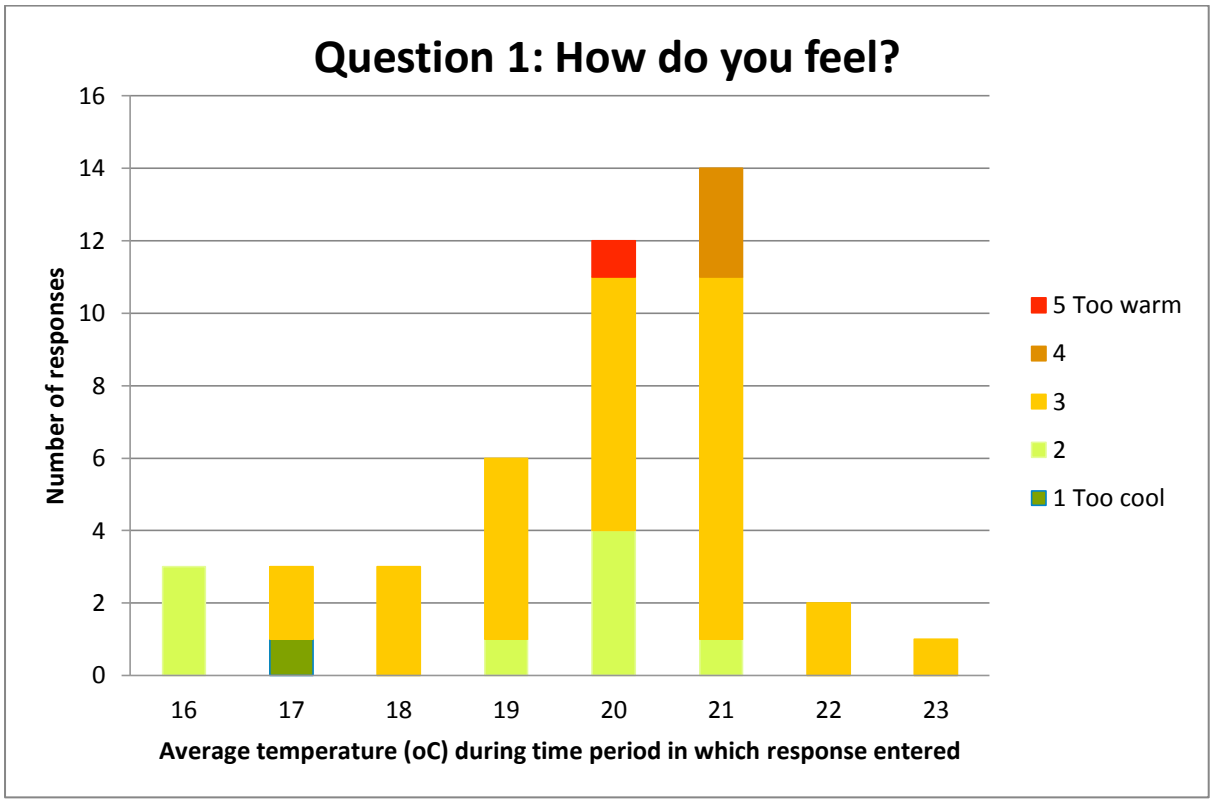


Figure 18: Statistical analysis of responses to question from survey correlated to average temperature during time period in which answer was provided. Note mode response of '3' occurs at 21° C. NB: results not statistically relevant due to low number of respondents.

It was noted that the pre-determined nature of the possible answers was frustrating for some participants who felt the diary did not adequately portray all potential contributing factors. One participant noted in conversation that they moved around a lot and tended to wear a cardigan inside and felt that this was not easily explained through the diaries although the researchers felt that they

had taken adequate precaution by including questions about clothing level and activity. But therein lies an issue with the use of such questionnaires, predetermined answers can bias the research findings towards the views of the researchers rather than the views the participants would like to express (Denscombe 2007).

3.1.2 Questionnaires used in conjunction with comfort diaries

Open-ended questionnaires were chosen in addition to the comfort diary in the hope that it might give a more personal input from the participants. It was felt that by asking open ended questions to participants about what *they* felt were important considerations for reducing energy consumption in the home, it might highlight areas that might potentially be missed by the research team. This was effective in highlighting the fact that energy consumption in relationship to fabric weaknesses varies from home to home and it would seem that for the most part, people have a good grasp of where the weak parts in their home are; this would suggest at least a basic understanding of where energy is lost in the home. It was interesting that nobody responded to questions about how they could reduce energy consumption by saying they could change their behaviour. It worth noting that there was a clear impression that technology rather than fabric improvements were the key to using less energy; it would seem people wanted less control over their environment and cited things like photometric light switching as an effective way of reducing energy consumption. While nothing can be inferred about the wider public through these few short questions with a limited response, it did help the researchers in identifying areas of further research and given the short amount of time demanded of both the research team and the respondents, this was a

Open-ended questionnaires can gather unique data from respondents.

Consider open-ended questionnaires to gather information you may not think to ask for.

"It worth noting that there was a clear impression that technology rather than fabric improvements were the key to using less energy…"

"…there is the potential for respondents to give what they feel might be the 'correct answer'."

very worthwhile exercise. It should be noted however, that there is no opportunity to probe further into the truthfulness of responses and there is the potential for respondents to give what they feel might be the 'correct answer'. This can be alleviated to a certain extend by explicitly telling respondents that the research requires opinion only and no correct answers exist but eliminating the risk entirely is impossible. In retrospect, asking these questions in person would probably have offered more insight as the researcher could gauge the respondents for signs that more probing questions may be required.

"In retrospect, asking these questions in person would probably have offered more insight as the researcher could gauge the respondents for signs that more probing questions may be required."

3.1.3 Blower-door test

A blower door test provides a measurement of the unwanted air infiltration in a building due to gaps in the building fabric. Not to be confused with ventilation, which is the fresh air you *do* want permeating your building, infiltration is the measure of unwanted air infiltrating the fabric. Assuming ventilation requirements have been met, which are essential to creating a healthy and comfortable environment, every cubic metre of air which escapes the building will be replaced by (generally) cooler air from outside. This additional volume of air has to be heated (during heating season) to the internal set point temperature and as such can be a significant consumer of energy. It can also lead to discomfort due to draughts which further exacerbates the problem when people use their heating systems for longer to compensate. Many people are surprised to learn that a typical house can lose about half the entire volume of air in the house per hour due to infiltration and often more (Energy Saving Trust, 2005). Figure 19 (overleaf) is an illustration of common causes of air leakage in dwellings.

The blower-door is a quick and reliable method of measuring air infiltration in a building.

"Many people are surprised to learn that a typical house can lose about half the entire volume of air in the house per hour due to infiltration and often more."

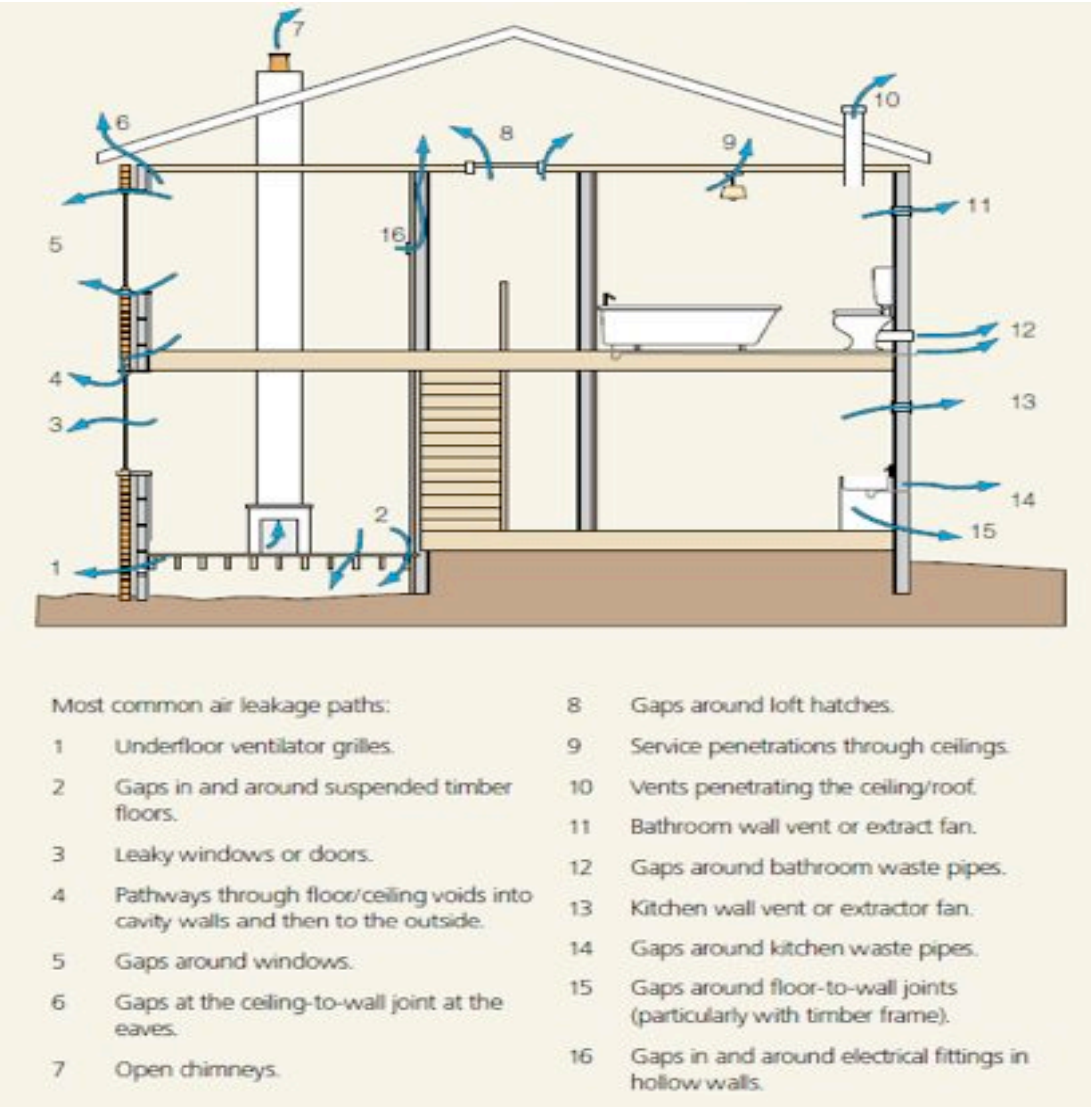


Figure 19: Common Air Leakage Paths. (Energy Saving Trust, 2005)

As building regulations improve and stricter targets for the conservation of energy are put in place, air tightness is becoming of increasing concern. To give an idea of the kind of levels

The procedure for testing a dwelling is outlined in numbered steps below

1. All ducts for ventilation and chimneys are sealed (this ensures the test is only identifying unwanted air infiltration)
2. A large fan in a tarpaulin is fitted to the front door of the house ()
3. The fan is then switched on the house becomes pressurised until the pressure differential is 50 pascals
4. Periodic readings are taken of ambient outdoor pressure, fan flow rate and internal barometric pressure

5. Building details are also recorded including internal volume and area of exposed building fabric.
6. These data are then fed into a formula to produce a result for the tested dwelling. Results are expressed as an air permeability index with units of $m^3/hr/m^2$ @ 50 Pascal. This figure represents the volume of air escaping the building per m^2 of exposed building fabric per hour while the internal space is pressurised to 50 Pascal. While this figure is notional and would never be experienced in normal operation, it is often expressed as air changes per hour due to infiltration by dividing the result by 20. While this is not exact, it is common practice for benchmarking.

An ISO standard exists which offers model procedure for use of the blower door test. (ISO 9972: 'Thermal performance of buildings. Determination of air permeability of buildings. Fan pressurization method'). This, as well as a wide variety of available literature, may serve as useful guidance when employing the test.

Table 2(data source: Energy Savings Trust, 2005) gives an idea of the typical results that should be expected. The lower the number, the more airtight the building is. Buildings with exceptionally good airtightness very often use mechanical ventilation.

Table 2: Air permeability values – best practice.

Air Permeability Index	$m^3/hr/m^2$
Building regulation requirements	10
Good practice	7
Best practice	3
Passive House standard	0.6

The authors carried out four air permeability tests using blower door equipment. The results are presented in Table 2: Air permeability alongside results from an alternative type of testing for the same issue, tracer gas decay testing, which is explained in the following section.

Blower door testing can be used as a monitoring and targeting exercise for identifying problem areas and the results can be used in SAP assessments for generating energy performance certificates. Air infiltration represents a very large energy expense in the home but it can often be tackled quite easily using inexpensive methods and materials such as draught-proofing doors and windows.

3.1.3.1 Limitations of blower door testing

The most obvious and well documented of limitations is the fact that the test simulates conditions that would never be experienced in normal building operation. Used as a tool to benchmark all buildings, one against the other, it is a valuable tool but perhaps not completely representative of actual building performance. This is partly because of what is known as 'valving'. Because the house is pressurised, it may create gaps that do not exist under normal barometric pressure. For example, pushing windows outwards from their frames to create a passage for air movement that does not normally exist.

During the testing, there were also issues with the equipment which largely went unexplained so results should be examined with the potential for equipment faults in mind. The use of the tracer gas decay testing validated them to a certain extent because the results were quite close (12% and 20% difference between tracer gas testing results and adjusted air permeability index from blower door testing in the two properties tested) but the lack of time afforded to the testing meant cross checking was impossible. A researcher from the Welsh School of Architecture led this testing and as such, the efficiency group did not have as much time with the equipment as they would have liked.

Buildings with exceptionally low infiltration typically require mechanical ventilation to supply adequate air quality. Heat recovery systems (MVHR) can be employed to conserve energy. Careful design of MVHR systems should ensure occupant behaviour does not grossly affect their performance.

Blower door testing measures infiltration at artificial pressure and corrects for this arithmetically.

3.1.4 Tracer Gas Decay Testing

Tracer gas testing measures exactly the same thing as a blower door test. The significant difference being that the infiltration rate is measured at normal barometric pressure and as such is far more representative of what happens in normal use of a dwelling. It is however, far more intrusive for occupants as they are required to vacate the property for a number of hours to do this test correctly. In the case of extremely airtight houses such as Passive Houses, this might extend to days. The air permeability is measured by raising the CO_2 significantly above ambient levels and the monitoring the time taken for the house to return to ambient CO_2 levels. These data can then be used to determine the air change rate under normal operation.

The test procedure is as follows

1. Outdoor CO_2 levels are recorded using a CO_2 monitor
2. The level of CO_2 in the dwelling is raised to approximately 2,500 parts per million (ppm) using canisters of CO_2 (a number of fans are placed throughout the house to ensure adequate mixing and limit the chance of having localised areas of increased CO_2)
3. The CO_2 sensor is attached to a data logging apparatus that records the level every 5 minutes
4. When the levels have been raised an appropriate amount, everybody must leave the dwelling for the duration of the test (it is not a dangerous level of CO_2 – about the same as a crowded lecture theatre – but having people breathing in the space would interfere with the results)

Tests showing air infiltration can be used to show the importance of draught-proofing doors and windows and all possible elements.

Many properties we visited had unsealed and uninsulated loft hatches – a significant source of heat loss.

Be careful that the limitations of blower door tests are understood.

Be sure to carefully inspect all testing equipment. As much as possible, ensure equipment is calibrated routinely.

Tracer gas decay testing measures infiltration at normal barometric pressure.

5. When the test is complete, the data points from the logger are imported into excel and the CO_2 levels (minus the outdoor ambient levels) are plotted against time intervals. This produces a decay curve as shown in Figure 20
6. Using a complex polynomial, these data are then converted to another straight line graph (Figure 21). The slope of this graph is the air change per hour rate of the building.

Complete guidance covering the use of tracer gas decay testing is provided in ISO 12569: 'Thermal performance of buildings and materials -- Determination of specific airflow rate in buildings -- Tracer gas dilution method.'

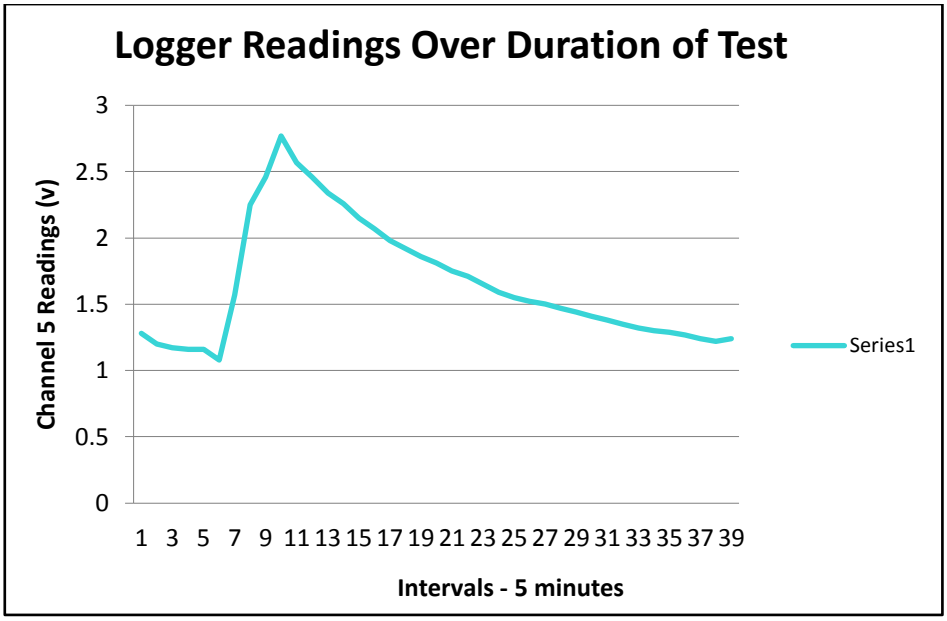


Figure 20 Tracer gas decay test logger readings registered at five minute intervals

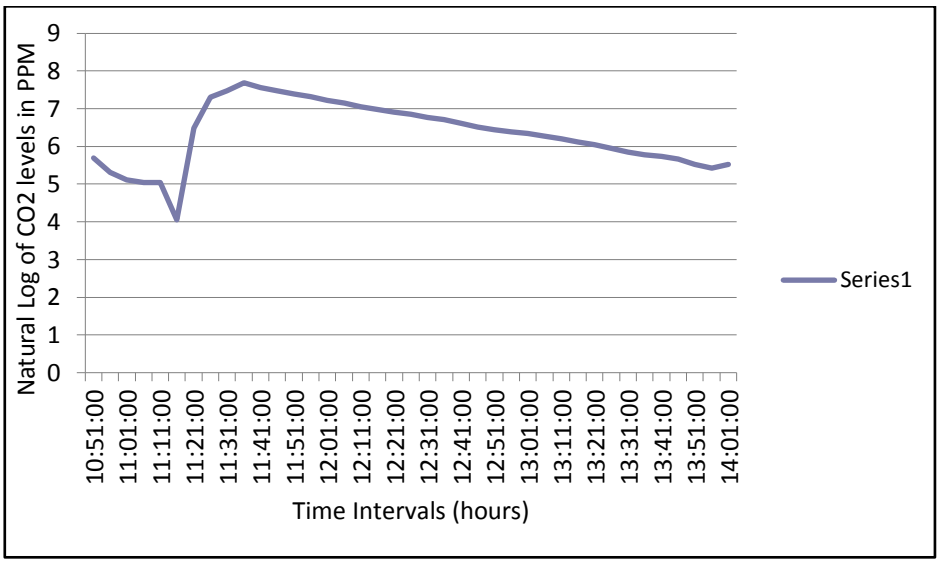


Figure 21 Tracer gas decay test results, showing slope indicating ach rate

3.1.4.1 Limitations of tracer gas decay testing

The main limitation of this testing is that it is quite intrusive in that it requires people to leave their homes for the duration of the test. In older properties, this might only be a few hours but in newer or better sealed homes, this could take considerably longer. People also seemed reluctant to have their homes filled with CO_2 despite assurances from the team that it was not to a dangerous level. The meter itself was also quite slow to respond to changes in levels, although newer equipment would not have this issue. The equipment available only had two inlets for monitoring levels so one was used on each floor. It was felt that using this method in larger properties would not produce reliable results with just two inlets. Ensuring proper mixing of the air the house is importance and will require a large number of fans. The CO_2 canisters were also prone to freezing because of the rapid diffusion of the gas and although it was possible to limit this by using a number of canisters, it was an issue during testing. In larger house, it would be even more so.

Tracer gas decay tests take at least two hours to complete and can take much longer. This can be disruptive to some homeowners.

We had trouble with freezing valves and canisters when 'dosing' houses with CO_2. Consider using larger canisters, and if possible having two sets of equipment on hand.

3.1.5 Visual Survey

One of the simplest and more effective testing methods was a visual audit. This is a simple monitoring and targeting exercise whereby a technically proficient person conducts a visual audit of a property to identify possible causes of increased energy consumption. Aspects that were examined included:

1. Heating and hot water equipment
    a. boilers – age, service history, signs of inefficiency
    b. radiators –TRV valves or lack thereof
    c. primary and secondary pipework – has it been insulated

Visual surveys do not cost money and are very effective, but require technically-proficient volunteers.

2. Building Fabric
    a. Loft insulation - correctly installed?
    b. Signs of poor insulation – possible improvements
    c. Condensation or damp issues
3. Ventilation & Infiltration
    a. Are vents clear
    b. Any signs of excessive infiltration around doors/windows etc.
    c. Has the loft hatch been sealed

This method can easily identify problems that are specific to each house that may not be identifiable by the homeowner (Figure 22, overleaf). The limitation is that it does require a reasonable level of technical knowledge in both construction detailing and building services. This is echoed by Stevenson, Leaman et al. (2010, p. 570), who write:

> *"Expert walk-throughs, with informal discussions. These are quick and usually effective, but experts can be fooled. Inexperienced researchers may miss important things, and are also unable to provide immediate comments and feedback to their hosts, whose patience tends to run out more quickly. Learners therefore benefit by visiting sites with more experienced researchers, especially for the initial visit or where uncertainties arise."*

Although there are limitations to the strengths of visual surveys in identifying issues, these can be addressed through education and skills development. The potential for developing networks between occupants and surveyors is a potential benefit of using walk-through surveys. The low-cost and simplicity of the method coupled with its benefits make this method a desirable

The quality of the information gleaned from surveys will be in direct proportion to the expertise of the surveyor.

Many problems that would be missed by physical testing methods can be found during a visual survey.

Surveying typically involves contact with the homeowner, which can serve as a useful opportunity to exchange knowledge and develop networks.

tool.



Figure 22: Results of authors' visual surveys. Left, solar thermal system distribution pipes without insulation. Right, boiler distribution pipes lacking insulation.

3.1.6 Thermal flux

The thermal flux, or heat flux test, quantifies heat flow across a building element. To measure the thermal performance of exterior walls in the chosen houses of Penarth, a heat flux was used with the aim of assessing the performance of the building fabric once the construction has been identified. Test locations on the wall were chosen to avoid probable atypical thermal bridge locations such as windows and corners. Ideally, the flux plate will be located about half-way between window and corner, and floor and ceiling

3.1.6.1 Methodology

The heat flux disc must be positioned on a shaded wall away from all sources of incidental heat (Figure 23). A heat flux disc was attached to the interior face of an exterior wall. Vaseline was used as a 'thermal contact paste' to ensure complete contact between the disc and the wall (using cling film between the Vaseline and wall to prevent marking the wall). A spreader pole and bracket was used to maintain constant pressure against the disc to ensure good contact with the wall. The disc was connected by a low-voltage wire which is inserted into a data logger. The system was then left in place for a number of days (minimum recommended length is 14 days).



Figure 23: Heat flux disc mounted on wall. Note bracket will minimal contact at back of disc (Photo: author).

Readings were logged at specified intervals to produce a graph of heat flux. Internal and external temperatures must be logged throughout the period of monitoring. The energy moving across the wall is registered by the disc and recorded as fluctuations of energy measured in millivolts. The data points are then converted using a conversion factor (including the internal and external temperatures) and using a rolling average technique, a u-value (transmittance value in units $W/m^{2o}C$) can be calculated for the element.

3.1.6.2 Product

Graphs produced by this method from various houses can be compared to see correlations between the thermal performance and response of various configurations of elements. This will indicate and confirm best practises for wall types, roofs, windows, or any element to be tested. This test can be used provide evidence and advice for retrofits as well as use as a demonstration tool. We used the test to measure transmittance. If surface temperatures are monitored, then conductance can be calculated with the flux disc test. The conductance test is typically used by building element suppliers.

3.1.6.3 Evaluation

Pressure against the disc must be maintained for accurate readings. The test was simple to carry out, though installation near coving, deep skirting, or in areas with high ceilings can be challenging (because of spreader pole). The primary disadvantage of the test is the time for which the disc must be left mounted to the element. If the logger or any other piece of equipment fails, a long period of a testing schedule can be lost.

Some ingenuity will be required to position the disc in varied environments.

Ensure that the disc is located on a shaded wall and away from all sources of incidental heat.

The test should be left in place for as long a period as possible – at least two weeks is recommended.

The heat flux test can convey the difference between thermal performance of different types of wall, roof, or other element construction. This could be used to encourage a homeowner to install cavity or surface-mounted wall insulation or similar upgrading.

3.1.7 Energy bill analysis

Energy bill analysis can prove a very useful strategy for both researchers and homeowners for identifying trends and impacts from specific consumption behaviour. By collating meter readings recorded in the energy bills of a homeowner, energy use over time can be plotted. Where enough data are available, this information can be used in conjunction with degree day data to see how the household performs relative to what is expected. Degree day data are available from the Met Office and various other sources. By overlaying this information, it becomes possible for researchers (and homeowners should they choose to do it) to examine and understand the correlations between climate, changes to the household (both physical and behavioural) and energy consumption.

If enough data are available, year on year trends can be examined. Through this, correlations are made visible and so understanding of the correlations can be gained. An example of this analysis which was completed by the authors of this report is shown in Figure 24 (overleaf).

Energy bill analysis does not cost money.

The technique is made more useful by having access to comprehensive consumption data and information about behaviour changes and upgrades to the house.

The impact of upgrades or behaviour changes can be shown very clearly to users.

During analysis, changes in total carbon emissions can easily be produced using conversion factors (see Carbon Trust, 2010).

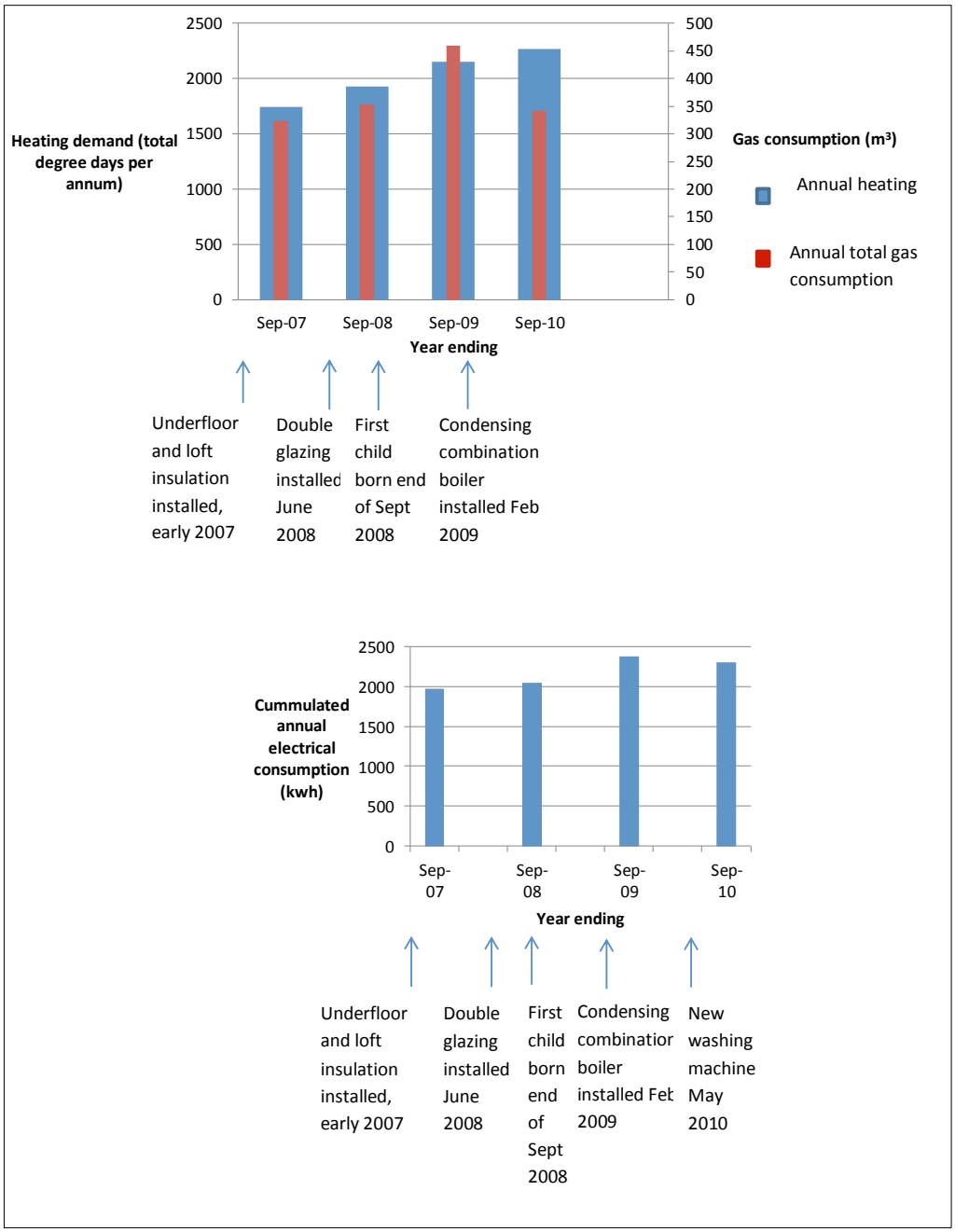


Figure 24: An example of energy bill analysis completed by the authors. Gas consumption (above) and electricity consumption (below) are plotted using meter readings obtained through utility bills. Plotted against consumption are significant household changes.

The biggest limitation of this approach is that regular meter readings year on year seem to be rare with estimated readings being the norm for most of the year with actual meter readings taken bi-annually and adjusted accordingly. This means it can be difficult to estimate accurately the periods of consumption. If householders are fastidious about keeping records or taking regular meter readings, this could be an excellent low cost source of information for targeting behaviour. Meaningful analysis is dependent on availability of recorded meter readings, on the consistency of

meter readings, as well having records of changes in building fabric, behaviour and usage patterns, or occupation.

The Government's 2007 Energy White Paper (DTI 2007b, section 2.61) echoes the importance of accessible archived data to saving energy:

> *The Government believes that additional information on bills or statements can help customers reduce their energy consumption. We propose that historic information, preferably in graphical form, which compares energy usage in one quarter with the same period in the previous year should be provided on domestic customers' energy bills or statements, or, for those customers with internet-based contracts, electronically. We will work with gas and electricity suppliers to incorporate this requirement within supply licences. This measure will deliver annual carbon savings of up to 0.2 MtC by 2020.*

Energy bill analysis should inform homeowners about the importance of keeping detailed records of energy consumption to assist in improving efficiency.

The Government is urging utility companies to provide more detailed information on customers' bills.

3.1.8 Thermographic imaging

Thermo-graphic imaging, thermal imaging, or infrared thermography are names for a technique which produces images (or video) of radiation in the infrared spectrum. As the radiation emitted by an object increases with temperature, thermo-graphic imaging in essence makes temperature differences visible by depicting different bands of infrared radiation using a spectrum of colour. In the built environment, thermo-graphic imaging has several notable uses. The primary use is to identify heat losses due to faulty insulation or thermal bridging. It can also be used to identify temperature differentials signifying moisture ingress, solar storage, dew points, as well as faults in heating and air conditioning units.

Thermographic imaging is a powerful communication tool. It visualises heat loss in buildings and the images are easily understood by laypeople.

Thermographic imaging has uses beyond recognising heat loss: it can also identify moisture ingress, solar storage, dew points, and faults in heating and air conditioning equipment.

The great advantage to use of a thermo-graphic camera

aside from its functional capabilities is that thermo-graphic images are very easily understood by most people. The images provide a clear depiction of building performance and can be used effectively as a communication tool. As the technical nature of energy efficiency is alienating to many people, employing a variety of approaches to communicating the message will increase uptake. Thermo-graphic imaging is a very visual communication tool and one which is likely to make subject matter which is difficult for some people to understand through verbal or written communication more easily understood.

Thermal images can overcome the alienation many feel to the technical nature of energy efficiency.

Unfortunately, thermal cameras are extremely expensive. Basic models today start at around £1000 and prices range greatly. A camera ideally suited for the purposes described here would likely cost between £2000 and £8000. Having experimented with the use of a variety of cameras, we would recommend proceeding with caution before selecting a model for purchase as there are many features and levels of quality which may influence a purchase decision. Given their expense, camera loans or rentals are probably an appropriate avenue for gaining access to a camera. A further idea would be to host a workshop and ask camera manufacturers or distributors to come demonstrate their use. Other ideas include purchasing or co-purchasing a camera with funding gained through an educational grant or through a partnership with a local business, school, or institution.

Thermal cameras are extremely expensive.

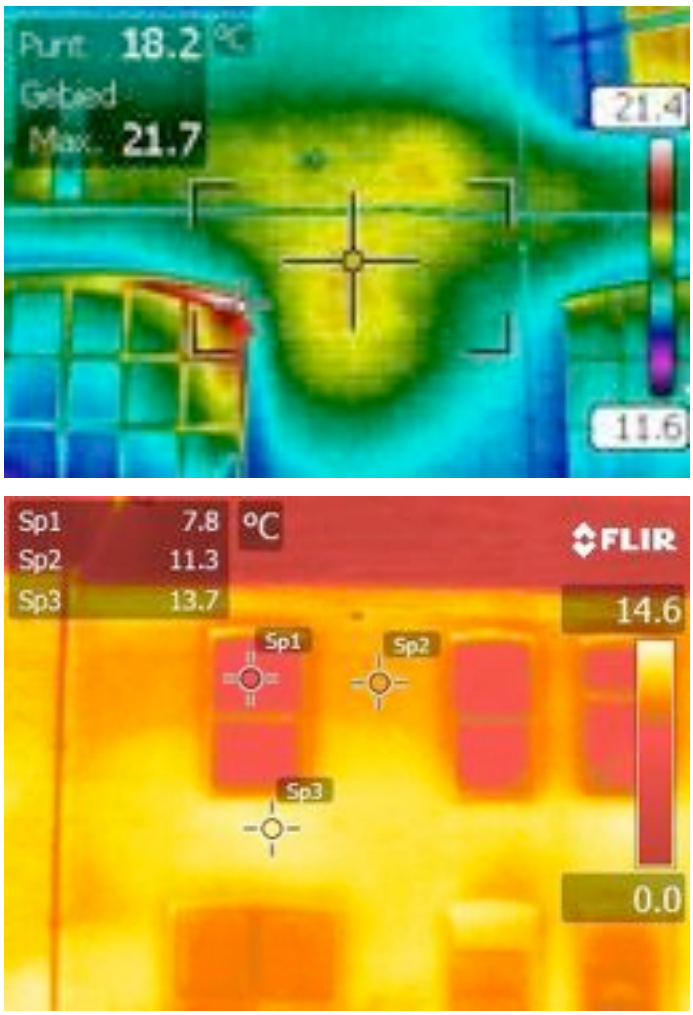
Consider loans or rentals to gain access to a camera.

Co-purchase with a business or institution may give access to a camera as well as sharing a valuable resource. This may have positive implications for social or knowledge networking.

There is also likely to be considerable benefit to using thermo-graphic images accessed online or in print media. Much of the facilitation of communication which these images provide can be gained from use of the images rather than the cameras as the communication tool.

While having access to the camera is important for use as a diagnostic tool, it is not strictly necessary to gain many of the benefits provided by an image.

It should also be noted that some experience and skill is required for effective imaging. This is demonstrated in two photos showing similar phenomena, one of which was taken by a camera manufacturer, and the other by report authors (Figure 25: Difference in thermal image quality. Above, high quality image from camera manufacturer showing area of poor insulation and heat leakage at edge of window (Flir 2011). Below, poorer quality image taken by authors showing poor insulation..)



The quality of thermal images produced is dependent on camera quality as well as knowledge and skill of the photographer.

Images are best made when a high temperature differential exists between internal and external environments.

Care should be taken to avoid solar heating skewing results – this may necessitate taking images at night.

Figure 25: Difference in thermal image quality. Above, high quality image from camera manufacturer showing area of poor insulation and heat leakage at edge of window (Flir 2011). Below, poorer quality image taken by authors showing poor insulation.

An understanding of the individual instrument is necessary to use it effectively. So too is an understanding of basic principles of using cameras. This includes appropriate angle of incidence to objects (<30 degrees), compensation for the emissivity of surfaces, reflections from other objects, appropriate ambient temperatures, temperature differentials, stored solar energy and thermal mass behaviour, and camera inaccuracy (typically =/- 2 degrees). Further information is contained within ISO standard 6781, 'Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes, infrared method. Further information is contained within ISO standard 6781, 'Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes, infrared method.'

Be careful to observe proper technique when using the camera. Results can be skewed by improper use.

3.1.9 SAP Assessments

The Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings is a methodology for calculation of energy performance and carbon emissions from buildings. The calculations produce notional, not actual, figures for a given dwelling (See Appendices H & M). These figures represent notional energy consumption per floor area unit, energy cost, the Environmental Impact rating (the EI rating) which is based on CO_2 emissions, and a Dwelling CO_2 Emission Rate (DER). The rating is based on energy costs incurred by space and water heating, ventilation and lighting gains and losses, and cost reductions from on-site energy generation.

SAP assessments produce theoretical energy performance and carbon emissions ratings for buildings based on real data.

To produce a SAP ratings, an extensive amount of data are gathered about the house including dimensions, building fabric, and services configurations. These data are entered into spread sheet software which produces the EI and DER ratings.

Building dimensions, fabric and services configuration are used in completing a SAP rating.

SAP assessment provides an indicative analysis of a dwelling. It has limitations in providing a definitive analysis (the rule of thumb is that when completed correctly it should align with actual performance by a +/- 20 per cent margin). These limitations are worsened by poor practice during data collection or calculation procedure. A notable drawback to using SAP in practice is that producing a rating can entail a time-consuming and at times arduous process.

SAP ratings are, however, useful indications of the performance of a building. They demonstrate the impact of improving or worsening a wide variety of performance factors in a building. They also serve to indicate the CO_2 emissions associated with a building. Many people will be familiar with the colour-coded ratings attached to white goods (see Figure 26). This format is also used to produce the Energy Performance Certificate (EPC) which is based

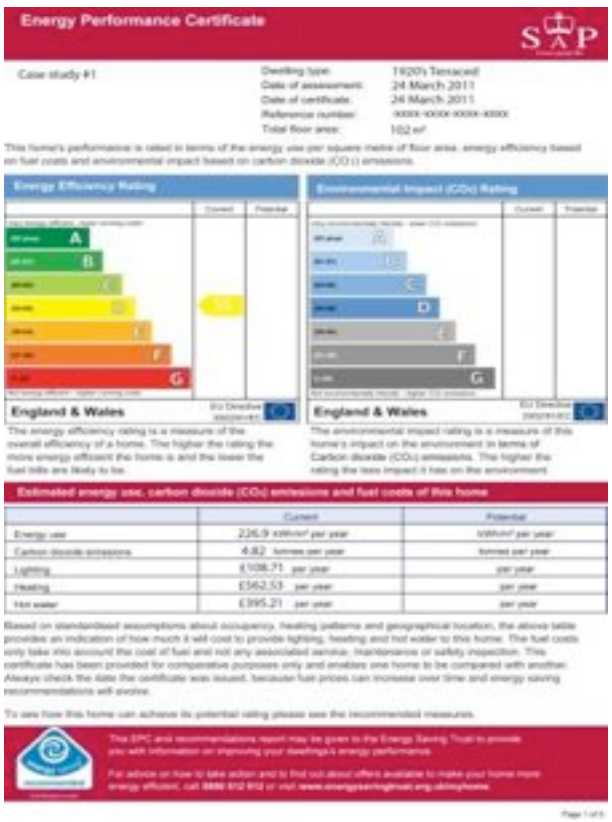


Figure 26: An example of a mock EPC derived from SAP calculations conducted for this research.

As SAP ratings produce only notional ratings, a large margin of error exists.

The results can be presented in the familiar letter grade format commonly seen portraying energy performance of household appliances.

For an inexperienced practitioner, completing the surveying and data input required to produce a SAP rating can be very time-consuming, easily taking several hours per house.

SAP ratings convey complicated information in an easily understood format

on a SAP rating. By grading a dwelling on the 'A' to 'G' scale and displaying the rating in visual format, the performance of a dwelling and the comparison of this performance to maximum potential performance can be relayed to homeowners with clarity and effectiveness. It is as a comparative tool that they have merit, used as a ruler by which all dwellings can be assessed, gives a fair comparison against each other. However, they should not be misunderstood as a prediction of actual performance.

3.1.10 Computer Simulations

Although only touched upon in this research, it is worth considering the use of computer modelling as a tool for predicting the energy performance implications of proposed improvement works. They offer quick feedback on the implications of strategies for improvements. Similarly to SAP assessments, modelling gives notional values for performance and should be treated as such. It takes no account of the implications of workmanship or quality of materials used and largely creates 'ideal' scenarios. Scenarios including workmanship issues and behavioural aspects can of course be replicated but it is a guess at best.

Despite this, they are a powerful tool and widely used in industry as they give quick useful analysis that can be extremely beneficial in design development. Dynamic simulation tools use real weather data and consider the 'inertia' of a building over time, they consider the rate at which a buildings fabric retains and dissipates thermal energy over time and the implications this may have a number of factors such as choice of glazing, ventilation strategies and heating & cooling load calculations.

Simpler tools which do not perform dynamic simulations, such as Ecotect modelling software are valuable visual

Computer simulations can produce visual images which are easily understood.

Simulations can be used to diagnose problems as well as predict the outcome of specific interventions.

Skill and – generally speaking – expense to purchase software are required to use simulations.

tools as they create impressive images allowing users and clients to quickly understand the implication of design decisions. Perhaps, where they are most useful is in examining day-lighting and shadowing analysis. They can of course be used for thermal calculations but are not as robust as dynamic simulation tools. While they can be used for predicting heat demands, perhaps where they are most valuable in a domestic setting is as a visual tool; it is the experience of the authors that strong visual tools can be invaluable in conveying messages about buildings which can often seem complicated to a lay person.

An exception to this is the use of dynamic simulation for predicting condensation and vapour issues in proposed construction details. As mentioned in section 1.7, thermal improvement of the building fabric can create condensation risk. Surface condensation can be unsightly and may lead to damage but interstitial condensation if unnoticed may create health and structural problems. As such the authors would recommend the use of a dynamic condensation risk analysis tool such as WUFI as a check against proposed improvement strategies, particularly when insulating walls from inside the dwelling.

Be very cautious that the limitations of computer simulations are considered. Typically, they are best used in comparative analysis to produce relative values. Prediction of absolute values can be potentially inaccurate.

3.2 Case studies

There was an excellent response from volunteers for testing, far in excess of what was anticipated and this is perhaps an indication of the interest in the subject area. However, due to various constraints of time, availability and practical application, few of the available volunteers were able to accommodate the entire suite of tests. The testing suite was designed to assess the energy performance of the building and the influence of behaviour on energy efficiency. Tests used included:

- Blower door testing
- Thermal transmittance testing (flux plate)
- Temperature logging and comfort diary
- Thermo-graphic imaging
- Tracer gas decay testing
- Visual survey
- Utility bill analysis
- SAP assessments.

Visual survey and temperature logging were used in all houses.

Volunteers seemed to prefer not to do the more intrusive tests such as tracer gas decay testing which was only done in two homes. The blower door testing required the assistance of a university researcher so there was limited availability of the equipment. Despite this, four properties were tested for air permeability using the blower door method.

Thermographic imaging was used on all properties over the course of one night. The camera was only available on loan for a very short time and unfortunately, this corresponded with a period of unseasonably warm weather. Because heating in most houses was assumed to be switched off for the time period preceding the imaging, and because of high stored solar energy in the houses, the images are not presented in the majority of the case studies. Discussion of thermal imaging, including of the experience of using the camera, is presented in Section 3.1.8.

3.2.1 Case Study 1



Figure 27: Case study 1, CO_2 meter



Figure 28: Case study 1, flux plate

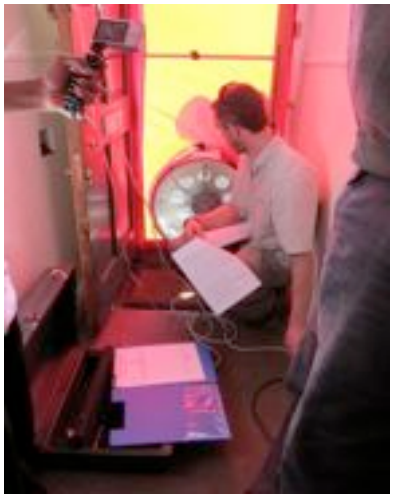


Figure 29: Case study 1, blower door

Case Study 1 was an Edwardian terrace built in the early 20th century; it also had a solid brick extension to the rear that was estimated to be built in the middle of the 20th Century.

Testing in this property included:

- Blower door testing
- Heat Flux
- Tracer Gas Decay
- Visual Audit

3.2.1.1 Air permeability testing

This property used both air permeability tests (See Appendices A & E) in order for the researchers to familiarise themselves with the equipment and methodology but also as a validation exercise. It was felt that this triangulation would add credence to the results. In terms of practicalities of the testing, there was an issue with the valves on the gas cylinders frosting due to the rapid release of the CO_2 but this was easily managed by alternating cylinders and removing a nozzle to increase the volume of gas being released. The testing using the blower door was relatively straightforward despite it being the first time the efficiency group had used it. There were two university researchers present to ensure it was conducted correctly.

Rather than discussing the two testing methods and their findings in isolation, discussing them together offers an opportunity to assess their validity. The results from both tests are presented in Table 3(overleaf).

Table 3: Case Study 1, air permeability results.

Test Property	Air Permeability Index: $m^2/hr/m^2$ @ 50 Pascal	Expected infiltration rate (ac/hr)	Tracer Gas Decay (ac/hr)
Case Study 1	9.5	0.37	0.33

The dwelling actually performs relatively well for air permeability. The current building regulations require new dwellings to score an air permeability index of 10 or less and with a result of 9.5; the property is just within the boundaries. While this would not represent 'best' or even 'good' practice, it exceeds what would be expected of a property of this age. This score of 9.5 roughly equates to an air change rate of 0.37 ac/hr if the property was not pressurised (this is found by dividing the air change rate at 50 Pascal by 20 – while it is an approximation and some contention exists about its accuracy, it is still commonly used for estimating fabric performance). This was only 12% away from the 0.33 ac/hr rate from the tracer gas decay testing. This triangulation would seem to validate the use of both tests.

In terms of using the testing as a monitoring and targeting exercise, the blower door test would be more useful as it can afford the opportunity to identify areas of high loss by using smoke or balloons. In a pressurised situation, the smoke will rush to the gap in the building fabric. Once identified, the necessary remedial works can be undertaken.

3.2.1.2 Heat flux testing

The results from the heat flux testing are not available because the external temperature sensors were not logging due to some confusion about the launching procedure. The data for the actual flux are available but without external temperatures, cannot be used to calculate U-Values. Despite this, the testing did actually provide some interesting experiences. On the second day of logging, one of the residents took the apparatus away from the wall as they did not realise why it was there. If nothing else, this is a good example of how people can interfere with testing.

3.2.1.3 Temperature logging

The first case study home happened to be that of one of the researchers and as such, it was possible to spot errors in the data. As can be seen in Figure 30(overleaf), on the 18th March between the hours of 12:00 and 18:00 approximately, there was a sharp rise in temperature which suggests the heating had been turned on. However, the researcher knew that not to be the case because it was actually on much later that day.

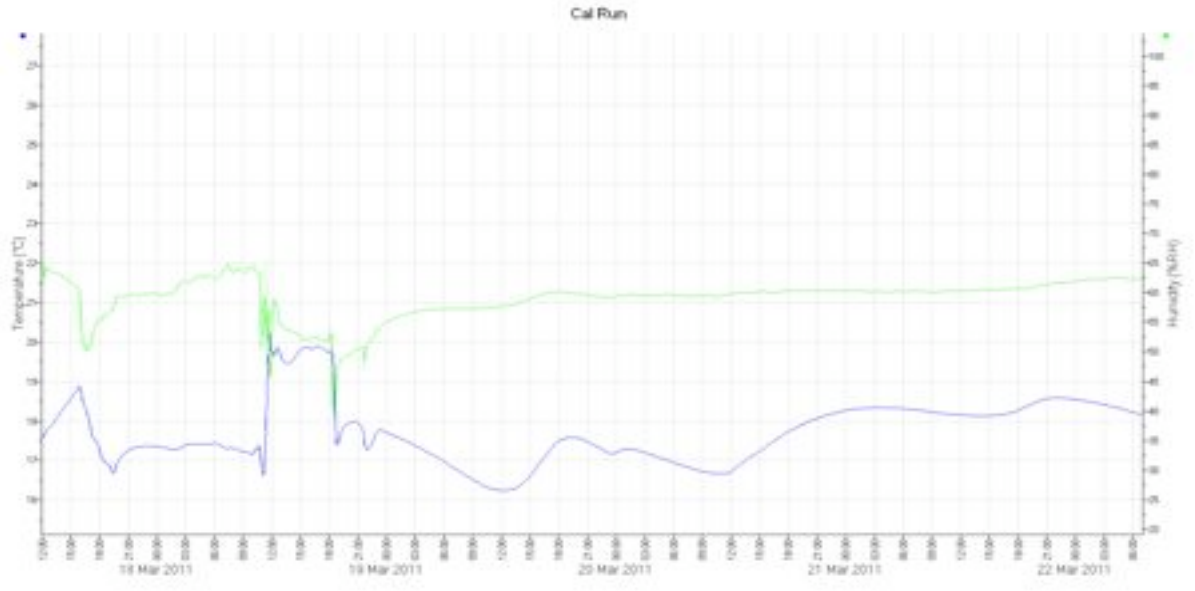


Figure 30: Case Study 1, temperature and relative humidity logger results.

The time had not been calibrated on the loggers correctly and this afforded the researchers the opportunity to re-calibrate the loggers in time for monitoring the subsequent dwellings.

The inhabitants had described the home as having damp problems and although interstitial condensation cannot be implied by high internal relative humidity, CiBSE guide A recommends between 40 – 70% RH (CiBSE 2007) for a comfortable internal environment and while this is within range, it is on the high side.

In terms of average internal temperatures, it had an average of 17.7°C. This was not the lowest from all the dwellings monitored. However, without adjusting for external temperature it is difficult to know how much is attributable to behaviour or the building heat loss co-efficient. It is important to recognise that the principle purpose of the logging was to examine in conjunction with the comfort diary. No diary was kept at this house as it was trial run to get used to the equipment before monitoring homes in Penarth.

3.2.2 Case Study 2



Figure 32: Case Study 2, front facade



Figure 31: Case Study 2, temperature and relative humidity reading

Case Study 2 is a 1950 's semi-detached ex-council house with an extension added in 2009 with partial fill cavity construction. There was also a conservatory to the rear of the dwelling but the conservatory was not considered as part of calculations as it is an unheated space but is worth noting when considering the performance of the building as it can act to buffer temperatures.

Testing in this property included:

- Visual Audit
- Temperature Logging

3.2.2.1 Visual audit

The visual audit of the house was a useful exercise as this was the only dwelling we had access to of that age despite a large number of dwellings having been built in the mid-20th century in Penarth. Notable observations included:

- Un-insulated primary despite a relatively new boiler, only 2 years old. It was serviced annually
- Radiators with thermostatic valves
- Approximately 50% low energy lighting
- 1 temperature zone, no programmer

3.2.2.2 Temperature logging and comfort diary

Logging of temperatures was relatively short in this dwelling at only 2 days so it is difficult to make assumptions about the behaviour of the occupants (Figure 33, overleaf). With that in mind, some of

the more interesting data include an average internal temperature of 20.6°C and a minimum of 18.6°C. Interestingly on the 23rd of April between 12 and 6pm the highest temperatures were recorded and the householder responded in the thermal comfort diary as being 'very comfortable' (Table 4, overleaf). The coldest temperature reading was at 7am on the same day and for that period the vote was 3, which is the middle of the scale ranging from very uncomfortable to very comfortable. On both occasions, the respondent had indicated that they had been exercising for the previous hour.

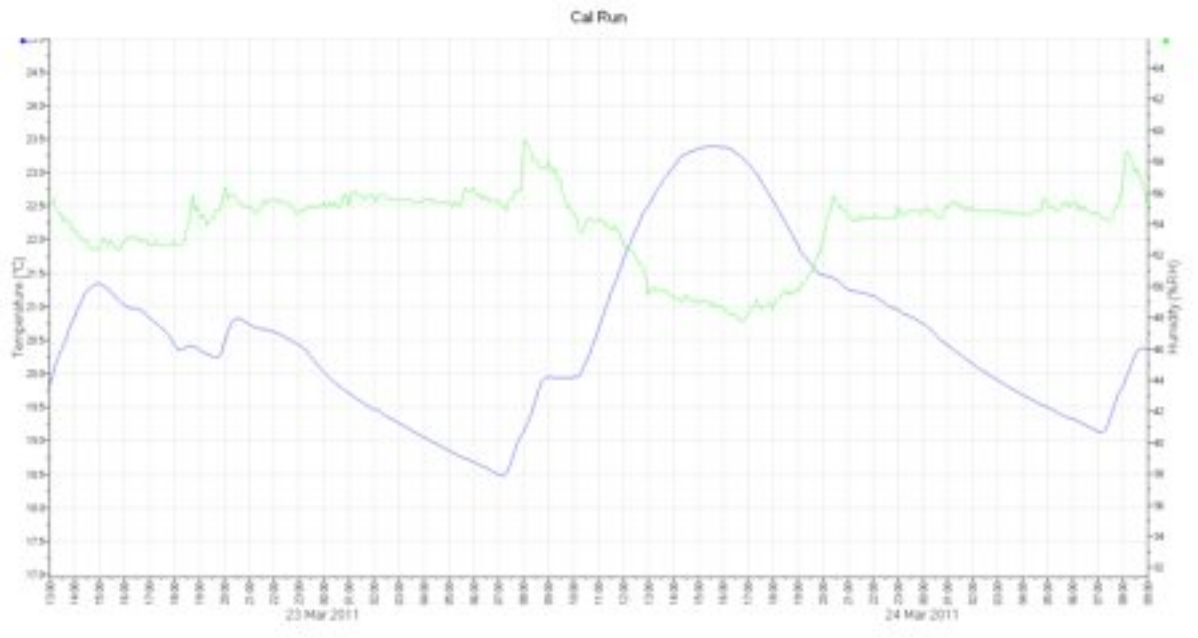


Figure 33: Case study 2, temperature and relative humidity logging results

Table 4: Case study 2, comfort diary results

Case Study 2 (respondent 1)	21/03/2011 9am-12pm	21/03/2011 12pm-6pm	21/03/2011 6pm-9pm	22/03/2011 9am-12pm	22/03/2011 12pm-6pm	22/03/2011 6pm-9pm	23/03/2011 9am-12pm	23/03/2011 12pm-6pm	23/03/2011 6pm-9pm	24/03/2011 9am-12pm	24/03/2011 12pm-6pm	24/03/2011 6pm-9pm
Question 1						3			3			
Question 2						3			3			
Question 3						1			1			
Question 4						4			5			
Question 5						1			2			
*Clothing **layers***						1			1			
Avg. temp. LR						21			22			
Avg. RH LR						55			52			
Case Study 2 (respondent 2)	21/03/2011 9am-12pm	21/03/2011 12pm-6pm	21/03/2011 6pm-9pm	22/03/2011 9am-12pm	22/03/2011 12pm-6pm	22/03/2011 6pm-9pm	23/03/2011 9am-12pm	23/03/2011 12pm-6pm	23/03/2011 6pm-9pm	24/03/2011 9am-12pm	24/03/2011 12pm-6pm	24/03/2011 6pm-9pm
Question 1					3	2	3	3	3	4		
Question 2					3	4	2	3	3	2		
Question 3					3	3	3	3	3	3		
Question 4					5	3	3	5	5	3		
Question 5					5	1	5	5	1	5		
*Clothing **layers***					1	2	3	1	2	1		
Avg. temp. LR					21	21	21	23	22	21		
Avg. RH LR					54	55	55	49	52	53		

We can also observe that both mornings the heating appears to have been switched on for 2 hours from 7am but because of the short period of monitoring we cannot say whether this is due to timed controls, habitual behaviour or coincidence.

3.2.3 Case Study 3



Figure 34: Case Study 3, north facade

Case study 3 is a 4 storey terrace house built in 1894, which has had a number of improvements over its life. This was a difficult property to assess; it had a mixture of glazing including modern double glazing, some older double glazing and some single glazing (Figure 34). Tests performed in this house included:

- Visual audit
- Temperature logging
- Energy bill analysis

While the volunteer was keen for the group to do the tracer gas decay testing, the size of the dwelling meant that the results would be difficult to validate and the decision was made not to conduct the tracer gas decay testing on dwellings any larger than a traditional 3 bedroom, 2-storey terrace. There was limited space for using the conductive plate testing; only two areas were identified as being adequate. In both instances, the presence of decorative coving meant the acro that held the flux plate in position, could not be used.

3.2.3.1 Visual audit

The visual survey highlighted some interesting points; there was a real divide in this building. Anywhere there had been remedial works, they were generally of a high standard but there were simple fabric measures that had not been addressed (Figure 35: Case study 3, Insulated cylinder with cylinder-stat visible at lower right of image and adjacent un-insulated primary pipework). A lot of insulation in the attic had been pushed out of the way to allow for storage and there were large gaps at the soffit towards one of the party walls. This would suggest that the roof would be a large area of heat loss in this dwelling.



Figure 35: Case study 3, Insulated cylinder with cylinder-stat visible at lower right of image and adjacent un-insulated primary pipework

There were zoned controls with two thermostats and a cylinder stat and a factory lagged hot water cylinder. This was a recent installation, approximately 2 years old. This is certainly good practice and yet despite this, much of the primary pipework was

un-insulated.

Although almost 100% of windows were draft-proofed there was still a large proportion of single glazing in the house, most of which was on the northern façade. This would represent a very large heat loss.

Although the building was not in the conservation area, this is a good example of a common issue. Householders may wish to make fabric improvements but are limited by virtue of the fact that efficient glazing may not be available that fits in with the area's conservation strategy.

3.2.3.2 Temperature logging and comfort diary

During the initial site visit, in a conversation with the volunteer, they described how they were quite happy to be just a little too cold in the home and to compensate with clothing but how they had a constant battle with their partner who would immediately switch the heating on if they were cold. Although a simple anecdote, it highlights both the subjectivity of thermal comfort and the varying attitudes and behaviours, be they energy intensive or otherwise.

There were large diurnal temperature swings in this building (Figure 36). This may be an indication of a poor building heat loss co-efficient but without correcting for external temperatures, this is difficult to prove. It is the opinion of the researcher however; that having visited and inspected the property, it would be expected to be the case. It also had the lowest average internal temperature of 16.9°C. Although at lower temperatures, the comfort diary did seem to indicate that the respondent was slightly uncomfortable and expressed the desire to be warmer, it did not result in using the heating (Table 5, overleaf).

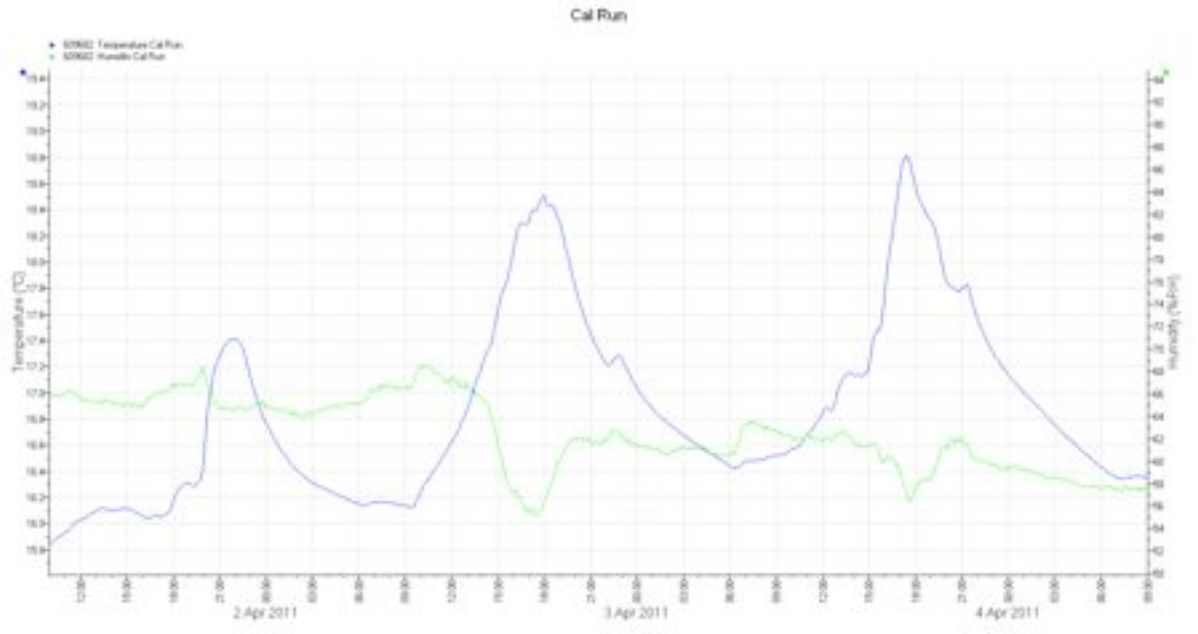


Figure 36: Case Study 3, temperature and relative humidity logging results

Table 5: Case study 3, comfort diary results

Case Study 3 (respondent 1)	28/03/2011 9am-12pm	28/03/2011 12pm-6pm	28/03/2011 6pm-9pm	29/03/2011 9am-12pm	29/03/2011 12pm-6pm	29/03/2011 6pm-9pm			
Question 1		3			3				
Question 2		3			3				
Question 3		3			2				
Question 4		4			3				
Question 5		4			4				
Clothing score		1.3			1.3				
Avg. temp. LR		21			20				
Avg. RH LR		48			49				
Case Study 3 (respondent 2)	28/03/2011 9am-12pm	28/03/2011 12pm-6pm	28/03/2011 6pm-9pm	29/03/2011 9am-12pm	29/03/2011 12pm-6pm	29/03/2011 6pm-9pm	30/03/2011 9am-12pm	30/03/2011 12pm-6pm	30/03/2011 6pm-9pm
Question 1		3	3	3	3	3	3	2	
Question 2		3	3	3	3	3	3	4	
Question 3		3	3	3	3	3	3	3	
Question 4		4	4	3	4	4	3	2	
Question 5		3	1	4	1	1	4	1	
Clothing score		1	1.15	1	1.15	1.3	1	1.15	
Avg. temp. LR		21	21	21	20	20	21	20	
Avg. RH LR		48	48	46	49	52	49	52	

3.2.4 Case Study 4

Case Study 4 is a ground floor flat in a converted house built in 1856. It had stone and rubble walls with external rendering and is situated in a conservation area. Testing on this property included:

- Visual audit
- Energy bill analysis
- Conductive plate testing
- Temperature logging

3.2.4.1 Visual audit

An extended conversation took place at this property between the researchers and the occupants about energy use in the home and some of the measures that had been taken. This was an interesting case study because the research team got introduced in some detail to a number of issues around the house.

For a number of reasons including conservation the windows had not been upgraded but the occupant had taken the initiative to install a secondary layer of plastic film glazing which they reported as being useful but not ideal (Figure 37).



Figure 37: Case study 4, plastic film secondary glazing

There were also excessive damp problems in parts if the building including what appeared to be rising damp. Although observations were made, it was felt that this was the realm of an expert and so one should be consulted.

It came to attention that there was a de-humidifier in the basement because of damp problems that was running constantly all year round. A quick 'back of an envelope' calculation estimated that this could be costing the householder in the region of £600 per year. A recommendation was made that it be replaced with positive input ventilation or mechanical extraction of the space using a fan with a favourable specific fan power.

3.2.4.2 Conductive plate testing

The equipment was in place for over a week logging temperatures and flux rates but unfortunately the logger collecting the data failed and so no analysis could be undertaken. This was very

disappointing as it was felt having left the equipment running for so long, the results from their analysis would be stronger.

3.2.4.3 Temperature logging and comfort diary

We were fortunate enough to have quite a large range of data for this house but unfortunately relatively little in the way of comfort diary entries which made examining trends difficult. This highlights one of the weaknesses of this method in that it is highly reliant on the volunteers to be of much value. They need to have the time to do it but also the enthusiasm to do it for a number of days. The coldest recorded temperature was 17.2 °C which is still quite high for a building that seemed to have apparent problems with heat loss (Figure 38). It should be noted that only the living area temperature is presented here which is where the wood burning stove was located. This was the primary heat source for the dwelling. Relatively consistent levels of comfort were recorded in the comfort diary (Table 6, overleaf).

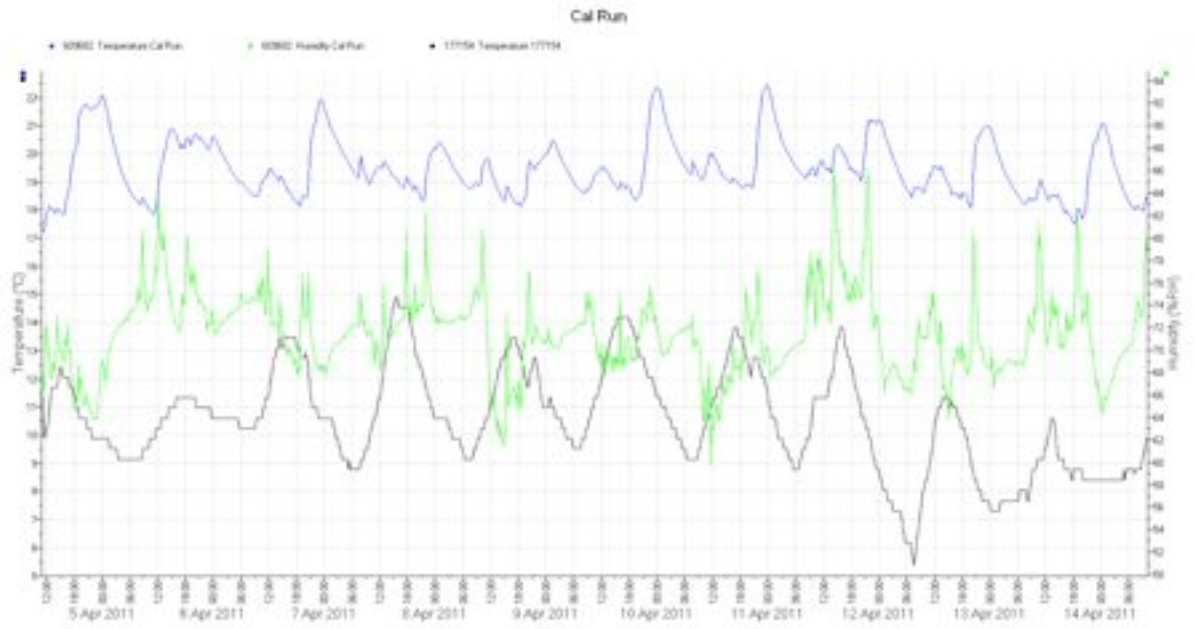


Figure 38: Case Study 4, temperature and relative humidity logging results

Table 6: Case Study 4, comfort diary results

Case Study 4	05/04/2011 9am-12pm	05/04/2011 12pm-6pm	05/04/2011 6pm-9pm	06/04/2011 9am-12pm	06/04/2011 12pm-6pm	06/04/2011 6pm-9pm	07/04/2011 9am-12pm	07/04/2011 12pm-6pm	07/04/2011 6pm-9pm	08/04/2011 9am-12pm	08/04/2011 12pm-6pm	08/04/2011 6pm-9pm
Question 1	3		4	3		4				3		3
Question 2	3		3	3			3			3		3
Question 3	3	3	3	3		3	3			3		3
Question 4	2			2						3		5
Question 5	2	5	5			3						1
Clothing score	1	1	1	1		1	1			1		1
Avg. temp. LR	18	20	21	19	19	19	19	19	19	19	19	19
Avg. RH LR	76	76	77	75	72	72	71	72	74	74	65	71

3.2.5 Case Study 5



Figure 39: Case Study 5, front facade



Figure 40: Case Study 5, blower-door testing



Figure 41: Case Study 5, TRV on radiator

This property was a three bedroom, mid-terrace, 1920s house with solid brick wall construction. It has no additions but has undergone a few improvements in within the last four years. These include full glazing replacement (uPVC double glazing), a condensing combination boiler, additional loft insulation, draught-excluding, and under floor insulation to the suspended ground floor.

Testing in this property included:

- Blower door testing
- Tracer gas decay
- Heat flux
- Temperature logging
- Comfort diary and questionnaire
- Visual Audit
- SAP assessment
- Energy bill analysis.

3.2.5.1 Air permeability testing

At this property, both air permeability tests were used (See Appendices A & E). This enabled comparison of the results of the blower-door test and the tracer gas decay test. The tests were carried out on separate days, but on days with equally acceptable climate conditions (see ISO standards listed in Sections 3.1.3 and 3.1.4). Using each of these tests in this house was reasonably straight forward. The blower door test was simple to prepare for. Blocking up open vents took a short amount of time although we had to jury-rig a chimney seal from some plastic bags. The tracer gas decay test was somewhat more difficult. The main problem with this test was the freezing of the CO_2 cylinders and valve due to the rapid change in pressure when releasing the gas. This indicated a need to use a large cylinder and valve than we had used (a two pound welding type canister).

The results of the blower-door and tracer gas decay tests are shown in Table 7. The results were surprising given the recent remedial work at the property. The infiltration rate is significantly higher than at Case Study 1, which had a similar construction. Current building regulations require new dwellings to receive a score of 10 or less for the air permeability index. The tested property has clearly scored significantly poorer than that as well as poorer than Case Study 1 did. Given the remedial works, we questioned the accuracy of the testing equipment. Given that the blower-door and tracer gas results were so similar, it appeared likely that the testing equipment performed accurately. In the future, data which seem to be outlying can be examined by calibration of the instruments. In this instance, we only had limited access to the property so we were not able to retest.

Table 7: Case Study 5, blower door and tracer gas decay test results

Air Permeability Index: $m^2/hr/m^2$ @ 50 Pascal	Expected infiltration rate (ac/hr)	Tracer Gas Decay (ac/hr)
22.5	0.74	0.89

As discussed in earlier sections (see Case Study 1), the use of the blower door in conjunction with smoke or balloons can assist in finding gaps in the building fabric. This can also be achieved through the use of a thermal imaging camera. By bringing the house under negative pressure, the thermal imaging camera can be used to show infiltrating warmer or colder outside air. This will identify areas which are 'leaking.'

3.2.5.2 Temperature logging and comfort diary

Temperature logging was carried out over a four day period at this property. Figure 42 (overleaf) shows results from the logger recording temperatures in the living room. The logging highlighted a relatively stable interior temperature with total variation of less than 3° C. Determining appropriate locations for positioning of the sensors was moderately difficult as the living room and bedroom locations both received a great deal of direct sunlight. This problem was overcome and suitable locations were found. Temperatures varied between 18° C and 22° C.

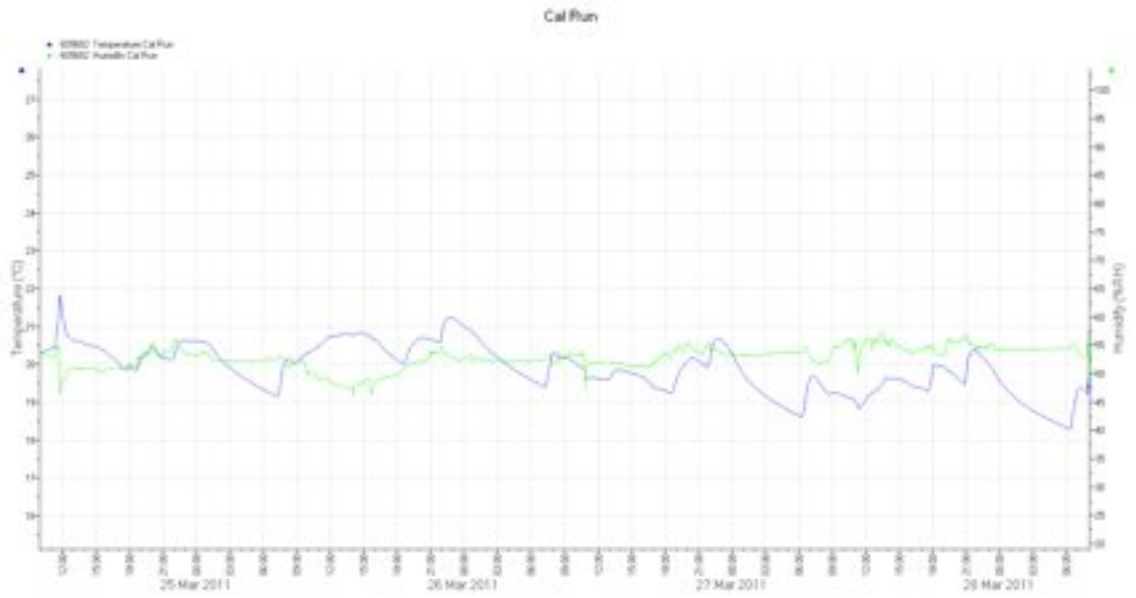


Figure 42: Case Study 5, temperature and relative humidity logging results

The comfort diary associated with the temperature logging exercise was completed over four days. This provided a total of eight logged entries, so four potential entries were not completed (Table 8Table 8: Case Study 5, comfort diary results). The results suggested that reasonably consistent levels of comfort were maintained and this was correlated with average living room temperatures of 20° C during most of the time periods the diary was completed in. The challenges of collecting useful data from comfort diaries are discussed in Section 3.1.1. It was particularly interesting in this house to note that set-point temperatures were maintained during unoccupied periods and that consistently remained relatively high. The questionnaire results displayed a good working knowledge of potential energy sinks in the home as well as appropriate actions to address these. This is a useful attribute of questionnaires as they enable an assessment of the occupant's understanding of energy-related issues and can be carried out with little time input from the questioner, as well as anonymity of the homeowner.

Table 8: Case Study 5, comfort diary results

Case study 5	24/03/2011 9am-12pm	24/03/2011 12pm-6pm	24/03/2011 6pm-9pm	25/03/2011 9am-12pm	25/03/2011 12pm-6pm	25/03/2011 6pm-9pm	26/03/2011 9am-12pm	26/03/2011 12pm-6pm	26/03/2011 6pm-9pm	27/03/2011 9am-12pm	27/03/2011 12pm-6pm	27/03/2011 6pm-9pm
Question 1		3	2			3		2	3	3	3	3
Question 2		3	3			3		4	3	3	3	3
Question 3		3	3			3		4	3	3	3	3
Question 4		4	3			3		2	3	5	4	4
Question 5		4	1			1		2	1	2	3	2
Clothing ***layers***		2						3		2	2	2
Avg. temp. LR		20	20			21		20	20	19	20	20
Avg. RH LR		51	53			52		52	54	55	55	55

3.2.5.3 Visual audit

The visual audit in this property was a useful exercise in that it gave us the opportunity to converse with the homeowner about the past building fabric upgrades and her plans for future upgrades. In many ways, this property has had most recommended works completed. Although nearly 100 years old, it has had a variety of fabric improvements completed already. This included TRV's fitted to all radiators, loft and underfloor insulation, glazing replacement, and a new condensing combination boiler. Some minor details that could be improved were spotted, which included improving the insulation of heating distribution pipes, insulating the loft hatch, and increasing the percentage of energy efficient light bulbs (which was roughly 50%). A stable door at the rear of the house is likely to be a source of high air infiltration. The blower door and tracer gas decay tests should considerable levels of air infiltration. Although there is some cause to consider retesting to ensure instrument accuracy, both tests produced similar results. This may indicate the need to consider more rigorous draught-proofing of the building fabric.

3.2.5.4 SAP assessment

A benchmarking exercise was undertaken in this case studied which utilised the SAP calculation procedure. This procedure was followed using recommended guidelines and the official calculation sheet, however was carried out by students, not accredited SAP professionals (See Appendix M). The result of the SAP calculations, however, is in line with what would be expected and correlates neatly with the findings from the other tests.

The house received a rating of 'D' and a numeric score of 56. Using the ratings produced by the SAP calculations, a mock Energy Performance Certificate (EPC) was produced for the building by using simple desktop publishing software (Figure 43: Case study 5,

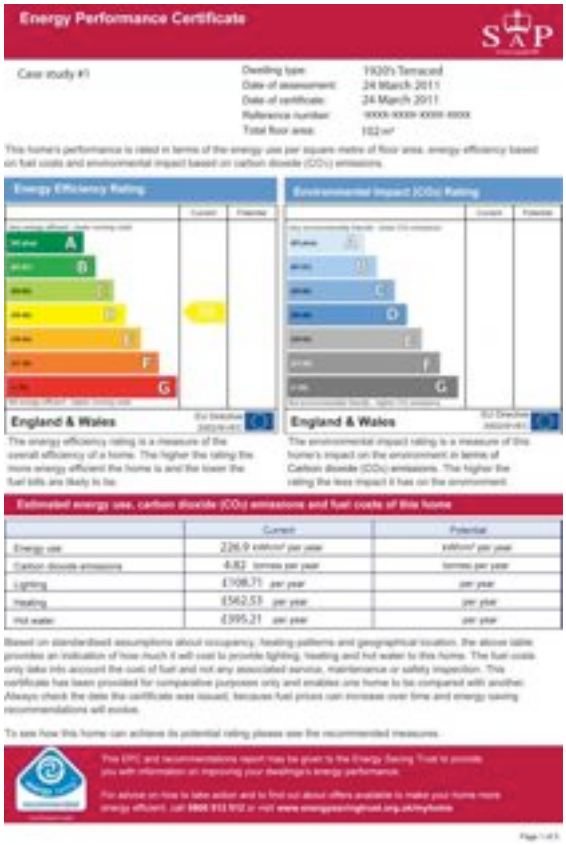


Figure 43: Case study 5, mock Energy Performance Certificate (for illustrative purposes only)

Full details of the SAP assessment procedure can be found in Section 3.1.9. Although they do have certain limitations, including producing only notional values based on assumed values, and being quite time consuming to complete, their use as a benchmarking exercise makes them a valuable communication tool.

3.2.5.5 Energy bill analysis

The energy bill analysis conducted in this case study was one of the most interesting tests carried out. Comprehensive archiving of energy bills was available for almost the full period that the owners had been living in the house. Details of significant changes in the building fabric (such as insulation and glazing replacement), as well as of information about changes in occupancy patterns (a new-borne child) were readily available from the owner. Plotting the changing consumption of energy (gas and electricity) against these events and correlating energy consumption with annual cumulative degree days showed clear correlations (Figure 44, overleaf). The analysis showed a marked decrease in gas consumption in relation to degree days, for instance, after the installation of a new condensing combination boiler. It also showed an increase in electricity consumption in the year following the arrival of a new-borne baby.

Despite the success of getting interesting data from the analysis, some challenges were found. As energy bills are not typically issued at uniform points throughout the year, this caused some difficulty finding benchmarks for annual consumption. If monthly meter readings were available, the analysis could have been made much more interesting, as well as easy to carry out. The problem of poor record keeping of bills and meter readings is likely to be presented in many homes. This case study represents a household with very good record-keeping and the task was still difficult to complete. Nevertheless, as can be seen, an interesting graphical analysis was produced and this represents a very useful communication tool to use to convey the correlation between energy consumption and building fabric and occupancy patterns.

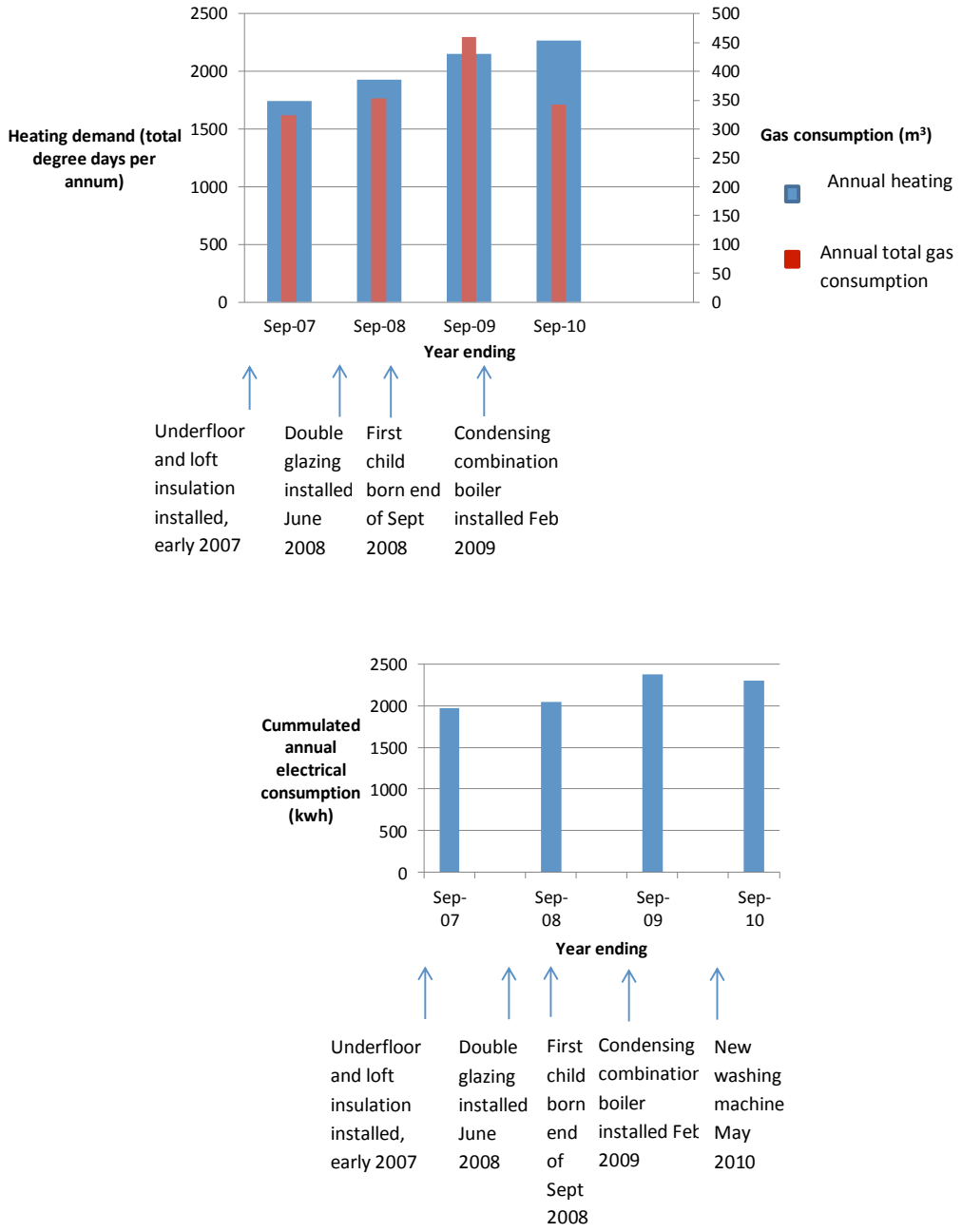


Figure 44: Case Study 5, energy bill analysis. Top, gas consumption against degree days and events. Bottom, energy bill analysis: electricity consumption and corresponding events.

3.2.6 Case Study 6

Case study 6 was a Victorian semi-detached house built in 1877 which had some subsequent additions. Tests conducted included:

- Blower door testing
- Visual audit
- SAP Assessment
- Temperature logging

3.2.6.1 Blower door testing

A blower door test was conducted on this property (See Appendix A), the results from which are presented below in Table 9. First impressions of this large property were that it was going to have a leaky fabric and results did not do much to dispel this notion. The occupants had said that they felt a lot of air got in from the suspended floor and it would certainly seem like one of the problem areas although as discussed earlier, no examination was done to identify problems, merely the test to benchmark its performance. With an air permeability index of 21.3, it is over twice as 'leaky' as current building regulations requires and 35 times that required for passive houses. With such a large volume of air, this is almost certainly the largest heat loss in the house. Subsequent testing and targeting of issues could see this significantly improved.

Table 9: Case Study 6, blower door and tracer gas decay testing results

Test Property	Air Permeability Index: $m^2/hr/m^2$ @ 50 Pascal	Expected infiltration rate (ac/hr)	Tracer Gas Decay (ac/hr)
Patricia's	21.3	0.77	n/a

3.2.6.2 Temperature logging and comfort diary

Despite the relatively high internal temperature (an average of 20.8°C) it should be noted that the sensor was in the only room being heated (Figure 45, overleaf). An Aga stove was used for cooking and heating. This is an interesting behavioural issue. As mentioned earlier, most occupants now require increased levels of comfort in each room of the house at most times of day but simple decisions like thinking about how often and for what reasons you use a room, can lead to significant reduction in heating bills. This simple measure does not cost anything.

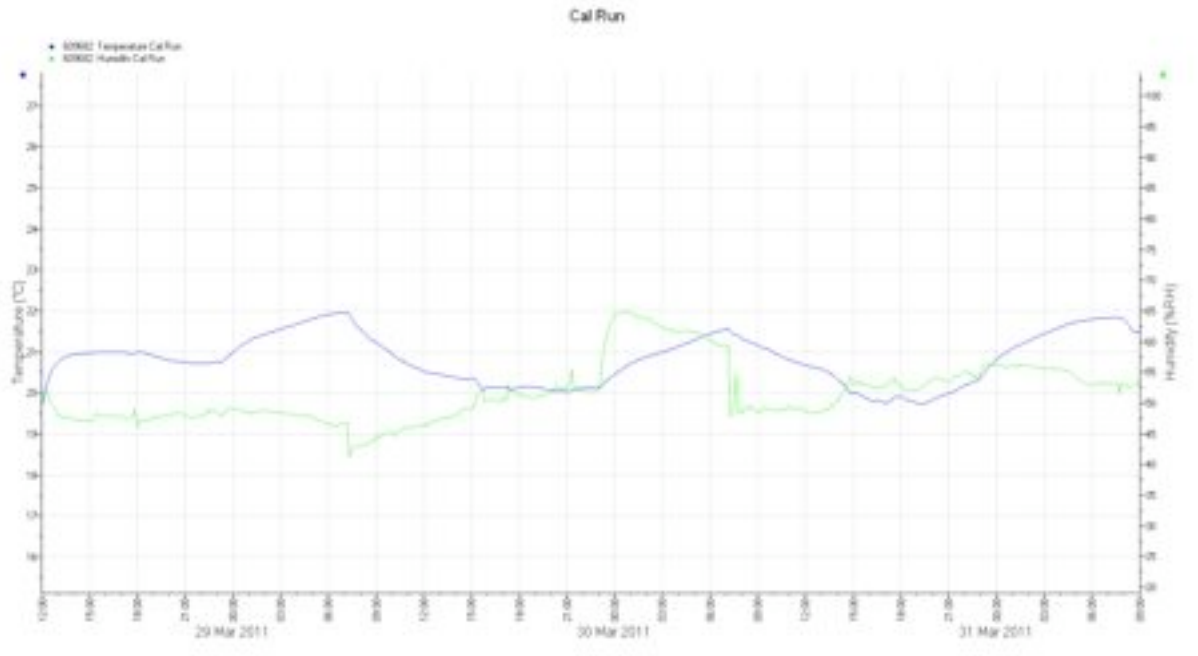


Figure 45: Case Study 6, temperature and relative humidity logging results

For the coldest recorded temperature, the vote for overall comfort on the 1-5 scale was 2; the numeral '1' on the scale represents 'very uncomfortable' (Table 10). It is difficult to infer anything about the comfort band in this dwelling because the swing from the average internal temperature 20.8°C is never more than +/- 1.2°C.

Table 10: Case Study 6, comfort diary results

Case Study 6	01/04/2011 9am-12pm	01/04/2011 12pm-6pm	01/04/2011 6pm-9pm	02/04/2011 9am-12pm	02/04/2011 12pm-6pm	02/04/2011 6pm-9pm	03/04/2011 9am-12pm	03/04/2011 12pm-6pm	03/04/2011 6pm-9pm
Question 1	2	2	3	2	3	3	3		
Question 2	4	4	3	3	3	3	3		
Question 3	3	3	3	3	3	3	2		
Question 4	2	2	3	2	3	3	3		
Question 5	2	2	2	2	3	3	2		
Clothing score	0.75	0.9	0.9	0.75	0.85	0.9			
Avg. temp. LR	16	16	17	16	18	18	17		
Avg. RH LR	66	66	67	68	61	61	62		

3.2.6.3 SAP assessment

As part of an exercise in benchmarking the case studies for the participation day, it was decided to conduct SAP assessments on a number of the case study dwellings. It should be noted that these SAP assessments were undertaken by students, not by accredited SAP professionals and are notional only. Despite this, they offer a quick ruler by which dwellings can be compared to each other.

The dwelling received a score of F which is only one band away from the worst possible score (See Appendix M). This was used to create a mock Energy Performance Certificate using basic desktop publishing software (Figure 46). It should also be noted that these assessments were done before the blower door test so in all likelihood, given the very poor air permeability index score, the rating would actually get worse.

While SAP assessments are a useful tool for benchmarking housing, they should not be treated as an actual prediction of energy consumption. They assume standard occupancy and use patterns real life consumption could be considerably better or worse. It is important to remember that buildings do not use energy, people do.

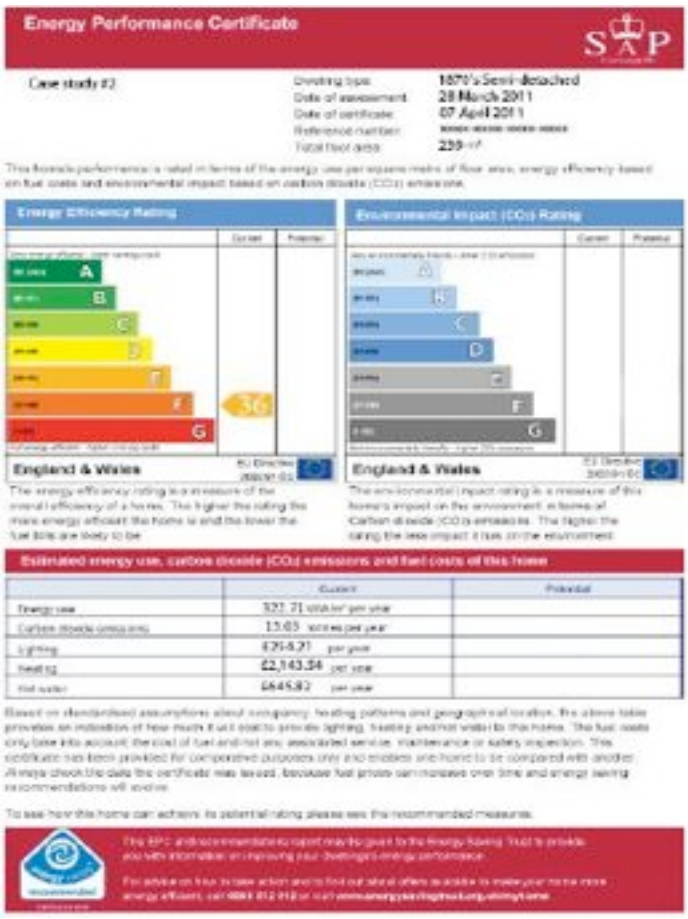


Figure 46: Case Study 6, mock Energy Performance Certificate (for illustrative purposes only)

3.2.7 Case Study 7



Figure 47: Case Study 7, front facade



Figure 48: Case Study 7, sedum roof and solar thermal cells

Case study 7 is a relatively modern 2 bedroom detached house built in 1998 on an infill site in the conservation area. It was extended in 2005 and features solar thermal hot water. Testing on this property included:

- Blower door testing
- Thermography
- SAP assessment
- Conductive plate testing
- Energy bill analysis
- Temperature logging

3.2.7.1 Blower Door Testing

A blower door test was carried out in order to assess the air permeability of the building (See Appendix A). The results of which are presented in Table 11. With a score of 9.5, it is within the limits of what would be required by a new build but could still not be considered a good score. It is worth noting that it has the same air permeability index score as Case Study 1, a dwelling which is approximately 100 years older.

Table 11: Case Study 7, blower door and tracer gas decay testing results

Test Property	Air Permeability Index: $m^2/hr/m^2$ @ 50 Pascal	Expected infiltration rate (ac/hr)	Tracer Gas Decay (ac/hr)
Lewis'	9.5	0.48	n/a

3.2.7.2 Thermography

Much like the air permeability testing, this was conducted in order to create benchmarking and visual data for disseminating information about domestic energy use to the people of Penarth. Figure 49: Case Study 7, thermal image of heat loss at eaves shows the dwelling at approximately 2am after a series of considerably warm days. Despite this, you can still see where there are areas of heat loss around the window lintels and soffit. These images are very quick and easy for people to understand and while we are using them as a visual aid, they are a useful tool in building diagnostics.

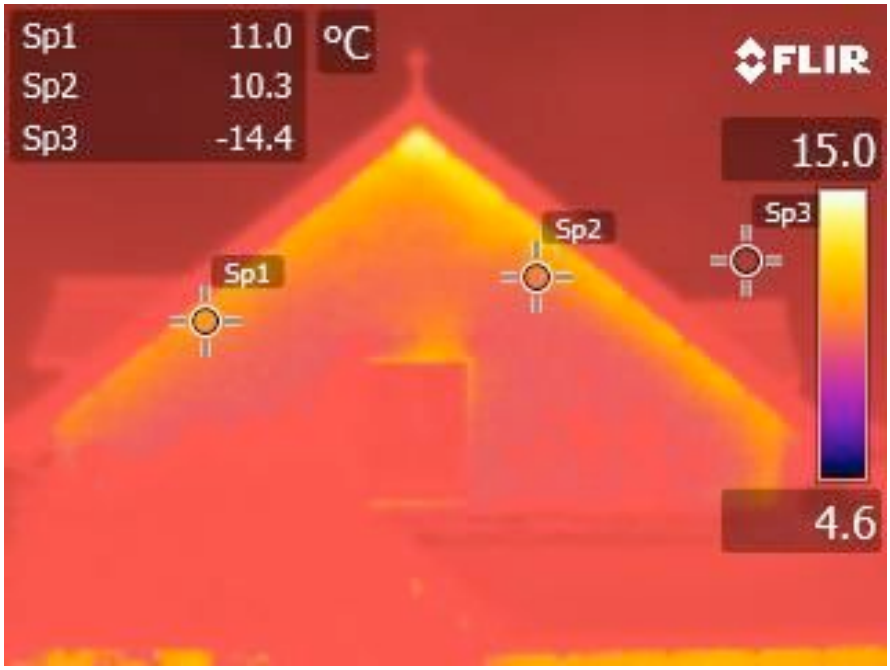


Figure 49: Case Study 7, thermal image of heat loss at eaves

3.2.7.3 SAP Assessment

An indicative SAP assessment was also conducted on the case study dwelling. Despite being only 12 years old, the building still only scored a D as show on the mock Energy Performance Certificate which was produced (Figure 50). This may give an indication of the difficulty and standards required in achieving an A-rated building.

The score would have been slightly worse if there had been no contribution from the solar thermal collector. It should be noted however that one of the observations made by the

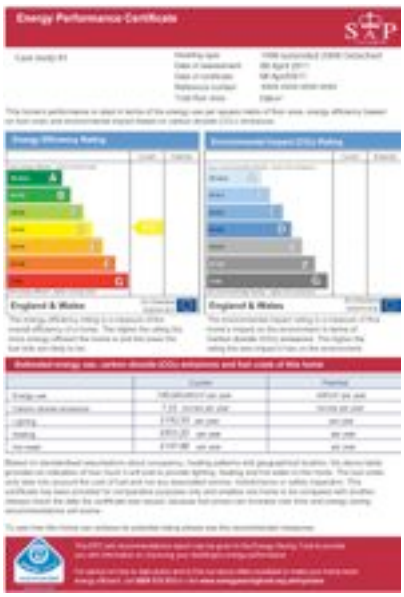


Figure 50: Case Study 7, mock Energy Performance Certificate (for demonstration purposes only)

group during the visual audit was that the insulation in the attic area had been pushed aside to allow for the solar collector installation.

It should be reiterated that when dealing with energy loss in the home, fabric comes first. Renewable energy sources should be looked to after building fabric and occupant behaviour have been optimised. This follows the 'lean, clean, green' hierarchy.

3.2.7.4 Conductive Plate Testing

Case Study 7 was the only dwelling where we managed to successfully complete the conductive plate testing. Figure 51 shows the results from the test plotted against time intervals

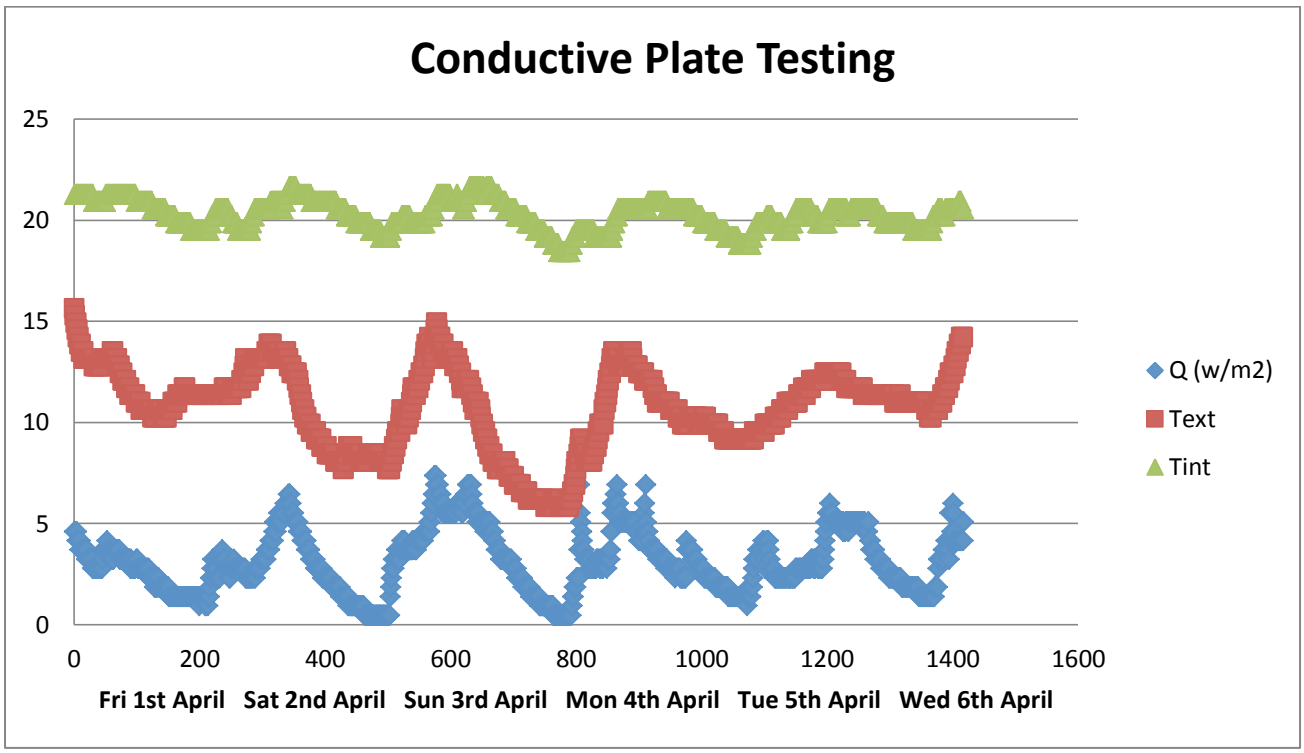


Figure 51: Case Study 7, conductive plate test results

Ideally this would be calculated using integration and the following formula (International Organization for Standardization 1994):

$$U = [\int q(t) \cdot dt\ ] / [\int (Ti(t) - Te(t)) \cdot dt\ ] \qquad \text{Equation 6}$$

However, this type of integration is beyond the ability of the Excel spread-sheet and would require specialist software, so an approximation has been made. An approximation can be taken for the U-Value if the test has been running for a sufficiently long time, usually in excess of 96 hours (overleaf) (International Organization for Standardization 1994):

$$U = [\Sigma n\ q] / [\Sigma n\ (Ti - Te)]$$ Equation 7

$$U = 0.32\ W/m^2/K$$ Equation 8

This U-Value was far in excess of what had been anticipated and indeed better than the SAP database suggests for walls of that age and type. The SAP assessment had assumed a U-Value of 0.35 $W/m^2/K$. This could be a limitation of using an approximation and that the integration method has not been applied. There had been a feeling prior to the testing that the U-Value's would be much worse than the SAP database had suggested so it was surprising to see the results. It should be noted however, that this is in no way representative of the entire wall make up of this building. The area of wall that was chosen for the test is just to the left of the window shown on the thermo-graphic image in Figure 49 and it does seem, from that image at least, that this is a relatively well insulated part of the wall. With more time, it would have been ideal to identify spots for concern using the thermal imaging equipment and try and develop a profile using several tests and use the results to develop an overall average elemental U-Value for the external walls.

3.2.7.5 Energy Bill Analysis

There were good records of gas consumption for the dwelling in the form of utility bills, however, because of the sporadic nature of actual meter readings (usually every six months) it was difficult to plot the figures against heating demand based on degree days. It would be a useful exercise if householders kept regular meter readings and used them as a targeting exercise for identifying times and/or behaviours that led to peaks in consumption. Figure 52 (overleaf) shows gas consumption against heating demand (cumulative degree days) but we can see that the time between readings makes the large it difficult to infer anything from the readings.

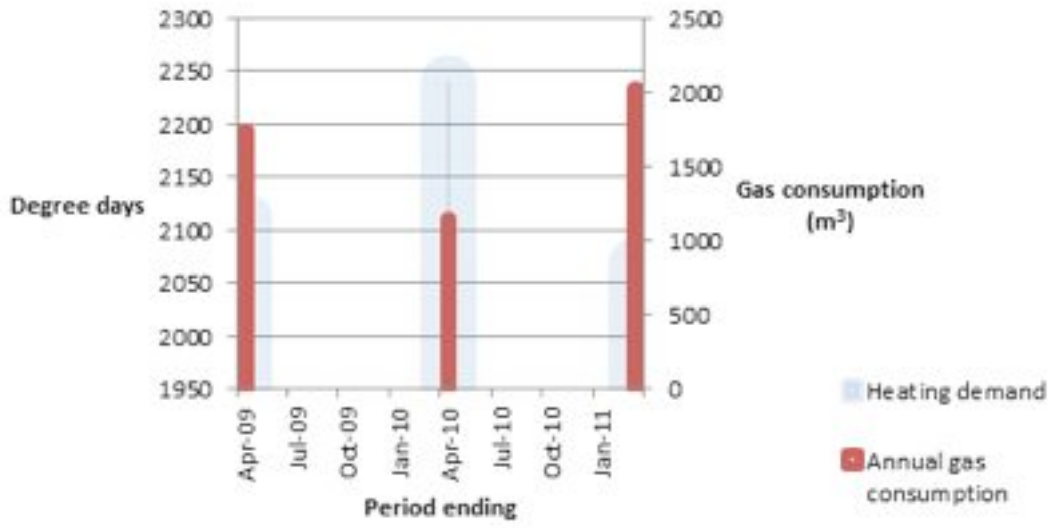


Figure 52: Case Study 7, gas consumption readings

3.2.7.6 Temperature logging and comfort diary

Detailed temperature logging data were available for 6 days (Figure 53, overleaf). The dwelling had a high average internal temperature 19.6°C with the temperature never dropping below 18.1°C. The comfort diary was unfortunately only completed for a two day period (Figure 54, overleaf). There was a mixture of comfort diary votes for this dwelling so it is difficult to make suggestions. However, for the purpose of highlighting an issue surrounding the use of timed controls, we shall look at one vote in particular. On the 31st March when the average internal temperature was 20°C, the vote for question 1 'How do you feel at this time?' was 5 – 'too warm'. It could be suggested that the use of timed controls removed the imperative to respond or adapt to the thermal environment.

This property did use timed controls and may be a good example of the techno-centric approach to heating adapted by many, whereby timed controls removed the imperative to think about gas consumption as one experiences the environment. This idea may be strengthened by examining one of the additional questions. When asked '*what do you think is the most effective way for you to reduce energy consumption in the home'* the response was *"an auto system which would reduce heat and light (switch on/off when room is entered or left)*". This gives an indication of how many people see the key to reducing consumption as a technology issue rather than a behavioural one. While it is not the intention here to suggest that this would be the wrong approach, it is an important and interesting point.

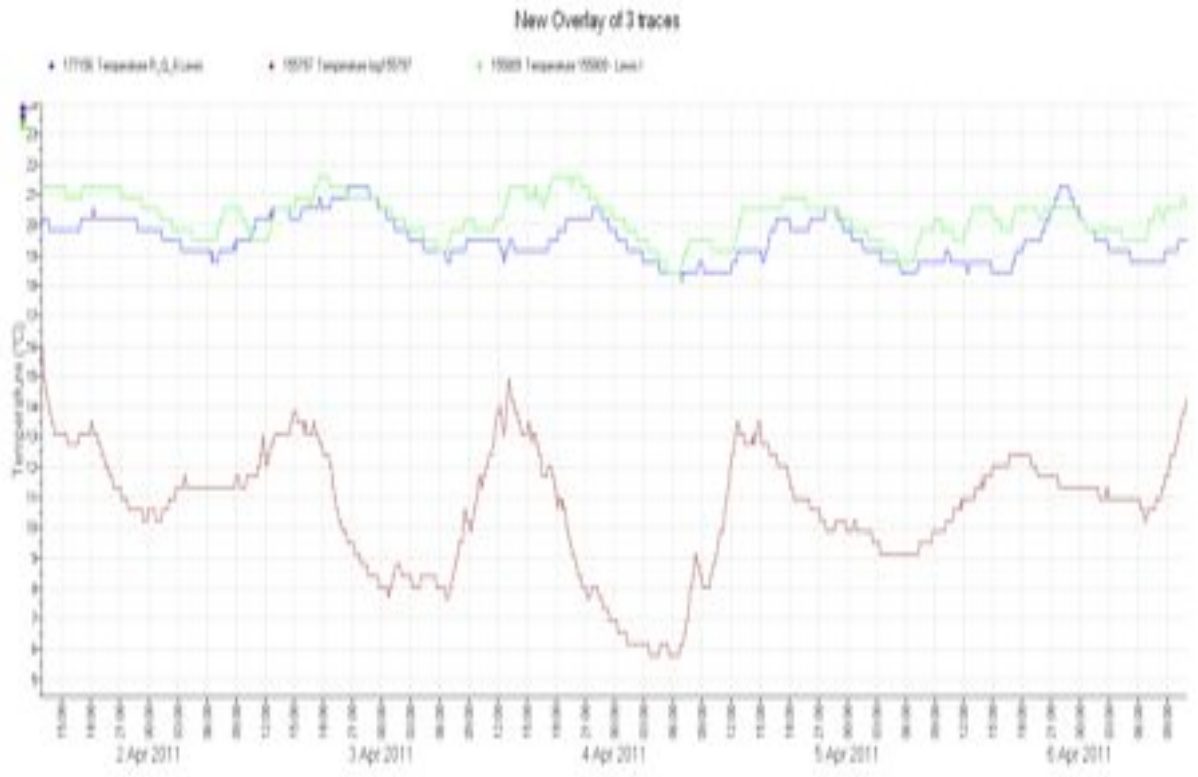


Figure 53: Case Study 7, temperature and relative humidity logging results

Case Study 7	30/03/2011 9am-12pm	30/03/2011 12pm-6pm	30/03/2011 6pm-9pm	31/03/2011 9am-12pm	31/03/2011 12pm-6pm	31/03/2011 6pm-9pm
Question 1	3	2	4	3	2	5
Question 2	3	3	3	3	3	2
Question 3	2	2	2	2	2	2
Question 4	4	4	4	4	4	2
Question 5	3	2	2	3	2	2
Clothing score	1	1	1	1	1	1
Avg. temp. LR	21	19	21	19	20	20

Figure 54: Case Study 7, comfort diary results

3.3 Participation day

On Saturday 9th April, the Theory and Practice of Sustainable Design students presented research the findings of their research to members of the Penarth community at a public open day held in Trinity Church, Penarth. This was an opportunity for members of the public to learn about the research and to contribute their thoughts about the topics raised. Members of the community were invited to see our work, ask questions, offer input and learn about future plans. Despite poor attendance, this event was a valuable opportunity to listen to members of the public and publicise our work to date.

We invited local authority figures, councillors, heads of housing associations, civic groups including Greening Penarth Group members and members of groups regularly scheduled to use the church hall where the event was held. We also distributed posters and flyers throughout Penarth and through local schools.

Poor attendance may be attributable to the event falling on an unusually sunny spring day when potential attendees may have decided to stay outdoors instead of attending the event. It may also indicate the potential for difficulty in persuading people to attend such an event. Suggestions for improving attendance at a similar event in the future include holding the event in conjunction with a more widely attending event such as a street fair or town celebration. It might also attract more attendees if a service is provided such as advice, demonstrations, or discount offers on local goods. Live music, barbeque, or other means of making a more attractive event could be conceived of to draw in large number of attendees.

Members of the community were invited to a 'participation day' to see our work, ask questions, offer input and learn about future plans.

We invited to the event local authority figures, councillors, heads of housing associations, civic groups, members of groups regularly scheduled to use the church hall where the event was held.

Attendance could be improved by holding the event in conjunction with a more widely attending event such as a street fair or town celebration. It might also attract more attendees if a services is provided.

Questionnaires enabled us to gather input from people in an anonymous and unintimidating way.

3.3.1 Questionnaires

At the open day, we solicited input from people through verbal as well as written exercises. By having a short questionnaire on hand, we were able to gather input from people in an anonymous and we hope unintimidating manner. We were looking to quantify the opinions and sentiments of attendees with regard to energy efficiency. The concept here was to produce a baseline against which future action and campaigning could be designed. Due to low attendance, the results were not statistically relevant. In future, however, this approach may offer an effective route to gathering such information.

Figure 55 shows the responses received and while the low response rates meant not much could be done in the way of statistical analysis and certainly nothing could be inferred about wider public opinion, it does give some insight into the potential value of such exercises.



Figure 55: Questionnaire used during participation day.

A good example of the limitations of this methodology came from examining the responses. One respondent, when selecting a number for the statement *"I have optimised my thermostat and radiator controls for the way I use my home,"* chose '1: strongly disagree.' They did, however, mark beside it in text that they had no control over this. Without the additional note, it might suggest that

the respondent either did not know how to optimise their heating controls or did not care to when in fact it was beyond their control. This is a good example of the limitations of such an approach.

Most responses seemed to side heavily on one end of the scale or the other, such as we had expected. Interestingly though, the statement *"I feel pressure to reduce my heating use through government and media"* got a range of responses with 30% of respondents choosing 4 on the scale, between neutrality and strong agreement but also 23% choosing 1 on the scale, strongly disagreeing. Upon reflection, this could be examined further by breaking the responses down by age. There *may* be a correlation between the age of the respondents and the media with which they engage. But also, upon reflection, the question itself is confusing. By saying *'government and media'* no distinction is made between the two. Some respondents may consider the combination of the two sources in deciding on their response, whereas some may give a bias to media or government in considering a response. These issues are easy to spot once the responses have been collected but could easily be missed in developing the questionnaire.

Be careful to use proper statistical analysis techniques. It is easy to skew results drawn from data.

Using a numerical scale is an easy way to standardise responses but can limit the quality of data gathered.

Consider options for collection demographic data or other information from respondents.

Gathering useful ancillary information during this sort of research is a useful opportunity to improve the quality and usefulness of gathered data and analysis.

Participation Day survey responses

	Strongly disagree		Neutral		Strongly agree	Unanswered
	1	2	3	4	5	
Electrical consumption	Frequency Count of Responses					
My electrical consumption has an impact on the environment	0	0	0	1	12	0
If I knew where I could reduce my electricity consumption, I would make more of an effort	0	0	1	8	4	0
It is inconvenient to turn things off when I am not using them	6	5	1	1	0	0
I could save electricity by changing appliances to more efficient ones	0	1	0	5	7	0
Reducing electricity consumption in the home is only for hippies / environmentalists	11	2	0	0	0	0
I would feel good if I/we used less electricity than other homes in Penarth	0	0	6	4	3	0
I would happily buy more efficient appliances for a slight premium (say 10%)	0	0	1	9	2	1
Everyone in the house needs to work together to save electricity	0	0	1	5	7	0
If I knew the most effective ways to reduce my energy use, I would make more of an effort	0	0	2	6	5	0
Heating & Hot water						
Reducing my heating/hot water consumption saves me money	0	0	0	1	12	0
I can make myself comfortable in the home without using the heating	0	0	6	4	3	0

I have optimised my thermostat and radiator controls for the way I use my home	1	0	1	6	5	0
I feel pressure to reduce my heating use through government and media	3	1	4	4	1	0
My behaviour has a large influence on my heating bills	0	0	3	4	6	0
I think I use less energy on heating and hot water than other homes in Penarth	2	0	3	7	1	0
I know how to change the thermostat and radiator valve settings throughout my house	1	0	1	3	8	0
I know how to change the thermostat and radiator valve settings throughout my house	0	1	4	6	2	0
Saving money on my heating bills is important to me	0	0	1	4	8	0

3.3.2 Video

The testing and survey procedures were displayed on laptops to enable people to understand what they entail. This was moderately effective. In future, we would suggest larger screens to encourage people to engage with the videos.

If displaying video at public events, be sure to use adequately-sized screens.

3.3.3 Posters

Posters enabled us to display information in an easy-to-understand format. They also served to draw people to our tables.

Large-format posters which have been attractively designed can draw-in attendees.

3.3.4 Samples

We brought along two or three dozen samples of draught-excluders and insulation materials. This was a very helpful tool to use in discussion with visitors about the merits of different materials. Many people of course were familiar with mineral wool, PIR and PUR insulation, but many were unfamiliar with natural insulation materials and surprisingly, even with draught-excluders.

Many of the attendees were intrigued to see samples of materials they had not seen before. It was a useful communication tool and enabled conversation about technical qualities of materials to be carried out easily.

3.3.5 Pin ups

Using two different large poster format pin-up activities, we were able to encourage input from visitors. These activities also served as 'ice-breakers' and spurred conversation with many of the visitors. One poster displayed a large detailed drawing of all potential factors in energy loss in a home and asked people to use post-it notes to demonstrate where they thought the largest energy losses typically occur. The second poster simply asked for responses to the question "what do you do in your home when you are feeling cold?" One noticeable trend was that many visitors felt we were looking for a specific response or that one response would be more correct than another. This was particularly noticeable with the energy losses poster. In future, this could be avoided

Pin-up activities served as 'ice-breaking' activities and spurred conversation at the event.

Some people felt that the open-ended questions had a 'right' and a 'wrong' answer. This could have been rectified with an explanatory note.

with a sentence or two explaining that there was no correct answer. Nevertheless, even those people who felt they may be putting down a 'wrong' answer tended to ask what would be a 'right' answer. This opened up conversation about the varied make-up of houses and the importance of studying buildings as unique cases (Figure 56). A word cloud of some of the responses we received to each question is presented here (Figure 57, Figure 58, overleaf).



Figure 56: Group member and member of public engaged with pin-up activity (photo: author).



Figure 57: Responses gathered at public participation day to 'pin-up' activity asking, 'Where do you think the biggest energy losses occur in your home?'



Figure 58: Responses gathered at public participation day to 'pin-up' activity asking, 'What do you usually do when you are feeling cold within your home?' Prompts of 'adjust your heating',' adjust your clothing' and 'other' were used.

3.4 Solutions

3.4.1 Wall Element

3.4.1.1 Solid Masonry Wall Construction

Solid stone or brick walls was a common construction method used in older properties up to the mid 1900's when cavity construction and the separation of inner and outer leaf was introduced within masonry building. The majority of homes within Penarth would have favoured the solid masonry wall construction due to the town's historic growth around the Victorian Era and it can be assumed that stone or brick clad properties dating up to the 1920's or 1930's will be of solid masonry build.

The original construction of the solid masonry wall would have limited with no insulation within the construction, allowing the volume of thermal mass and depth of construction to act as an insulating property. The only way to increase the thermal properties of the construction is to add insulation externally or internally, both of which require major structural work and considerations to take on board:

Internal insulation

- Can be cheaper than external insulation
- Does not affect the external appearance of the property
- Can cover any wall irregularities
- Can cause Greater Interstitial Condensation risk and cold bridges.
- Will reduce room sizes
- May require joinery items such as skirting, cornice and window architraves to be repositioned or replaced
- May require Electrical items such as power sockets and light switches to be repositioned

External insulation

- Will considerably alter the external appearance of the property
- Causes minimal disruption to the occupants when installed

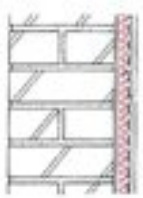
It should be noted that solid walls maybe dressed in external render or timber cladding.

Providing additional insulation to the external face of the building will require planning approval and is unlikely to be acceptable in the case of listed buildings as it may considerably alter the appearance and 'character' of property.

When considering repositioning of rainwater downpipes, the detail to the drain entry point from the pipe must be considered.

- Building fabric is protected from weathering
- May cause problems at eaves level depending on overhang available
- Will require the repositioning of rainwater goods such as gutters, downpipes.

3.4.1.2 Applying Internal Wall Insulation



Inside

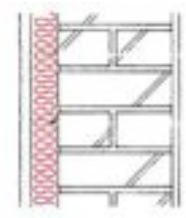
'Drylining') the internal skin with insulated plasterboard (with Vapour Check) as illustrated above (ECD at al 1988 p13). Fixing can be adhesive or mechanical direct to substrate or by providing a timber batten frame to offset drylining from wall (damp proof membrane maybe required).



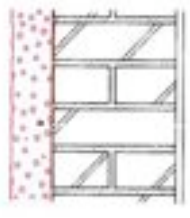
Inside

The most commonly preferred method of 'drylining' is by using a battened frame as illustrated in the image above (ECD et al 1988 pg 13). Insulation is held within a timber frame, spaced off the substrate creating a ventilated cavity between. This solution is ideal for areas of wall prone to wind driven moisture penetration.

3.4.1.3 Applying External Wall Insulation



inside



inside

Image below illustrates an insulated plasterboard product [ultimatehandyman:2011]



Insulated plasterboard is commonly a low sustainable product with high embodied energy, however they have a high thermal property to thickness ratio and therefore are worth considering where internal space is limited

External insulation should be installed by a specialist supplier and should meet all British Standards of third party accreditation.

NB: Remember that planning approval may need to be agreed to alter the external appearance of the building.

External insulating render systems as illustrated above, (ECD et al:1988 pg 13) can come in varying depths depending on the thermal desired property of the wall. Where thickness needs to be limited a simple insulated render may be considered however these systems will never be able to compete with the insulation systems available.

3.4.1.4 Masonry Cavity Wall Construction

Cavity construction is where a void has been provided within the wall construction, separating the external (cold) leaf from that of the internal (warm) leaf (as shown in Figure 59 [Foster JS:1994, pg75]), reducing the thermal bridging of the fabric element. In older properties this cavity remained clear as a ventilated void allowing for a degree of insulating property between outside and inside the dwelling and reducing the effect of wind driven moisture to penetrate through the fabric to the internal skin.

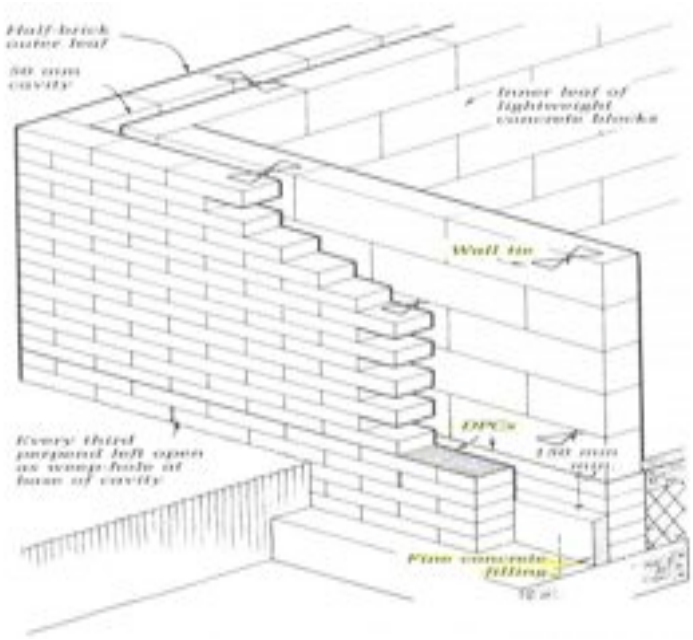


Figure 59 – Detail of cavity wall construction

As discussed in Section 1.2, a 'cold' or 'thermal bridge' is formed when a single structural material 'bridges' the building fabric allowing heat to transfer along it. A solid wall construction could be considered as producing a thermal bridge effect. Different materials will create a different level of thermal bridge depending on its conductivity or thermal insulating value. For example metal has a much higher conductivity property than timber, therefore creating a more pronounced cold bridge and greater potential for internal surface condensation resulting in fabric damage, mould growth and energy loss.

NB: Cavity width can vary from building to building 50mm is nominally considered as the minimum.

NB: A parge coat or wet plaster maybe an alternative to drylining to reduce air permeability of a masonry wall construction.



Figure 60- Picture of cavity blown insulation being applied through external leaf (ECD et al:1988 & Igloo Insulation 2011)

Insulation can be injected through small holes as shown in Figure 60 (Igloo Insulation 2011), externally or internally into the cavity to create a full fill insulated cavity. Care should be taken with dwellings in exposed areas that suffer from wind driven moisture as this can use the insulation to bridge the cavity creating moisture ingress. An internal drylining insulated plasterboard maybe an alternative to injection fill.

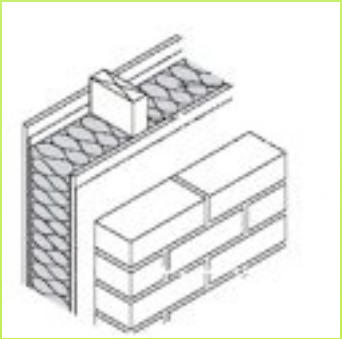
3.4.1.5 Timber Frame Wall Construction

Timber fame has been constructed as an alternative to masonry throughout history. The main (load bearing) leaf is constructed from sawn timber studs with a void between (Figure 61, overleaf). 'Racking' or 'sheathing board' is applied to one vertical face (usually the external) to allow for additional strength.

As timber has a greater potential for decay from weathering, the structural frame needs to be provided with a rain-screen, this can take the form of a masonry outer leaf, a rendered or timber panel.

If the construction of a particular dwelling is in doubt, sometimes by simply knocking on the internal skin of an external wall can ascertain if the substructure is timber (produces a hollow sound) or Masonry (produces a dead hard sound).

Insulation can be fitted between the timber studs in the frame, level of thickness will depend on stud depth. For additional thermal up-grade an insulated plasterboard can be used on the internal face or additional drylining off studs to increase depth of insulation



Typical timber frame construction diagram. The insulated timber frame is clad in a brick outer leaf (Trada 2011)

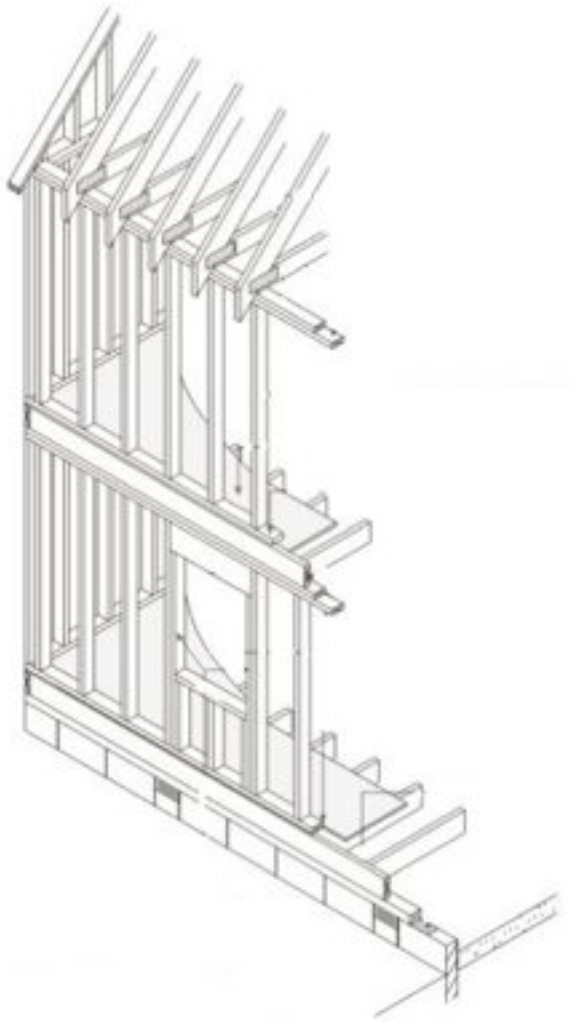


Figure 61 – Detail of typical timber frame construction indicating external wall, ground floor, intermediate floor and roof makeup (Woodsepc 2011).

3.4.2 Ground Floor Element

3.4.2.1 Solid Floor Construction

Solid ground bearing floor construction is usually found in smaller, older properties and can be identified by a solid screed or earth topping which is cold to the touch and has no visible ventilation grilles at low level externally (Figure 62, overleaf).

If major building renovations are scheduled for the property consideration should be given to: Replacement floor slabs including insulation above or below structural slab: inclusion of Damp Proof Membrane: Replacement of screed topping to a proprietary insulating screed: Inclusion of a vertical isolation insulating strip at wall junction to limit thermal bridging.

NB: the risk of interstitial condensation must be considered when suggesting the increase in the floor finishes thermal quality.

NB: (Figure 62, overleaf) the image indicates a cavity external wall construction however other forms of external wall construction maybe applied alongside a solid floor construction. Early forms of solid floor construction may not have a damp proof membrane providing protection from ground moisture and condensation.

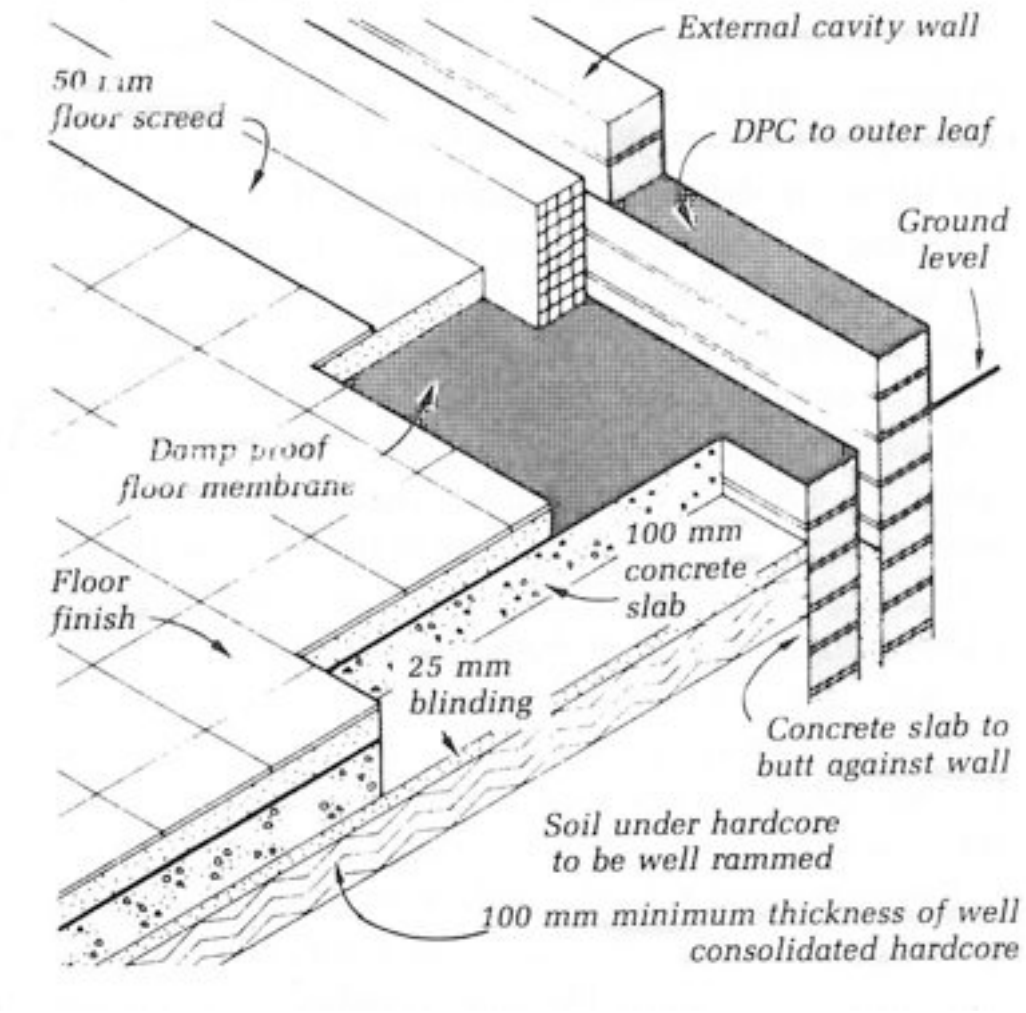


Figure 62 – Detail of solid ground floor construction (Foster JS 1994)

Unless extensive building works are considered for the property, up-grading solid floor construction can be difficult due to applying a top level of insulation, raising internal finished floor levels creating knock on effects such as to door heights.

A simple method of improvement may be suggested by up-grading the existing floor finish, the use of carpet with a thermal underlay or linoleum.

3.4.2.2 Suspended Timber Floor Construction

This form of ground floor is expected to be the usual construction method found within medium to larger size properties of Penarth due to the build Era and is shown graphically in Figure 63 (Foster JS 1994, pg. 179). It can be identified easily by the sound when walking on and by having a timber floorboard finish with low level external air bricks or grilles just above the external ground level on the outside of the property.

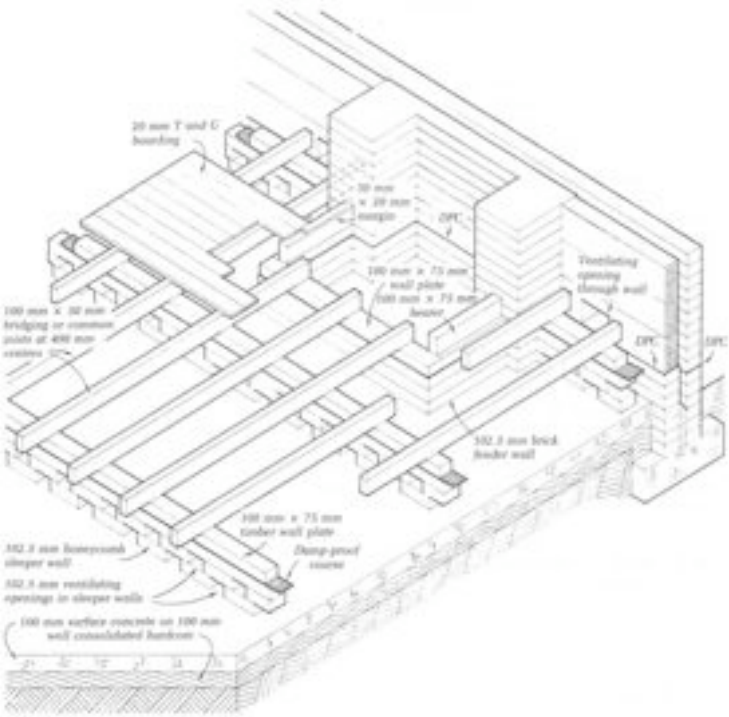


Figure 63 – Detail of suspended timber ground floor construction

Insulation installation options available:



1 Insulation placed between joists



2 Insulation placed above joists



3 Insulation placed below Joists



Decorative air brick grille in stone wall ventilating a void beneath a suspended timber floor.

[image source google images: air brick]

Suggested methods of thermal up-grading indicated will result in the removal of the timber floorboards and in that respect maybe quite disruptive to the occupiers.

***Do** draught-proof floor boards*

***Do** retain a clear & well ventilated void under floor construction.*

***Do not** use a vapour/damp membrane.*

***Do not** forget the narrow areas running along wall junction.*

NB: Option 2 may cause difficulties in raising finished floor levels and consideration must be given to loading potential of insulation.

Image source adjacent ECD et al: pg12

3.4.3 Roof Element

3.4.3.1 Cold Roof Construction

A 'Cold Roof' construction is one where the roof or loft space is completely ventilated with fresh air and the thermal property of the element lies at the ceiling joist level between the living area blow and the roof space above as shown in Figure 64 (ECD Partnership, 1988, pg. 9).

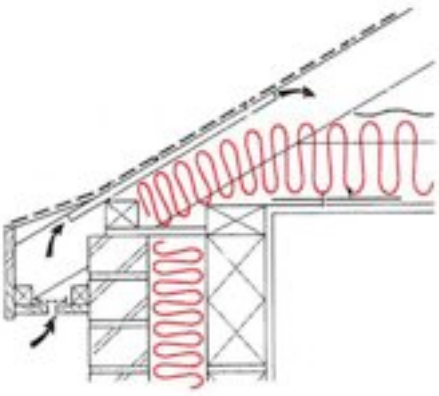


Figure 64- Detail of typical eaves assembly of a cold roof construction with insulation applied

Figure 64 shows a typical ventilated eaves detail for a cold roof construction. When applying insulation a continuous air gap should be maintained between the insulation and the top of rafter. These can be formed by proprietary products allowing for ease of construction.

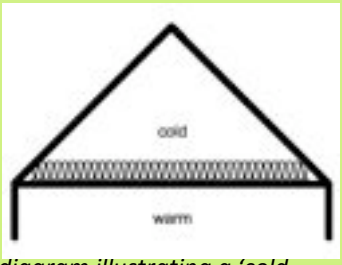


diagram illustrating a 'cold roof' where where insulation lies at ceiling joist level.

***Do not** insulate under water tanks in the loft space (unless they are raised above the joists)*

***Do** insulate all pipework and tanks within cold roof space*

***Do not** bury cabling under insulation*

***Do not** forget to fire protect around recessed light fittings when applying insulation*

***Do not** forget to leave an air gap around chimneys and flues penetrating through ceiling and insulation.*

***Do not** block up air/ventilation pathway at eaves level with insulation.*

***Do** draught-proof and insulate loft hatch.*

***Do** apply insulation between and over joists to limit cold bridging of joists.*

.





image adjacent: rolled batt insulation between joists and Warmcell insulation being applied [www.csi-itd.co.uk/loft-insulation.htm] [ww.belfastinsulation.com/warmscell.html]

Figure 65 – Picture of cellulose Insulation (CSI Ltd 2011) being applied and above sheepswool (Belfast Insulation 2011)

As an more sustainable alternative to standard mineral wool batt insulation consideration should be given to Sheeps Wool Insulation (Thermafleece) or Recycled Newspaper blown insulation (Warmcel) shown here being installed in Figure 65.

3.4.3.2 Warm Roof Construction

A 'Warm Roof' construction is one where the roof or loft space is insulated at rafter level producing a 'room in the roof' area. In this instance ventilation occurs between the roof external finish and insulation as shown in Figure 66 (ECD Partnership, 1988, pg. 9).

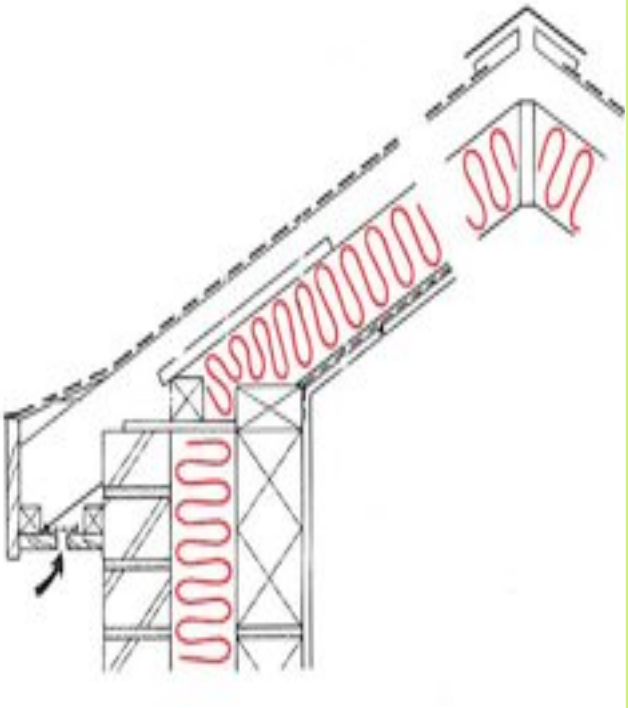
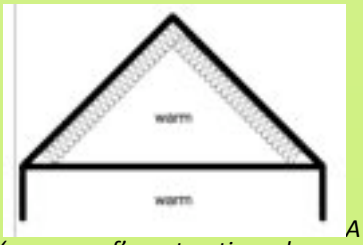


Figure 66 – Detail of typical eaves assembly for a warm roof construction with insulation applied between rafters

As with the Cold Roof construction above, a clear and continuous ventilation gap should be maintained along rafter level. Insulation could be provided between the rafters only, but for a higher thermal property consideration should be given to applying insulation to the underside of the rafters, limiting cold bridging. This could be constructed by fixing an insulated plaster board (with vapour check) across the joists.



A 'warm roof'construction where insulation lies at rafter level

***Do** remember to pay particular attention to seal service penetrations and other instances like roof lights through the rafter level.*

***Do not** forget the vapour control layer to the warm side of the insulation to avoid condensation risk.*



Image: rigid insulation between rafters Hammer Zone 2011]

3.4.3.3 Dormer Window Construction

A dormer is an extension of the roof construction to allow for a vertical opening just as a window to be located within the roof space. By their very nature, their construction is simple with structural member sizes substantially less of that from the main roof as potential loading and forces are considerably less.

As the diagram below in Figure 67 (Ellis, 1925, pg. 254) indicates, the sides of the dormer which are known as the cheeks, are of minimal depth and any up-grading of insulation values must take this into consideration and not impede on the window frame or opening.

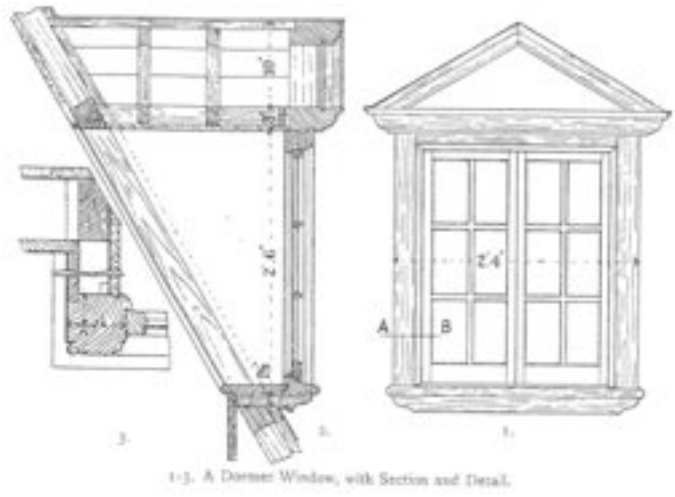


Figure 67 – Detail of traditional construction of a dormer window

3.4.3.4 Roof-Lights

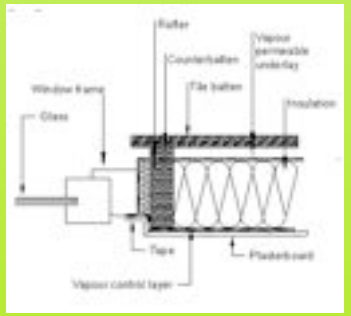
A roof light is a window or opening running parallel with the rafter line. They are common in loft extensions and usable roof space areas. Where roof-lights are present in warm roofs particular attention should be paid to sealing around the structural opening and draught-proofing the opening casement. If single glazed, consideration may be given to replacing roof-light with a modern double glazed alternative, or providing secondary glazing as a minimum.



(image sources for above and below: google images: dormer & conservation rooflight}

NB: dormers can be considered as timber frame construction and any insulation, vapour check and weather protection should be advised accordingly.





3.4.4 Penetrations & Openings within structural Elements

3.4.4.1 Windows

A necessary evil when it comes to considering the thermal integrity of a buildings fabric. Glass is by its nature is a poor insulator so the larger the expanse of glass the greater the potential for heat loss through the widow fabric. Below (Figure 68 [Ellis, 1925, pg. 231]) shows the construction of a traditional sash type window.

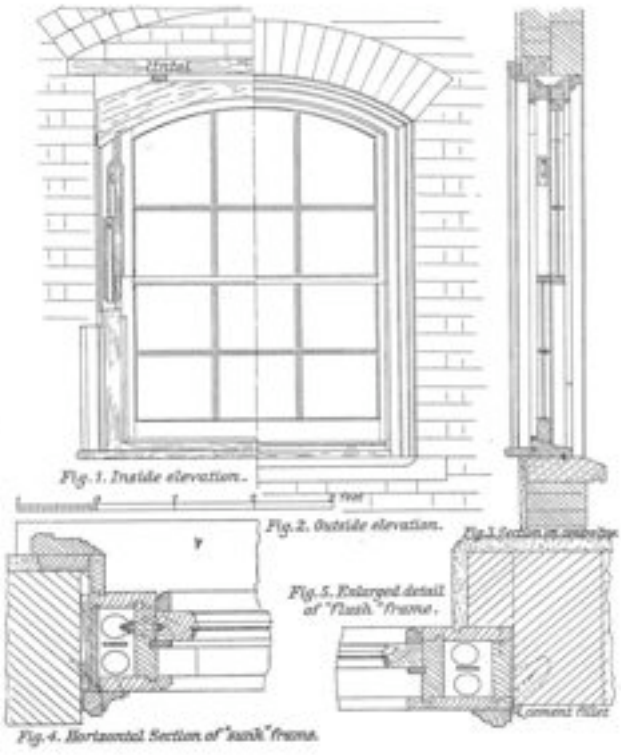


Figure 68 – Detail of a traditional construction of a timber sash window

There are some methods of increasing the thermal property of an existing window:

- Mastic seal around the window frame to the wall fabric both internally and externally.
- Provide draught proof measures between the

Energy loss through window openings can be reduced simply by the closing of internal curtains or timber shutters.

NB: if considering replacement of windows throughout the property considerations should be given to double or triple glazed units, with higher thermal properties and built in draught-proofing compression strips, also integrated trickle vents for controlled back ground ventilation.



Secondary glazing film [CSE 2011] can be a cost effective DIY solution to up-grade existing windows.



Secondary glazing can be an effective alternative to up-grade existing windows and retain historic character and appearance image DGMS 2011].

opening casement and frame if practical

- Fill in any cracks in the wall adjacent to the window opening
- Choose double glazing over single glazing
- Consider secondary glazing as an alternative to window replacement.

3.4.4.2 Doors

Entrance doors can come in differing styles and designs however they all create an opening or puncture within the building wall element, creating a potential for air penetration and leakage. Figure 69 (Ellis, 1925, pg. 204) gives examples of traditional external doors

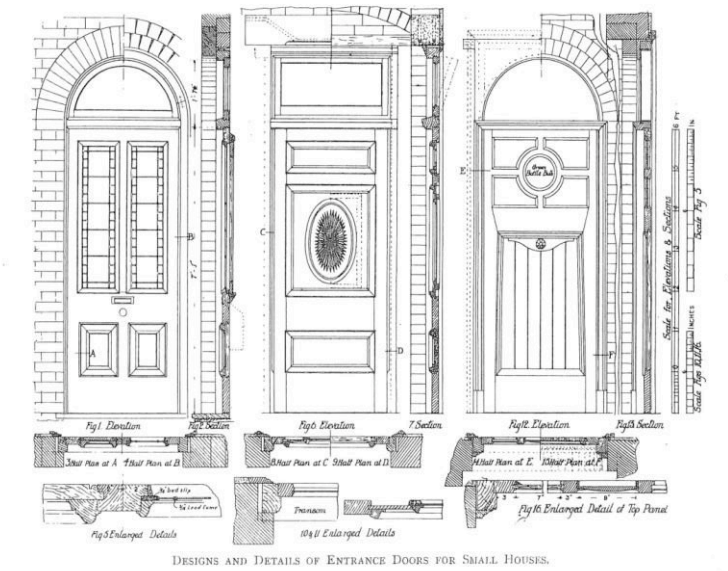


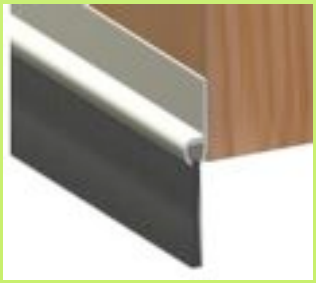
Figure 69 – Detail of a traditional external door

There are some simple methods of increasing the thermal property of an existing door and frame:

- Mastic seal around the door frame to the wall fabric both internally and externally.

NB: Energy loss through the entrance door opening can be reduced simply by the installation of a thick material curtain to the inside of the opening.

NB: if considering replacement of door leaf and frame, thought should be given to the installation a modern, low U-Value, high thermal door system, several of which can be purchased from local building merchants or DIY stores. Particular attention should be paid to the installation method and practice to avoid air leakage around frame.



Simple 'brush' draught excluder applied to the base of the door leaf. Can be fitted at varying heights and trimmed to accommodate undulations within the floor finish.



NB: when applying draught excluders and/or self adhesive draught strips, consideration must be given to frame and leaf tolerance otherwise you may find that the door no longer 'fits' within the frame if the wrong depth strip is installed.

- Provide a draught excluder to the base of the door
- Provide draught proof measures between the door leaf and frame.
- If the entrance door has a fan-light window above, apply draught-proof measures and/or secondary glazing (see windows above)

3.4.4.3 Chimneys and Flues

The traditional open fire (Figure 70 [Foster JS, 1994, pg. 196]) creates a 'draw' of air up a vertical stack terminating at roof level. This air movement allows smoke created by the burning of solid fuel within the grate to be drawn up the chimney and disposed of. Chimneys with an unsuitable 'draw' of air will 'smoke' or puff smoke back into the habitable space. Most chimneys will have a low level air brick intake positioned close to the fire to create this 'draw' or air motion, when the fire is not in use, the air movement or 'draw' continues to function and therefore can create a major element for heat loss and draught from and through the property.

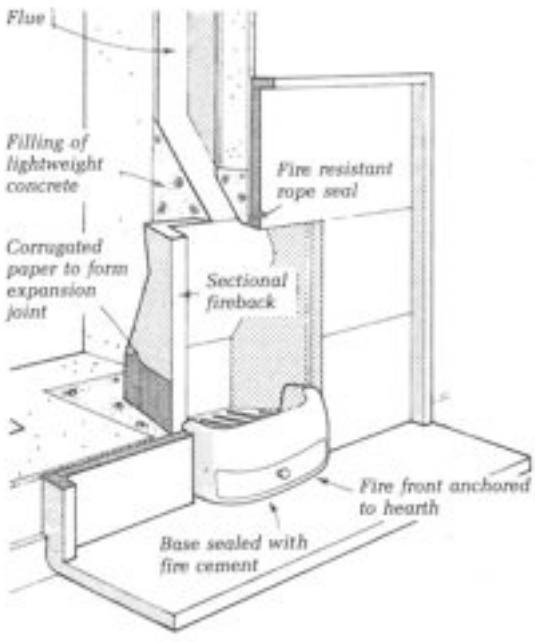
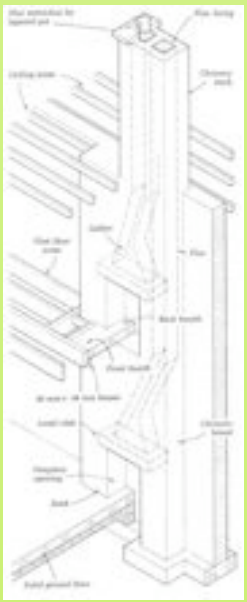
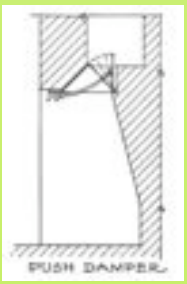


Figure 70 – Detail of a typical open fire



typical construction detail of a domestic chimney [Foster:Mitchell's pg195]



A detail of a built in chimney damper [Belle:Traditioanl details pg221]



A diagram indicating a chimney balloon in situ [www.cleanmychimney.co.uk/chimney_balloons.htm]

Methods for reducing the thermal loss and draught through an existing open chimney:

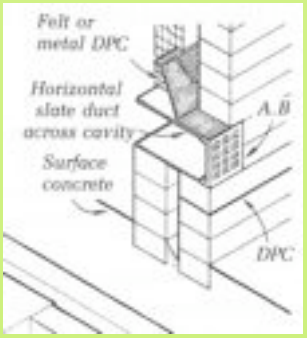
- Close the chimney dampers when not in use if present.
- Install a 'chimney balloon' within the flue when not in use.
- Convert the open fire grate and flue to a Wood Burning Stove.

3.4.4.4 Air Bricks and Room Ventilators

It has been established that background ventilation is necessary to remove smells, replace carbon dioxide with fresh air, remove excessive moisture and provide combustion air and 'draw' to heating appliances and fires.

Within modern construction this back-ground ventilation is commonly provided by means of 'trickle vents' positioned at the top of windows or 'heads'. Trickle vents are 'controlled' ventilation methods. Other controlled methods are from 'air bricks' through the structural wall element.

In older properties air bricks and room ventilation can be crude 'holes' penetrating directly from the internal space to external air and therefore providing an uncontrolled means of ventilating a room. These vents should not be sealed but up-graded to modern insulated air brick systems (Figure 71, overleaf [Triton Ultravent, 2011]) providing greater occupant control.



above:typical air brick detail [Foster:Mitchell's pg179]

below: a decorative air brick grille within a brick façade [flickr 2011]



NB: A simple means to control these air penetrations internally, is by installing an internal grille with slide action. This will allow the occupant greater control of air movement through the vent. Draught sealing should be remembered around the grille.



Figure 71 - Image of a modern insulated air brick ventilation system allowing air to move passively whilst reducing draughts.

3.4.4.5 Heating Appliances & pipework

The model identifies a typical boiler, water storage and heating system scenario found within many homes.

Boiler appliances should be well maintained and serviced in order for them to perform efficiently. Hot water pipework should be lagged (insulated) to avoid unwanted heat loss through the central heating system and hot water supplies. If a hot water storage cylinder is present then this should be insulated to a high standard with pipework running to and from lagged to avoid heat loss. A schematic of a typical domestic hot water system is presented in Figure 72 (overleaf [Fixedfast, 2011]).



image of pipe lagging [plumbing supply services 2011]



image of an insulated hot water cylinder

[housing energy advisor 2011]

NB: remember to seal around pipework penetrating from warm to cold areas to avoid air leakage. Particularly though ceiling level into loft space if cold roof construction.

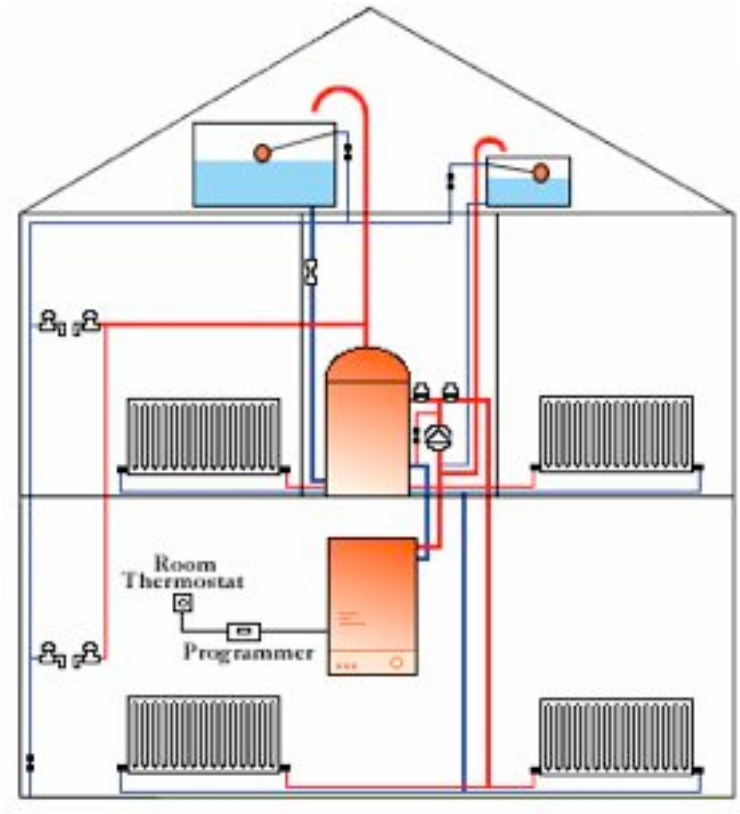
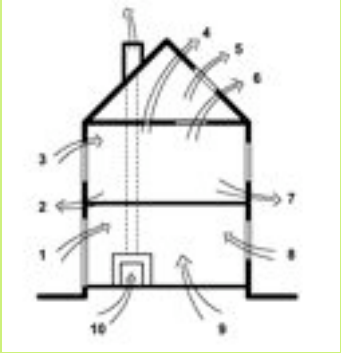


Figure 72 - A diagram of a typical domestic hot water and central heating system, identifying the routes of hot water pipes around the dwelling.

3.4.5 Summary

- Fill in any cracks in walls, floors and ceilings
- Seal cracks & holes around pipework, drainage and cable runs penetrating the property not forgetting the roof space.
- Seal around windows and external door frames
- Draught-strip windows and external doors
- Draught-strip loft hatch (and insulate if cold roof)
- Suggest secondary glazing measure if practical
- Suggest loft insulation at joist level if cold roof, and rafter level if warm roof.
- Suggest full filled cavities or internal wall insulation if practical
- Suggest the consideration of applying an external insulated render system if practical
- Suggest the application of an internal parge coat to masonry inner leaf if practical
- Suggest closing chimney dampers or installing 'chimney balloons' for when not in use
- Suggest the conversion of the open fire to sealed wood burning stove and insulated flue.
- Do not seal or block up existing air bricks but suggest insulated controlled back ground ventilation paths (Trickle vents and airbricks)
- Make sure controlled ventilation has been considered to avoid excessive moisture build up within fabric, resulting in mould growth



ventilation pathway diagram (redrawn ECD.et.al:.pg19)

Chapter 4 – Looking Forward

4 Looking forward

Discussion in this chapter focuses on the opportunities for carrying this research forward in the context of the development of educational resources and the structuring of awareness and activist campaigning.

Beyond an intention to better understand the challenges of delivering improved domestic energy efficiency, the research presented in this report has been undertaken with the goal of delivering a useful resource for future educational or activist campaigns at the local scale. Working in Penarth, we have endeavoured to place our research firmly in the context of this town. This has entailed discussions with community members, council employees and activists belonging to the Greening Penarth Group (GPG).

"…the research presented in this report has been undertaken with the goal of delivering a useful resource for future educational or activist campaigns at the local scale."

4.1 Context

As a young organisation, GPG is lucky to have a number of enthusiastic members who are committed to working for an improvement in a variety of aspects of sustainability in Penarth. Notable achievements to date have included the 'Shopping in Penarth' scheme, 'Open Garden' events, the organisation of a community orchard and basis for a community garden, and a food festival. Numerous other initiatives have been discussed.

Look to prior successful events held by GPG to design future events.

As an outgrowth of this research, we hope to support the development of an energy efficiency campaign. We have met with leading members of GPG to discuss concepts of such a campaign and to understand available resources, perceived feasibility and potential obstacles to success.

Understand potential obstacles and available resources.

4.2 Campaign concept

The vision of a campaign to encourage homeowners to improve their energy efficiency has been an inspiration throughout our project. One of the goals of our work has been to produce a set of resources which might be used in support of a campaign to promote efficiency. We recognise that we have only been able to provide the foundation for this effort and that it is important that the campaign organisers determine a campaign structure which is appropriate to their capabilities and resources. In light of this we have attempted to structure our work in such a way that it can provide inspiration, guidance, and historical context for a variety of potential campaign formats.

A comprehensive review of the principles underlying communication of climate change and structuring of awareness and educational campaigns was carried out in the first episode of research conducted by this group. This review was summarised in two reports (see Creaney; Forman in Alexander, 2011) and provides a useful background for those considering forming a campaign or forming a communication strategy with regard to environmental issues.

As an outgrowth of this research, we feel that campaigns and communication should observe the following guiding principles:

1. Reach community members of the broadest possible demographic range
2. Use a variety of media and repeated messaging
3. Frame messages in a variety of ways -- largely positively and in 'outcome' terms -- but accounting for the fact that different people will

"We recognise that… it is important that the campaign organisers determine a campaign structure which is appropriate to their capabilities and resources."

Useful information regarding communication, campaigning, and community participation is contained in reports produced during background research for this project.

Based on background research, this report presents guiding principles for successful communication and campaigns.

be spurred to action by different message framing

4. Guide people to proactive response and engagement with the issue(s) of the campaign

When designing a campaign, it is important to carefully consider its message. Changing attitudes towards sustainability at a community and indeed at a world level can only come when there is a convergence of understanding about what exactly it means (Barton 2000). The term sustainable development hardly grips most people; in fact it is usually falsely understood to focus only on environmental issues, particularly in the construction industry.

While the focus on reducing emissions from building is important, careful consideration of the opportunity for social cohesion and capacity building, both in an economic sense and resilience to climate change. The idea of framing the issue as one of health may be worth pursuing. Health is something people understand inherently and while it is important that people understand the implications of their actions and choices in terms of energy and resources, results matter more.

"Health is explicitly anthropogenic, where sustainable development is sometimes falsely side-lined as a 'purely' environmental issue. Health of our community, health of the city, health of the planet, health of our children – all have a convincing ring, and health relates very well to the reasons for reinventing neighbourhoods: local work, safety, community, equity, accessibility, climate stability, clean air and water etc." (Barton 2000 pg 248)

While forming campaigns with a narrow focus helps to make them more easily achievable, it is important to consider all possible foci for an energy efficiency

Carefully consider the message behind campaigns.

Consider the opportunity for building social cohesion.

Consider framing energy efficiency in terms of implications for comfort or reduced pollution. "Health is something people understand inherently…"

While narrowly-focused campaigns are easier to organise, consider using a variety of methods to reach a target audience.

campaign. An effective strategy for campaigning will have carefully examined how it intends to reach members of the public.

The approach of 'radical activism' is not discussed in this report. There are many arguments for (and against) taking such an approach to communicating and motivating others. The focus of the research presented in this report is on the development of widely-inclusive approaches. Although it has been not been discussed here, the benefits of radical activism may be worthy of consideration when developing a campaign strategy.

Radical activism may play a useful part of a campaign to motivate behavioural change or communicate messages.

Penarth has a number of individuals with technical expertise who are not members of GPG.

Proximity to Cardiff means a large number of university students live within several miles of Penarth.

An abundance of institutional resources are available to campaign organisers.

4.3 Available resources

GPG has a membership of roughly twenty members including an architect, an engineer, and several individuals with an interest in energy efficiency and the built environment but with limited expertise. Living in Penarth, but not members of GPG, are numerous individuals with relevant technical expertise including academics, professionals, and tradespeople. While the population of Penarth on the whole is older, close proximity to Cardiff means many university students live within several miles of the town.

Notable institutional resources that might support an efficiency campaign exist, including the Energy Savings Trust, the Vale of Glamorgan Council, the Vale Council Voluntary Services (VCVS), the Welsh Assembly Government, the Penarth Public Library, several universities and schools.

Local businesses include a DIY shop in Penarth and numerous builders' merchants in close proximity to the town, as well as numerous builders and tradespeople.

Congruence may be found with the Governments Renewable Heat Initiative and Feed-in Tariff programmes, the Cardiff Home Energy Volunteers, Canton Carbon Cutters, the Energy Savings Trust Green Energy Scheme, and the Household Energy Service operated by Lightfoot. Additionally, advice or collaboration may be found through myriad other organisations and initiatives working to promote energy efficiency. The 'Environmental Champions' appointed within organisations such as the Vale of Glamorgan Council or the 'Eco School Board' employees of local schools may provide useful points of contact for collaboration in an efficiency campaign.

Consider liaising with local businesses and tradespeople to form a campaign. Not only will this strengthen your ability to reach your audience, it will also support the local economy.

Examination of the merits and costs of various campaign formats and approaches to message framing should be undertaken.

4.4 Campaign format and framing

Discussion with leaders of GPG has explored the merits of various campaign formats and approaches to framing campaigns. Continued examination of these merits as well as potential obstacles will need to be undertaken to ensure that an appropriate direction is selected.

The concept of a year-long or permanent campaign addressing domestic energy efficiency was well-received during discussion. An alternative to this is a single-issue or short (1-3 month) campaign being undertaken. A principal factor influencing the format of the campaign is the availability of time and resources.

Much discussion has centred on how best to reach the largest possible cross-section of the Penarth community. An overarching message gleaned from research has pointed to the success of repeated messaging and multiple

How long will the campaign last? Will it be a single-issue short-term effort, or a permanent complex campaign?

How can the largest possible cross-section of Penarth be reached?

communication strategies in building environmental issue campaigns. Further debate should be undertaken to explore the merits of framing an energy efficiency campaign in terms of potential for financial savings versus the reduction of environmental impact, or some combination of the two.

Rather than decide for GPG what subsequent campaigns would be, it was decided it would be far more beneficial for campaigns to be an organic process derived from the needs of the community at a given time; the principles should remain the same for the next several years, allowing GPG to dip into this document for relevant information and develop strategies based on what is suited for that particular time e.g. a newly available grant or incentive. This would allow campaigning to be a dynamic process, specific to Penarth's needs at any time. This is not ambiguity for ambiguities sake, quite the opposite in that the efficiency group feel that narrow scope and structure can help in gathering momentum and keeping people interested but a working process

Ensure social equity is delivered by the campaign.

Framing energy efficiency in terms of financial savings may be useful.

The development of a campaign can be an organic process; responding to available resources and limitations.

4.4.1 Concept of an 'Efficiency Champion'

From the experience of surveying residents' homes we found that most residents were eager to receive technical advice and guidance to help them improve the energy efficiency of their homes. We also found that testing and surveying these homes required a degree of technical proficiency; including an understanding of energy flows within a building, construction technique, as well as competence using various forms of testing equipment and analysing testing results. The scope of knowledge that we as students possess is something which may either already be held by members of the Penarth community (and GPG) or which could be developed over time. Spreading

An Efficiency Champion could spearhead a campaign, serve as a point of contact, and provide technical expertise.

More than one persons could share the role of Efficiency Champion.

knowledge about efficiency upgrading throughout Penarth could be facilitated by having one or more people who can serve as an 'Efficiency Champion.'

The Efficiency Champion would fulfil several roles. Chief among these is to serve as a point of contact for those seeking assistance. In this capacity, the Champion would provide advice, access to resources, as well as serve as a gateway to various contacts and services. The Champion could work in conjunction with an energy efficiency sub-group to publicise a broader campaign run by GPG.

In order to bolster the resources available to GPG in conducting an efficiency campaign, the group might consider soliciting the involvement of an Efficiency Champion from outside the group. Given the proximity of an number of universities as well as a large diverse population in Cardiff, it is likely that an a non-member could be found to serve as Efficiency Champion if no one within GPG is qualified or willing. The experience gained by serving as a Champion could provide useful vocational skills or background. In a broader sense, this could provide a form of unpaid employment (or with grant support it could provide paid employment). This serves purposes of social well-being and economic vitality which are a theme of sustainability discussed elsewhere in this report.

Discussions with GPG leaders identified the lack of availability of volunteers with adequate technical expertise as a potential barrier to filling this position. In these discussions, strategies for overcoming this potential were considered. These included splitting the position between two or more volunteers with adequate expertise but

The Champion could serve as a gateway to various contacts and services.

Consider reaching outside of GPG to find an individual to serve as the Efficiency Champion.

The experience gained while serving as a Champion would provide valuable experience and skills development. This could also provide vocational experience for some individuals. This offers a form of social benefit from the campaign.

Advertising within local universities or non-academic institutions may reach previously uninvolved people.

inadequate available time. The possibility of advertising within Penarth as well as the local universities (for instance, within architecture departments) was also discussed. It was speculated that the Champion 'job' could be made more attractive by presenting the benefits of vocational skills development discussed above.

4.4.2 Seasonal Campaigning

During discussions with GPG leaders, an idea that piqued their interest was the concept of seasonal campaigning. By presenting in campaign outlets elements of energy efficiency during the times of the year that they are most relevant, owner-occupants can be encouraged to take specific actions on a continual basis. This would be a less resource intensive approach and would style the campaign in terms of 'outcome framing.' The seasonal campaign breaks the work into smaller more manageable chunks. One of the key challenges to ensuring the success of campaigns that has been identified is ensuring that clearly defined roles and manageable workloads are established. Seasonal campaigning is an easy and practicable way of structuring a campaign.

When we examined the idea of seasonal campaigning, it brought some interesting ideas to light. Framing issues as abstract environmental problems as discussed earlier can alienate people and make them feel powerless. Framing issues in a way that people inherently understand would seem to provide a better chance of success. Take family homes for example, they are used to preparing for the 'back to school' time of the year, they are used to preparing for Christmas and spring. With this in mind, we return to the question of what influences behaviour and what makes people take action when presented with information. In Section 1.2 we mentioned that people

Consider a seasonal approach to framing campaign efforts.

"The seasonal campaign breaks the work into smaller more manageable chunks."

"Framing issues as abstract environmental problems… can alienate people and make them feel powerless. Framing issues in a way that people inherently understand would seem to provide a better chance of success."

made decisions based a result if a combination of experience, education and information. Assuming the campaign can provide the education and information, what are their experiences and how can you relate it to the seasons?

A proposed format is given here. This is not supposed to be definitive, but rather to give an idea of how a campaign might be framed (Figure 73).

- Approaching summer, we remind people of the importance of draft proofing right at the time of year when they want to be switching their heating off for the season.
- Moving into autumn, we remind them of the importance of boiler servicing and understanding controls as they begin to think about using their heating again
- Moving into winter, we encourage people to make fabric improvements such as loft insulation just in time for the cold winter ahead.
- Moving into spring, we encourage people to change their behaviour while the memory of expensive energy bills is fresh in their mind and they can easily see the relationship between each.

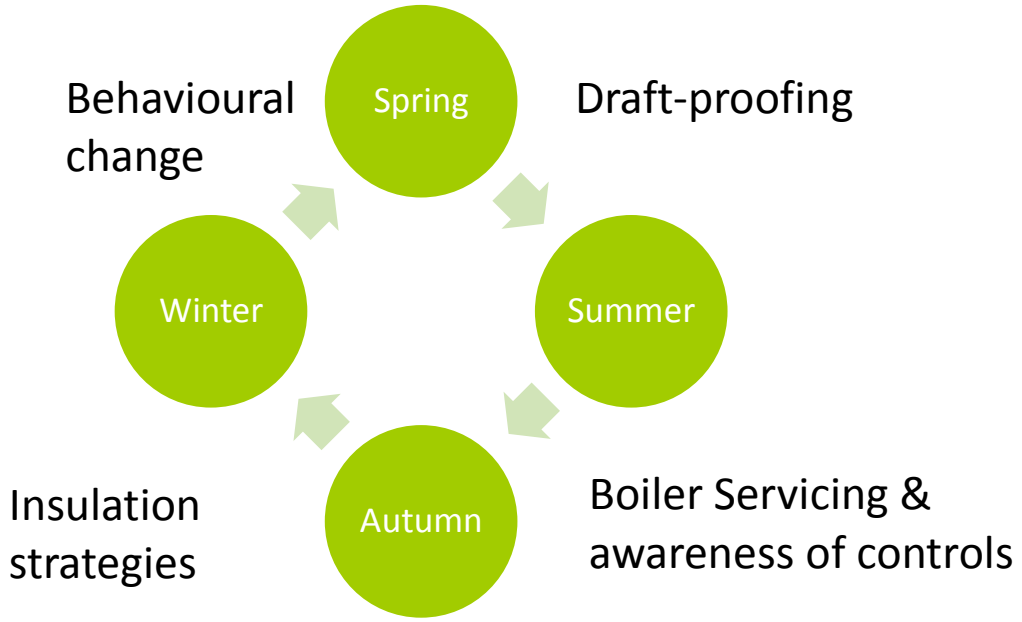


Figure 73: Diagram showing actions to present in a seasonal campaign with relation to different times of year.

4.4.3 Providing information

An important role that should be fulfilled by an energy efficiency campaign is to provide information to homeowners and residents. Numerous examples exist of activist campaigns whose success has been thwarted by not being supported by educational resources. In light of this, an energy efficiency

campaign should seek not just to motivate people to change behaviours or alter the physical fabric of their homes, but it should also provide as much of an information resource in support of that motivation as is possible.

In large part, the information required to support a homeowner in improving energy efficiency already exists. The principal challenge here is in mapping this information and making it readily accessible. Two forms of information provision are likely to exist here, including directly-provided guidance as well as redirection to third parties (e.g. the Energy Savings Trust, tradespeople).

The Penarth Public Library has made a bookshelf available to GPG and this space could be exploited by placing a variety of resources including books, grey literature, information leaflets, and summaries of efficiency upgrade projects carried out in Penarth and outside of Penarth.

A campaign should not only seek to motivate, it should also provide support. This support can be provide directly by the campaign organisers or by referring to third parties.

4.5 Successful campaign models

4.5.1 Bristol Green Doors – about it

One of the more interesting case study examples of awareness campaigns was the Bristol Green Doors (BGD) campaign. It followed the format of an existing arts trail in the city whereby people who had made energy efficiency upgrades to their homes invited local residents into their homes to see for themselves what had been done. Having over 70 volunteer homes, the BGD team mapped the homes and displayed posters throughout the city advertising the open weekend and invited people to come along and see for themselves. A more detailed examination of the campaign was reported in the first episode of the group's work in Penarth. The reason this

Bristol Green Doors established a 'trail' connecting residents hosting open door events.

One of the reasons that the Green Doors campaign was so successful was that it followed a format that the city's residents were familiar with for almost twenty years.

may be of interest to any campaign in Penarth is the idea of using an existing format that people are familiar with. One of the reasons that were cited to explain why the BGD was so successful was that it followed a format that the city's residents were familiar with for almost twenty years.

The idea for Penarth is that any subsequent campaigns could first try and identify a format that residents are familiar with, and perhaps piggy back that existing format to garner interest in a home energy efficiency campaign. The opportunity of using the Open Gardens event held by GPG as a possible model is discussed below.

The idea of showcasing homes also helps develop social cohesion and make the improvement works more tangible and relevant to Penarth residents who may be considering upgrade works but are confused about the process or benefits.

One of the key points arising from researching the BGD campaign was the importance of being careful of the implications of adopting too much of a top-down approach; in terms of social sustainability, adopting a bottom up approach whereby campaigns are a function of the community they wish to serve seems to be a much more favourable approach. A detailed analysis and critique of BGD was provided in Episode 1, should it need to be explored further.

4.5.2 10:10 campaign – about it

The *10:10* campaign founded by The Guardian offers a useful model for a campaign in Penarth. The campaign was devised to involve participants by gathering pledges to reduce individual or institutional carbon footprints by 10 per cent in a year. This campaign is an excellent example of a positive format which encourages people to join a

The Green Doors campaign follows a very similar model as the Penarth Open Garden event does.

Showcasing homes helps to develop social cohesion.

Making improvement works more tangible and relevant to residents is a noteworthy outcome.

This is a bottom-up approach to building community participation.

The 10:10 campaign was designed to encourage individuals to join a collective effort by pledging to reduce individual carbon emissions by 10%. It utilised advertisements showing celebrity and non-celebrity figures an relaying their testimony about actions taken to reduce their carbon footprint.

broader effort to cut carbon. Campaign promotion utilising photographs and testimony from celebrity as well as non-celebrity figures delivers a message that you, as viewer, can and should join a collective effort. The use of branded signs, stickers, and jewellery reinforces this message; the campaign gained a positive feedback as greater numbers pledged their commitment (Figure 74).



Figure 74: Screenshot of the webpage for the 10:10 Campaign (10:10 Campaign, 2011).

This format would make an interesting model for use in Penarth. Well-known figures from the community, as well as workers, union members, and other 'everyday people' could be portrayed individually and with families in advertisements for the campaign. In testimonials describing their actions and the significance of the campaign to them, their influence could encourage campaign viewers to pledge their involvement.

Such a campaign would be made much more effective if coupled with development of an educational resource and support network for those pledging involvement. By securing robust support for anyone becoming involved and ensuring that this support is visible and highly accessible, individual involvement in the campaign is more likely to lead to positive outcomes.

'Everyday' people, as well as well-known figures within the community could be portrayed in campaign advertising. This promotes the harnessing of 'opinion leaders.'

The campaign "would be made much more effective if coupled with development of an educational resource and support network for those pledging involvement."

4.5.3 Renewal areas

The Vale of Glamorgan Council operates a programme called 'Renewal Areas,' which "form an integral part of the Council's Private Sector Housing Renewal Policy and enable the Local Authority to focus action on particular communities' needs with Area Based Action" (Vale of Glamorgan, 2011). As part of a project conducted in Penarth, council officials conducted a survey of households (the number surveyed is not known) in Penarth in 1999, examining building condition (100 per cent external surveys and 10 per cent randomly selected internal). 76 per cent of the surveyed households were determined to be in "unfit condition." Further details of the findings can be found in Appendix I, 'Penarth Central Renewal Area, 2000-2010' (Vale of Glamorgan Council, 2011).

An important outgrowth of these surveys was the launch of "Group Repair Schemes" operating within the designated Renewal Area within Penarth. This was a grant scheme which covered at least 80 per cent of the cost of works. The scheme worked by targeting blocks of houses at time, working through the neighbouring area over the ten-year life of the scheme. Works included replacement of chimneys, doors and windows, re-rendering of walls, and replacement of roof coverings.

This could serve as an interesting model to duplicate with relation to energy efficiency retrofits. By achieving a 'critical mass' in Penarth, homeowners not involved in the scheme may be encouraged to upgrade their houses by witnessing the upgrades in the neighbourhood. A scheme such as this, does of course present the need for a very large capital investment. Presumably, this would require

The concept of Renewal Areas and Group Repair Schemes used by the Vale of Glamorgan Council could be adopted to use for efficiency-oriented retrofit programmes.

" By achieving a 'critical mass' in Penarth, homeowners not involved in the scheme may be encouraged to upgrade their houses by witnessing the upgrades in the neighbourhood."

Adopting this model would require an extensive effort to secure funding.

an extensive effort to secure funding. Nevertheless, this is a very interesting model for future action in Penarth.

4.5.4 The Act on CO_2 campaign

The interdepartmental initiative called 'Act on CO_2' (Directgov. 2009c) involves the Department of Energy and Climate Change (DECC), the Department for Transport (DfT) and the Department for Environment Food and Rural Affairs (DEFRA). This campaign includes a large amount of media advertising focusing on the link between CO_2 emissions and climate change. As pointed to in Episode 1 of this research by Creaney and Forman (Alexander M., et al., 2011), the fear-provoking tone of some of these advertisements has been of questionable value to promoting positive engagement with the issue. This sort of approach can create *emotional distance* between an issue and audience member. Despite the negative framing of some of its media campaign, it does represent a noteworthy presence in contemporary awareness campaigning about climate change. As part of the campaign, the Energy Savings Trust operates local advice hotlines which provide information and tools to assist in saving energy. The Energy Savings Trust, in partnership with the Act on CO_2 campaign also offers 'The CO_2 Calculator' which allows for the calculation of direct CO_2 emissions based on lifestyle and provides recommendations for reducing these emissions.

4.5.5 The success of the GPG Open Gardens events

The 'Open Gardens' events that have been held in Penarth to date have been widely attended and been met with great success. During the events, attendees visit a number of house gardens belonging to event participants. The purpose is to share enjoyment of notable gardens, exchange knowledge and expertise and to provide a social occasion within the community. At these events, maps to participants' homes are sold, and

Many of the advertisements run by the Act on CO_2 campaign are examples of fear-provoking message framing. This approach can have the effect of creating emotional distancing from the issues.

As part of the campaign, the Energy Savings Trust operates local advice hotlines.

The format of the Open Gardens events could be used to promote efficiency upgrading . Open gardens promotes knowledge exchange, enjoyment of gardens, and provides a social occasion for community members to share with each other. This has a positive effect on the social fabric of Penarth.

refreshments are provided to attendees.

A similar format could be adopted to publicise green homes within Penarth, or perhaps in an adjacent community. Another possibility would be the organisation of excursions to model homes outside of Penarth, such as those involved in the Technology Strategy Board's 'Retrofit for the Future' programme or in the 'Green Streets' programme funded by the Institute for Public Policy Research (IPPR) and British Gas. Visit such as this would be made relevant by focusing on building typologies particularly relevant to Penarth such as Victorian, Edwardian, and Post-War era structures.

4.5.6 Further design considerations for a media campaign

The importance of a creative and varied approach to communicating what is often a highly technical subject matter cannot be overstated. So too is this character important to bridging the alienation many feel in response to the dire nature of climate change issues. A media campaign which endeavours to be outcome-oriented, positively-framed, and which inspires its audience to join collective efforts will be afforded a high likelihood of success.

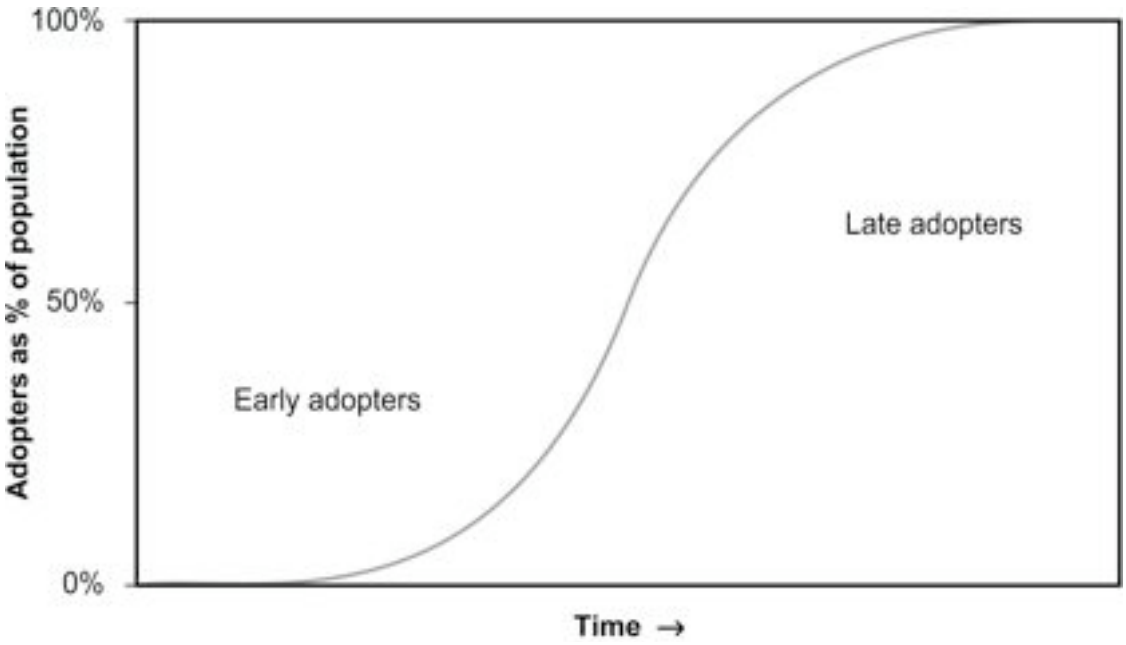


Figure 75: Rate of adoption of new behaviours in social systems. A critical mass effect can be observed in many campaigns.

A media campaign highlighting success stories of individuals or businesses within the community who have reduced their energy use would provide a positive format for advertising. This draws on

the concept of "opinion leaders" discussed in Episode 1 of this research. There is a convincing body of research which points to the impact that opinion leaders can have in influencing the behaviours of others (Figure 75 [Keys et al. 2009, adapted from Rogers, 2003]). One example of this concept being used in advertising is a campaign run by Bullfrog Power (Figure 76: Images of Bullfrog power advertisements are models of opinion leader oriented messaging



Figure 76: Images of Bullfrog power advertisements are models of opinion leader oriented messaging

A novel idea for a campaign theme that has been discussed by the group would publicise the financial savings associated with improved energy efficiency. This could see a series of advertisement slogans such as 'What would you do with an extra £100?' 'Easy money,' or 'My DIY earned me a holiday.' Such a campaign could then direct the audience to a variety of possible resources.

This idea could also be coupled with a regular column in the Penarth Times or a similar form of media. This column could provide monthly or seasonal tips on timely actions to be undertaken to improve efficiency in an easily comprehended format such as a checklist as discussed in Section 4.4.2. This could include advice on winterising, low-energy cooling, or summertime maintenance projects, as well as providing discount coupons or other support services. By appearing regularly, this column could serve

Campaigns should bridge alienation. Consider the use of 'opinion leaders.'

Campaign framing strategy could include the use of advertising slogans such as 'What would you do with an extra £100?'

to reinforce the campaign messages being delivered through other avenues.

Effective structuring of the campaign may be enabled by focusing on specific approaches. In the context of behavioural changes, this might include publicising a 'Cardigan Day' to encourage wearing insulating clothing, or thermostat reduction campaigns. Specific interventionist approaches might include loft insulation; draught-proofing, plugging up unused flues and chimneys, or boiler servicing and upgrading.

Reinforce campaign slogans with a regular advice column in the local newspaper, discount coupons, or other support services.

4.5.7 Workshops, surgeries, community interaction

A drop-in clinic or 'surgery' event could be held during which members of the public were engaged in discussion and consultation about energy efficiency issues. This event could provide a venue for dissemination of information and could be staffed by people with energy efficiency expertise as well as by laypersons available to pass out information literature or direct visitors to appropriate resources. GPG has investigated the option of using a vacated shop-front in the past for similar purposes. Another possibility would be to park a caravan or erect a temporary structure or pavilion in a central location in Penarth for use as a venue. Similarly, workshops could be held to provide specific advice on popular undertakings such as draught-proofing or loft insulation.

A drop-in clinic could make use of disused shop fronts. This would have the added benefit of having a regenerative effect on the town streetscape.

Clinics could also be held in a temporary structure or purpose-built pavilion in a central location.

By working with children in-school or through after-school programmes, not only can the message of sustainability and energy efficiency be taught to a new generation of Penarth residents, but reinforcement of the campaign message can be delivered to the parents of children.

Working in schools can educate children as well as reinforce messages already received by the parents.

Consider the mutually-beneficial aspects of involving local businesses or tradespeople in a campaign.

Garnering the participation of local businesses (retailers or tradespeople) could comprise part of a multi-pronged campaign. By offering discounted goods or services, businesses could benefit from increased patronage as a campaign partner. A dedicated section of the local DIY shop, for instance, could serve to provide goods covered in the efficiency campaign. Similarly, a local contractor could offer a loft insulation service at a discounted rate in exchange for the publicity gained by being a campaign partner.

A highly-visible structure situated in Penarth could provide a focal point for the campaign as well as serve as an educational resource. This could take the form of a pavilion or life-scale model positioned on the high street or on the grounds of the train station. Another idea discussed has been the 'adopting' of a bus stop in town to demonstrate double glazing, solar shading, insulation, or thermal bridging.

A highly visible pavilion or similar structure would provide a focal point within the town for the campaign.

4.6 Challenges

Obstacles to running a campaign in Penarth exist in the variation in demographics and the physical landscape.

Anecdotal reports indicate the presence of a broadly-shared perception in Penarth that it is a community comprised of at least five distinct sub-groups. These physical areas (including Cogan, the Headlands, the Marina, Downtown, and the estates to the west of Redlands Road) exist in an abstract sense as discrete communities within Penarth. Pedestrian transit and vehicular travel between these areas is perceived as being limited and many seem to feel that this translates to the existence of several distinct communities within Penarth.

The variation of demographics and physical landscape in Penarth may present challenges to running a campaign.

Understand the impact of physical barriers, as well as abstract barriers like neighbourhood divides.

This division is likely to be reinforced by the topography of Penarth which separates the Marina and other districts by large changes in altitude as well as by large heavily trafficked roads (most notably Redlands Road) which limit pedestrian movement.

The coexistence of a professional class largely comprised of people working in nearby Cardiff city, with a working class experiencing high rates of unemployment and relative disadvantage creates a socioeconomic divide in Penarth which may also pose an obstacle to a broad-reaching campaign. To address this obstacle, campaign design should ensure appropriate message framing, varied approaches, and where necessary physical outreaching such as doorstop visits or leafleting.

In discussion with GPG leaders, there is a perception that some GPG members have been reticent to work on domestic energy efficiency campaigning due to a feeling that they lack requisite skills or expertise. This can be addressed through knowledge exchange within GPG and through consultation with experts provided by outside institutions such as the Energy Savings Trust.

Finally, an inherent challenge to improving energy efficiency is that targeting the most important factors of efficiency is often seen to be a more difficult undertaking than targeting some of the more superfluous factors. For instance, many campaigns encourage homeowners to install appropriate levels of loft insulation because this is a very straightforward message and an opportunity for a relatively easily obtained improvement in efficiency. Yet equivalent improvement could be gained at no financial or resource cost if, for instance, temperature set-points were reduced in homes, or occupants were encouraged to wear heavier clothing in winter. Effecting behavioural change,

Penarth has a varied demographic make-up. This should highlight the need for varied approaches to message framing.

How can reticence on the part of volunteers to involve themselves in a technical subject be overcome?

Are 'easy wins' easily won?

although typically designated as an ideal first-tier approach to reducing energy consumption, is broadly accepted as being more difficult to realise than physical interventions (Gordon, McDermott, Stead, Angus, & Hastings, 2006). To an extent, this asymmetry may be difficult to overcome. A campaign strategy may be devised, however, that encourages uptake of "easy wins" while also communicating the importance of considering the "difficult" issues such as behavioural change. By directly addressing the fact that these low-environmental impact and low-cost actions bring about very high levels of benefit, campaign audiences can at least be afforded the opportunity to follow an ideal hierarchy of action.

"Effecting behavioural change, although typically designated as an ideal first-tier approach to reducing energy consumption, is broadly accepted as being more difficult to realise than physical interventions."

4.7 Educational resources

4.7.1 Model

By revisiting the business plan produced by GPG, which explains their overall goals for energy consumption within Penarth, the authors asked themselves, from a social aspect 'who are the people that GPG are trying to reach?'

By establishing that socially, Penarth home owners were of no single typographic social order it was fundamental to consider how best to encourage differing groups of people to up-grade their properties in order to start reducing the energy consumption carbon emissions from the residential sector within Penarth.

It was important to the group to be able to reach out and educate people of different social standings and age groups throughout Penarth as a whole and therefore important to establish some basic principles to be able to carry implementation forward.

A three dimensional physical model has been produced to aid in the understanding and education of building construction. It will hopefully act as a visual link to the recognisable built environment around Penarth and be a starting point for the public to interact and encourage awareness on the subject of energy consumption and waste.

When considering possible up-grading to existing buildings it is important to establish and understand the construction of the property in question. A model (*not to scale*) has been produced to give an initial visual understanding of the basic traditional construction methods that are most likely to be found within homes in Penarth. The model has been further supported by construction details and images in Section 3.4 for further



Beyond the traditional construction methods discussed here, modern methods of construction, such as concrete or steel frame, may be used when upgrading. Solutions like these would be most associated with multiple occupancy structures such as purpose build apartment blocks (not to be confused with larger property conversions into separate flats).

understanding of up-grading principles identified.

The traditional construction methods identified include:

- Masonry Solid wall
- Masonry Cavity Wall
- Timber frame Wall
- Timber Pitched Roof Construction
- Solid Ground Floor
- Suspended Timber Ground Floor

It has been established earlier in section 1.2 of the report that the fundamental principle of reducing the carbon emissions from homes is to reduce the air infiltration and exhaust from the building fabric. This section will look at established methods of up-grading existing properties of a more traditional construction as mentioned above to reduce un-wanted air movement, whilst allowing controllable ventilation needed for the building and occupant comfort.

4.7.1.1 *Air infiltration and exhaust pathways*

The model should be used as a visual aid, along with the diagrams and details in Section 3.4, to help explain to property owners the most common pathways in which uncontrolled air can penetrate or leak through the building fabric. This is discussed in detail in Section 1.2 of this report

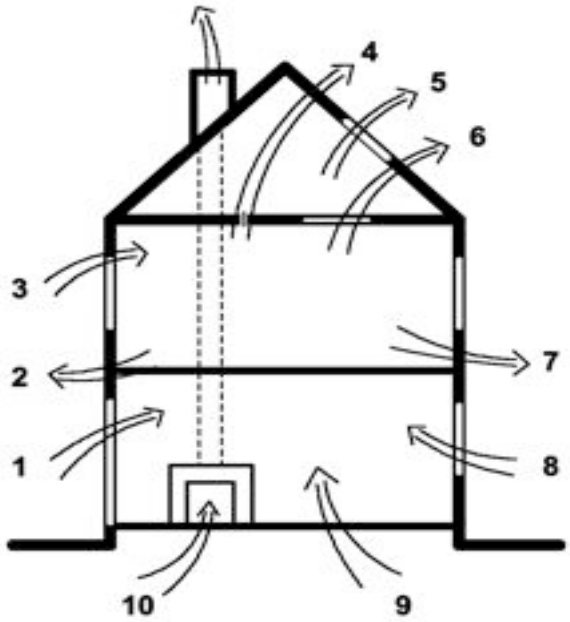


Figure 78 - Typical Air infiltration pathways redrawn from (ECD Partnership, BSI & Baker.N et al :1988: A designers manual for the energy efficient refurbishment of housing. Milton Keynes: BSI: p19)



Figure 77 -the model has been constructed in such a form as to explain the construction and possible air leakage pathways

Air infiltration occurs through:

-Cracks around doors

-Unsealed junctions at building elements

-Cracks around windows

-Cracks around pipework and cable penetrations

-Roof openings

-Loft hatches

-Cracks in the building substrate

-Badly sealing window casements

-Ground floors

-Unsealed chimneys.

4.7.2 Pamphlet

Producing pamphlets can be an effective and affordable way of communicating with a broad audience. We have developed a pamphlet that conveys information about improving energy efficiency through the 'lean-clean-green' hierarchy (Appendix P). This example frames the message in positive terms as well as points to a broader effort to improve efficiency being under way in Penarth. This is one example of how a pamphlet could be written and other approaches should be examined and feedback on their effectiveness gathered.

Pamphlets can be an affordable and effective way of communication.

Our example uses positive language, frames the message in 'outcome' terms, and points to a broad collective effort being underway in Penarth.

Chapter 5 – Conclusion

5 Conclusion

Building on research carried out during Episode 1 of the research project, this report presents the results of six months spent exploring energy efficiency in the domestic built environment. Penarth provided an interesting lens for this exploration and a number of interesting lessons were gained.

Against a backdrop of growing commitment on the part of the government to address climate change, energy efficiency has risen in the priority list of both public and private bodies. This has manifested itself in a growing number of governmental initiatives targeting initiatives. There is evidence that take-up of energy efficiency measures is gaining momentum at the domestic scale (World Economic Forum, 2010). It is very apparent, however, that there is a great deal left to be done to assure that energy consumption in the domestic sector is as efficient as possible.

The implications of improving energy efficiency are not just environmental. Although air pollution, greenhouse gas emission, habitat loss, resource depletion, and broader ecological considerations are integral to the arguments for why energy efficiency needs to optimised, there are other arguments which need to be heard. Energy efficiency has implications for economic and social spheres as well.

In economic terms, efficiency is linked to new and bolstered supply chains: stimulating labour markets and the development of specialised skills and industries. Efficiency will assist in the conservation of household income and stemming the flow of money outside of local communities for energy costs. It will bolster resilience to the impacts of climate change and Peak Oil. In these senses it strengthens local economies and conserves economic resources.

There are many contributions to social fabric and quality of life made by energy efficiency. Benefits to local and extra-local ecological environments improve the psychological health of humans and also have positive implications for individual health. The regeneration of homes or even communities has many positive ramifications including sense of well-being, pride, happiness, and improved comfort. The development of new knowledge and technical industries has not only positive economic implications but also benefits social fabric. The growth of skills, education, training, community and national networks are all positive changes presented by energy efficiency.

Realising improved levels of energy efficiency is not an easy task. This report argues for a pro-active approach to motivating individual homeowners to understand their energy use and to address causes of energy inefficiency. Careful strategy is needed to effect this change and there are key lessons to learn in forming this strategy.

Substantial research points to increased success of building community participation through bottom-up approaches that adopt the priorities of communities and individuals first. Wherever possible, utilising this approach will is ideal as it offers the greatest chance of involving individuals in a larger action. Communication, too, needs to adapt to individuals. This means communicating in ways which are audience-focused and utilise a variety of messages and media to reach the broadest possible section of an audience.

Careful framing of campaign messages, and of communication generally, should be undertaken. This must be rooted in a thorough understanding of the intended audience. The demographics, and cultural context in which communication is received, will have dramatic implications for the success of that communication. Lessons on forming positive messages and on *outcome framing* are key points which are embodied in the recommendations made by this report. Audiences will vary widely. Fuel poverty may at issue for one section of an audience, while for a wealthy section, financial savings maybe be of little motivation. Similarly, environmental implications of energy use may of paramount or of no relevance to an audience.

The efficient use of energy is a difficult topic to understand fully. The complications presented by working in dwellings which have their set of unique characteristics can be vast. Enabling the uninitiated homeowner to engage with energy consumption and efficiency can be a difficult task. Communication needs to convey often technical and complicated information to an audience with little expertise or even background knowledge.

This report strives to present methods for communicating about energy efficiency. Equally, it also seeks to offer effective means of motivating change which are based on models which have proven success. Examining the lessons gleaned from research into successful communication and campaigning will provide future efforts in this vein the greatest possible chance of success.

The lessons learned from research has been highly informative, but given more time, a full suite of tests would be conducted on each case study, which would give more robust foundations for analysis. More representative results from questionnaires by receiving a more widespread set of results from feedback by a greater selection of people could be gathered, and more investigation could be conducted into what it is that would make individuals take more notice and act on climate

change issues. Information such as whether figures in terms of costs or CO2 emissions make more impact, how much individuals are aware of various issues, and where they were educated on them. It would be interesting to have a wider view on why people do, or do not take personal measures to help reduce their consumption, and what influences them to do so.

In highlighting the lessons learned in our research, and in seeking to develop our own technique for communicating about energy efficiency, we have endeavoured to present opportunities to form campaigns that maximise the opportunity for social and economic, as well as environmental benefits that they can offer. Campaigns which help boost local business or improve social fabric, for example, are likely to have broad ranging positive benefits. By harnessing the concept of opinion leaders, not only can campaigns be made more successful, but the awareness of interconnectedness within a community can be strengthened.

The tactics of reducing energy which are put forward by educational or awareness campaigns should also be informed by thorough research. This includes understanding appropriate hierarchies of interventions (the 'lean, clean, green approach for instance), as well as the centrality of occupant behaviour. The notion of 'easy wins' is a complicated one. Many of the actions which are low-cost and highly effective are also the most difficult to motivate homeowners to carry out. It is far easier, for instance to install insulation than it is to change set-point temperatures or clothing habits. Campaigns will need to address this situation. They need to convey complicated information simply. Targeting complex behaviours such as the direct rebound effect will require nuanced and well-informed approaches.

Strategy must consider the unique qualities of a community and the infrastructure in which it sits. In retrofitting, for instance, the available supply chain will have limitations and qualities which are essential to comprehend fully. Within the supply chain, materials and human inputs present a multitude of considerations to 'get right.' Strategies to install resource intensive technologies manufactured overseas, will present a number implications for the environment, the local economy, and social fabric that a behavioural change or use of a low-intensity technology may not. Interventions should be examined against the full scale of environmental, economic, and social considerations.

This report presents findings gained through three avenues of research. Desk-based research has provided the basis for many of the recommendations presented here. This has provided the understanding of the importance of bottom-up models of building community

participation and positive message framing. A number of case studies of successful models have been presented to support these findings of the research.

Discussion with community members has guided the research and hopefully made it more relevant to GPG and the Penarth community. Interaction with homeowners, GPG leaders, council officials and members of the general public has influenced development of suggested campaign approaches.

The concept of utilising physical testing and surveys has been an important outcome of this research. This was undertaken to develop a technique for communicating technical issues in simple terms, to allow homeowners to be involved in setting priorities for reducing consumption and to foster knowledge transfer and interactions within communities. A campaign utilising these techniques would not only benefit individual homeowners, but it would also provide an avenue to skills development, bolstered local business, increased networking, as well as reduced environmental impact.

While carrying out the physical testing and surveys, we found opportunity for a great deal of interaction with homeowners. We also witnessed a ripple effect whereby the homeowners we visited were encouraged to share with others the actions they were undertaking in their home. The testing was successful in identifying energy inefficiency in every home that was visited and it also illuminated potential solutions for most if not all of the energy sinks that were found.

Building an awareness campaign in Penarth and developing educational resources is at once an exciting opportunity as it is also a large undertaking. Although in principle, any undertaking such as this should strive to reach the maximum possible number of Penarth residents, it may be more approachable by adopting a step-change approach. Adopting a long-term strategy to 'start small and grow' is probably the most suitable for the GPG organisation. This research has presented a variety of resources to GPG and has highlighted a large body of useful research.

By examining the research presented in this report and taking on the conclusions drawn from it, consideration of the many options available for the development of a campaign in Penarth will be more informed. A number of successful campaign models as well as novel concepts for campaign formats and resources have been offered. It is the authors' hope that the information

presented here will enable the development of successful campaigns in Penarth and ultimately will deliver improved energy efficiency across the town.

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6 Bibliography and further reading

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