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Thermal Comfort, Energy Usage and Fuel Poverty in a Sample of Older Person's Households in Dublin

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Abstract

This research was conducted in twenty nine Dublin City Council senior citizen sheltered housing dwellings. Temperature (°C) and relative humidity (% RH) was recorded inside all dwellings using data loggers over two separate monitoring periods of four months between December and March of 2011-2012 and 2012-2013. Energy usage including gas and electricity was also recorded for each dwelling during both monitoring periods. Outside ambient temperature data for both periods was acquired from Met Eireann. A dwelling occupant questionnaire was completed to obtain relevant technical, social and behavioural data, and to establish the prevalence of fuel poverty amongst the sample. The Building Energy Rating and information on age, design and heating systems was obtained for each dwelling.

The average daily inside temperature for all dwellings was 19.3°C during monitoring period 1 and 18.5°C during monitoring period 2. In 70% of the dwellings during both monitoring periods the average daily temperature was below 20°C, which is the lower limit recommended by the World Health Organisation for thermal comfort. The average daily outside temperature was 6.6°C during period 1 and 4.4°C during period 2. Households consumed on average 20% more gas during period 2 when compared with period 1. This was an additional household spend of €62 on energy during period 2. However, despite this additional energy usage the sample dwellings maintained lower average temperatures during period 2. There were 32% and 21% of dwellings during periods 1 and 2 respectively which had average daily relative humidity levels above the ASHRAE recommended higher bound threshold for thermal comfort of 60%RH. The households who experienced the highest average daily relative humidity also experienced the lowest average daily temperatures. The subjective method of measuring fuel poverty using the EU-SILC indicators revealed that 17.9% and 25% of households during periods 1 and 2 respectively were experiencing fuel poverty. Fuel poor households (those declaring an inability to adequately heat their home) maintained lower average daily temperatures than other households.

It is recommended that best practice in the design of housing for vulnerable groups including older people should incorporate smart home technologies i.e. integrated monitoring systems for security and health including temperature sensors for detection of extreme temperatures in the home. It is recommended that funding to Local Authorities for improving the thermal efficiency of their housing stock should continue and senior citizen complexes should be prioritised. It is also recommended that an additional fuel allowance payment is needed during particularly cold winters in order to prevent people falling into the fuel poverty trap. It is recommended that a survey similar to the Northern Ireland House Condition Survey and to include temperature monitoring, be conducted in the Republic of Ireland to provide a current picture of the housing stock in order to inform policy from both a health and environmental perspective.

Declaration

I certify that this thesis which I now submit for examination for the award of MPhil, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for another award in any other third level institution.

The work reported on in this thesis conforms to the principles and requirements of the DIT's guidelines for ethics in research.

DIT has permission to keep, lend or copy this thesis in whole or in part, on condition that any such use of the material of the thesis be duly acknowledged.

Signature______________________ Date________________

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Abbreviations

ASHRAE	American Society of Heating Refrigerating & Air Conditioning Engineers
BER	Building Energy Rating
BRE	Building Research Establishment
c/KWh	Cent per kilowatt hour
CFL	Compact Florescent Light
CO_2	Carbon Dioxide
CSO	Central Statistics Office
DCENR	Department of Communication, Energy and Natural Resources
DEAP	Dwelling Energy Assessment Procedure
DECC	Department of Energy and Climate Change
DECLG	Department of Environment, Culture and Local Government
DETR	Department of Environment, Transport and Regions
DOELG	Department of Environment and Local Government
DSP	Department of Social Protection
EBD	Environmental Burden of Disease
ECRHS	European Community Respiratory Health Survey
EHCS	English House Conditions Survey
EPBD	Energy Performance of Buildings Directive
EU	European Union
EU-SILC	European Union Statistics on Income and Living Conditions
GFCH	Gas Fired Central Heating
GHS	Greener Homes Scheme
GP	General Practioner
GWh	Gigawatt hour(s)
GWH/yr	Gigawatt hour(s) per year
HEEP	Household Energy End-Use Project
HES	Home Energy Savings Scheme
ISO	International Standards Organisation
Kt/CO_2	Kilotonne(s) of carbon dioxide
KWh	Kilowatt hour(s)
KWh/m^2/annum	Kilowatt hour(s) per metre squared per year
LARES	Large Analysis & Review of European Housing & Health Status
NEEAP	National Energy Efficiency Action Plan
RH	Relative Humidity
ROI	Republic of Ireland
SAP	Standard Assessment Procedure
SEAI	Sustainable Energy Authority of Ireland
SHIP	Social Housing Investment Programme
TGD	Technical Guidance Document
UK	United Kingdom
WHO	World Health Organisation

WHS	Warmer Homes Scheme
°C	Degrees Celsius

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CHAPTER 1

INTRODUCTION

The purpose of this research was to establish the thermal comfort and household energy usage for a sample of older people living in Dublin City Council sheltered housing dwellings. It was also the aim of this study to establish the level of fuel poverty amongst the sample i.e. the number of households unable to afford to heat their home to a level that is healthy and safe.

The links between cold housing and health are long established. People living in cold housing are exposed to a range of health hazards related to cold strain including reduced resistance to respiratory infection and increased strain on the cardiovascular system. Research has shown a strong relationship between cold homes and excess winter deaths. Cold housing negatively effects dexterity and increases the risk of accidents and injuries in the home. Low indoor temperatures can also lead to mould growth and mildew which can be detrimental for people with existing conditions like asthma. Cold homes are also known to have a negative impact on mental health. The links between cold housing and health are particularly evident among older people as they are more likely to have long-term health conditions and spend long periods inside the home.

All of these factors have a social and financial cost to society. The number of older people vulnerable to ill-health from cold homes will increase as part of significantly aging population. Fuel poor households i.e. those unable to afford to heat their home to a level that is healthy and safe are more likely to occupy cold housing and are therefore more likely to suffer the negative health impacts of low indoor temperatures. Older people are considered the most vulnerable to fuel poverty and are also the age group most likely to occupy poor housing condition. A significant contributing factor to indoor temperature in the home is energy usage and more specifically energy used for space heating. Many households living in cold homes will have poor energy efficiency and are therefore hard or expensive to heat, as well as accounting for a significant share of carbon dioxide emissions from the housing stock. Cold homes are therefore negatively contributing to climate change. It can therefore be concluded that data on both indoor dwelling temperatures and energy usage is important to inform both health and environmental policies.

This research was conducted in 29 Dublin City Council dwellings. The dwellings were within senior citizen sheltered housing complexes. The majority of the dwellings surveyed were either studio flats or one bed flats. All of the dwellings were single occupancy with the exception of one dwelling which had two occupants and the average occupant age was 75 years. The principal component of the research was the monitoring of temperature and relative humidity in the dwellings over two separate monitoring periods during the winter months of 2011-2012 and 2012-2013. The research undertaken involved both primary and secondary research methods.

There were four components to the primary research:

1. Measurement of temperature (°C) and relative humidity (% RH) inside all dwellings using data loggers over two separate monitoring periods of four months during the winter.
2. Recording electricity and gas meter readings at the start and end of the monitoring periods to calculate energy usage in the home.
3. Dwelling occupant questionnaire to obtain relevant technical, social and behavioural data and establish the prevalence of fuel poverty amongst the sample.
4. Researcher dwelling survey to confirm presence of supplementary heating, energy efficiency measures, dampness problems etc.

There were two components to the secondary research:

1. Obtaining the outside ambient temperature data for both the monitoring periods.
2. Establishing the Building Energy Rating (BER) and the age, design and heating systems in each dwelling.

The inside air temperatures recorded using the data loggers was the principal element of the research but the dwelling occupant questionnaire and the information on the physical building gave greater scope to allow a better understanding of the data logger results. The questionnaire was also used to establish the level of fuel poverty in the sample and the dwelling occupant perception of thermal comfort in their home. The inside dwelling temperatures and relative humidity data was used to assess thermal comfort in the sample dwellings. The recording of the electricity and gas meter readings allowed an energy usage to be calculated for each dwelling which could then be cross referenced against both the inside temperature data and the Building Energy Rating for the dwelling. The outside air temperature data was compared with the inside air temperatures and the patterns investigated.

This dissertation includes a literature review of housing and health, household energy usage, energy efficiency in the residential sector and a summary of previous studies relating to thermal comfort and energy usage in dwelling houses. Chapter 3 includes an overview of a pilot study which was completed and published in 2011 as part of the report: Fuel Poverty Older People and Cold Weather: An all-island analysis. Chapters 4 and 5 provide an overview of the study rationale and its limitations, as well as the study procedures and data collection. Chapter 6 presents a summary of all the data including the temperature and relative humidity data as well as the energy usage and dwelling occupant questionnaire data. Chapter 7 analyses and discusses the results, and Chapter 8 summarises the findings and outlines the conclusions and recommendations from the study.

CHAPTER 2
LITERATURE REVIEW

2.1 Housing and Health

We give shape to our buildings, and they in turn shape us (Winston Churchill in a 1943 speech to the House of Commons). Expectations and aspirations are conditioned by experience so that poor housing and deprived neighbour-hoods may lead to pessimism, passivity, chronic stress and a general state of dissatisfaction (Cohen et al, 2000).

There are a number of aspects of housing that are understood to have a direct impact on health: the structure of the housing, internal conditions such as damp, cold, indoor contamination, and the behaviour of the occupants (British Medical Association, 2003). The links between housing and health are long established; in particular the relationship between damp and "non-decent" housing and respiratory, cardiovascular and circulatory diseases (Lavin et al, 2006). These links are particularly evident among older people; they have the highest prevalence of long-term adverse health conditions and may spend long periods inside the home. Older people are considered the most vulnerable cohort to the effects of poor housing and are also the age group most likely to occupy poor condition housing (Donald, 2009). Older people in particular are more likely to be at risk of economic hardship and lack money to improve or maintain their homes to incorporate the best currently available materials and design (Lavin et al, 2006).

Older people in Ireland are more likely than their younger counterparts to inhabit poor quality housing. This is due in part to the tendency of older people to occupy ageing properties which are more likely to lack central heating and therefore are hard to heat (Central Statistics Office 2012, Watson & Williams 2003). The most comprehensive available nationally representative data on housing condition in Ireland is the Irish National Survey of Housing Quality conducted in 2001-2002. Thirteen per cent of all Republic of Ireland households reported problems with the condition of the house. Twenty-two per cent of lone older households reported problems with condition compared to 16% of other older person households. Interestingly older person households were no more likely to report major problems with leaks/dampness or heating than the general population. However, the proportion of lone older households reporting these problems was higher than the proportion of other older person households. The household type with the highest average number of problems with household condition comprised an older person living alone (Watson and Williams, 2003). Older people in Ireland have the highest rates of deprivation of housing-related items when compared to other age groups; older people are more likely to have damp walls, leaking roofs and rotting doors and windows (Prunty, 2007). Research by the Economic and social Research Institute (Layte et al, 1999) revealed that older people are less likely than younger age groups to experience basic deprivation but are more likely to experience housing deprivation.

2.1.1 Cold Homes

Living in cold homes places the body under thermal stress which can contribute to acute respiratory and cardiovascular events, and worsen health for those with pre-existing long-term conditions. Excess winter mortality does not refer to deaths from hypothermia, on the contrary, this is rarely the case; instead excess winter mortality can be attributed to these thermal stresses on the body and existing conditions. Goodman et al (2004) have shown the relationship between cold weather and increased mortality from respiratory and cardiovascular disease for people living in Dublin.

Table 2.1 below shows both the direct and indirect health impacts of cold homes, reported by the Marmot Review Team on behalf of Friends of the Earth. The review presents convincing evidence on the health impacts of cold homes and fuel poverty. There are strong relationships between cold temperatures and cardio-vascular and respiratory morbidity and mortality. Strong associations are also observed between cold homes, fuel poverty and mental ill-health. Cold housing negatively effects dexterity and increases the risk of accidents and injuries in the home (Marmot Review Team, 2011). There is also a body of evidence suggestive of significant independent associations between living in a cold home and mental ill-health (Liddell and Morris, 2010).

Table 2.1 Direct and indirect impacts of cold housing

Direct Health Impacts	Indirect Health Impacts
Excess Winter Deaths (EWD's) lower in countries with more energy efficient housing	Cold housing negatively effects children's education and emotional well-being
Definite relationship between EWD's, low thermal efficiency of housing and low indoor temperature	Fuel poverty negatively effects dietary opportunities and choices
EWD's almost 3 times higher in coldest quarter of housing than in warmest quarter	Cold housing has a negative effect on dexterity & increases the risk of accidents & incidents
40% of EWD's attributable to cardiovascular diseases	Investing in energy efficiency in housing can stimulate jobs and the economy
33% of EWD's attributable to respiratory diseases	
Strong relationship between cold temperatures & cardiovascular & respiratory diseases	
Children living in cold homes twice as likely to suffer respiratory problems than children living in warm homes	
Negative effect on mental health for fuel poor & cold homes for all age groups	
1 in 4 adolescents living in cold homes at risk of mental health problems compared with 1 in 20 adolescents living in warm homes	
Cold homes increase minor illness e.g. colds & flu & exacerbate existing conditions e.g. arthritis	

Source: Marmot Review Team 2011

Encouragingly, there is now evidence from intervention studies which shows that these health effects can be minimised by tackling those underlying factors making for a cold home, for example through improvements in household energy efficiency and/or income support measures. Lloyd et al.'s (2008) case control intervention study on housing improvements scheme in two apartment blocks in Glasgow, demonstrated the positive effect on blood pressure (an indicator of stroke/coronary heart disease risk) of heating and insulation interventions. Increased indoor temperatures as a result of thermal insulation improvements in housing have been shown to have a positive effect on both physical and mental health (Green & Gibertson, 2008). There is also convincing evidence of positive health and financial outcomes from interventions from other international studies (Marmot Review Team), 2011.

2.1.2 Thermal Comfort

Thermal comfort may be defined as the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (American Society of Heating Refrigerating & Air Conditioning Engineers, 2013). Many physiological, psychological and environmental variables play a part in a human's perception of thermal comfort. The most important physical parameters include air temperature, air velocity, relative humidity and the mean radiant temperature of surrounding surfaces (Fanger, 1972). A more general definition of thermal comfort is a sense of relaxation and freedom from worry or pain.

The ASHRAE standard for thermal comfort is based on the "heat-balance approach". This method was derived from experiments conducted in climate chambers during the 1960's. These experiments involved subjects being placed in climate chambers and exposed to varying temperatures. The aim of these experiments was to determine the range of temperatures at which building occupants were comfortable (Fanger, 1970). Fanger determined the comfort range using the Predicted Mean Vote (PMV) method.

Another method used to determine thermal comfort is the "adaptive approach", which is based on field studies of thermal comfort. Field studies have shown that people can be more tolerant of temperature changes than controlled laboratory experiments predict. People consciously and unconsciously act to affect the heat balance of the body (thermoregulation). These actions may change metabolic heat production (changing activity or doing something more or less vigorously), the rate of heat loss from the body (clothing, posture) or the thermal environment (windows, doors, blinds, fans, thermostat adjustment) (Humphrey's, 1995). Oseland (1995) concluded that for sedentary individuals at home, at work and in a climate chamber, simply being at home, in a controlled and familiar environment, is conducive to comfort and makes people less sensitive to temperature.

Thermal Comfort and Indoor Air Temperature

While the term "thermal comfort" is used to cover a variety of circumstances, the World Health Organisation (WHO) guidance on thermal comfort is not just about ensuring a sensation of satisfaction with the ambient temperature; it is inextricably linked to health. It is guidance for the home environment, and aimed at protecting health, particularly the health of those most susceptible and fragile to temperature outside that range, such as older people (Ormandy & Ezratty, 2011).

The principal mechanism in determining guidance for thermal comfort in dwelling houses has been indoor air temperature. The WHO recommends a minimum temperature of 18°C (Collins, 1986), with increases of 2-3°C for those more vulnerable to the effects of cold strain including the elderly. The WHO recommends that indoor temperatures are maintained at 21°C in living rooms and 18°C in bedrooms for at least 9 hours a day with an increase of 2-3°C for the elderly.

The WHO first made reference to indoor air temperature in dwelling houses, in the 1968 report entitled "The Physiological Basis for Health Standards for Dwellings" (Goromosov, 1968). This report looked at thermal regulation of the human body, and identified the temperature range where human energy expenditure is minimal. This temperature range was between 15°C and 25°C. The WHO reviewed its guidance on ambient air temperatures in the home in 1982. The report entitled "The Effects of the Indoor Housing Climate on the Health of the Elderly" stated that ambient temperatures between 18°C and 24°C posed little health risk to sedentary individuals, including the elderly (WHO, 1984). Further reports published by the WHO, including the report "Health Impact of Low Indoor Temperatures" (WHO, 1987), continued to use the temperatures recommended in the 1984 report.

Table 2.2 Ambient air temperature in homes and health effects

Physiological Effect	Ambient Air Temperature (°C)
Comfortable temperature	18-21°C (increase of 2-3°C & minimum 20°C for susceptible groups including elderly)
Increased risk of respiratory disorder	<16°C
Strain on cardiovascular system	<12°C
Risk of hypothermia	<6°C

Source: WHO (1984, 1987), Collins (1986), Marmot Review Team (2011)

In 1986 Collins reviewed the effects of varying temperatures ranges on different population groups, including those aged 65 years and over. Collins concluded that if "health" is taken to mean normal physiological functioning in the absence of stress, such as that produced by thermal discomfort, then the temperature range 18-24°C poses little threat to sedentary, healthy people adequately clothed (Collins, 1986).

Collins also concluded that below 16°C there was an increased risk of respiratory infection, below 12°C an increased risk of cardiovascular strain, and below 6°C a risk of hypothermia. In the 1987 WHO report entitled “Health Impact of Low Indoor Temperatures” the WHO concluded that for the very old and the very young, a minimum indoor temperature of 20°C should be maintained. Although this report states that no conclusion can be drawn on a minimum indoor temperature below which the occupant’s health is at risk, it does conclude that indoor air temperatures below 12°C pose a health risk to susceptible groups such as the young and the old. It is important to consider the time exposed to these temperature ranges. People spend roughly 50% of their time at home being sedentary, regardless of their age, or how much of each day they spend in the home (Boardman, 1985). Elderly people spend a higher proportion of their lives at home. They are more likely to suffer from cold strain than the young, so that even short periods of cold stress may damage their cardiovascular and respiratory systems (Healy & Clinch 2002).

Thermal Comfort and Occupant Perception

It is not always practical to measure temperature in housing surveys, and therefore the self-reported dwelling occupant perception of thermal comfort has been used in some studies. This method has advantages as an individual’s perception will include taking into account a wide range of factors, in particular those that are difficult to measure directly, that may contribute to thermal comfort. It also makes it possible to assess the perception of thermal comfort of individual members of a household, who will have different characteristics and different health risks (Ormandy et al, 2012). Thermal comfort is a personal preference and this has been particularly evident in recent years with energy efficiency schemes for the housing stock. The Warmer Homes Scheme in Ireland has shown that whilst thermal energy consumption per dwelling has decreased, total energy savings are liable to be reduced by the uptake of increased comfort (Sustainable Energy Authority of Ireland, 2013).

Healy & Clinch (2002) used both self-reported and objective measures of thermal comfort for a national household survey in Ireland. They found significant variances between self-reported and objective measures for certain population groups, most notably the over 65’s group. Up until 1996, the English House Conditions Survey utilised both self-reported and objective measures of thermal comfort. The 1996 EHCS found that there were significant variances between the dwelling temperatures recorded and the perceived thermal comfort of the dwelling occupants (Department of Environment Transport & Regions, 2000). Goodman et al (2011) used the perception method to measure thermal comfort for a national sample of older persons in Ireland. Goodman et al reported that 24% of the sample stated their home was “too cold”. A summary of some of the key findings of this survey are in table 2.3. The “too cold” sample also described poorer quality housing, higher rates of falls inside and outside the home and higher rates of arthritis, compared to those homes who were not self-rated as “too cold”.

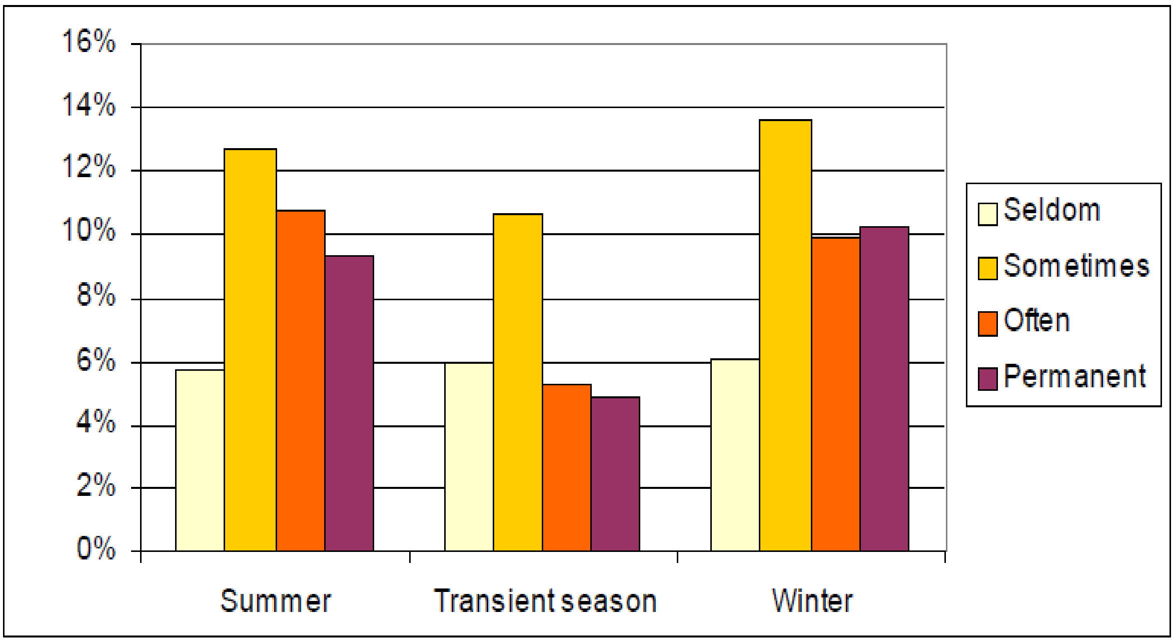
Table 2.3 Summary of total sample & subsample on key issues

Respondents stated they experienced…	"Too Cold" (24.1%)	Total Sample (100%)
Disability	53.4%	37.1%
Arthritis	49.7%	42.6%
Had Central heating system	72.2%	83.5%
Mould, damp in home	32%	15.1%
Draughts in home	57.1%	29%
Fall inside home in previous 6 months	16.5%	10.9%
Fall outside home in previous 6 months	17.8%	13.4%

Source: Cotter et al (2012)

The WHO Large Analysis and Review of European Housing and Health Status (LARES) used the perception method to measure thermal comfort, for representative samples of dwellings in eight European cities. Household occupants were asked if they had problems with the indoor temperature in their homes during different seasons. It can be seen from figure 2.1 below that problems with indoor temperature were reported for all seasons.

Figure 2.1 LARES % households reporting thermal problems by season



Source: WHO (2007)

In total 47% of all households reported “too cold” temperatures in the winter and/or transient season. The reasons for cold indoor temperature were reported to be not tight windows, the low efficiency of heating systems, a lack of heating regulation, or the lack of heating equipment in some rooms. Homes without central heating were more likely to report perceived temperature problems, as well as those in which heating was not available in all rooms. Not tight windows and single-glazed windows almost doubled the perception of temperature problems (WHO, 2007). The survey also concluded that for those aged 65 years and over, there was significantly greater reporting of problems with arthritis and increased respiratory problems for those living in perceived cold dwellings during winter.

Thermal Comfort and Relative Humidity

Relative humidity (% RH) is a measure of the moisture in the air, compared to the potential saturation level and is one of the determinants of thermal comfort. ASHRAE recommend a relative humidity range of 25 to 60 percent for normally clothed building occupants (ASHRAE, 2001). At moderate temperatures (<26°C) and moderate activity levels, the influence of relative humidity has only a modest impact on thermal sensation. For higher temperatures and activities, the influence is greater, and under transient conditions, the humidity can also have a significant influence. If humidity limits are based on the maintenance of acceptable thermal conditions based solely on comfort considerations, including thermal sensation, skin wetness, skin dryness, and eye irritation, a wide range of humidity is acceptable (International Standards Organisation, 2005).

2.1.3 Dampness and Mould

Since the 1990’s dampness, moisture and mould in indoor environments have been associated with adverse health effects in population studies in Europe and North America. The most commonly reported health effects are airways symptoms, such as cough and wheeze, but other respiratory effects, and skin and general symptoms have also been reported (WHO, 2011). In addition associations between buildings with excess moisture and asthma in both children and adults have been documented by Fisk et al (2007).

Both subjective and objective measures of dampness in houses are used in research, and criteria are being established for evaluating observations in relation to exposure and adverse health effects, but it can be assumed that an estimate of the size of moisture damage is a reasonable surrogate for the exposure (Haverinen et al, 2001). A general indicator for dampness includes observations of high relative humidity, condensation on surfaces, moisture/water damage, signs of leaks and stained/discoloured surface materials (WHO, 2011). Mould is more likely to grow in damp houses and is usually measured by the size of the visible mould patches, or the mass of active colonies (Koskinen et al, 1995).

The WHO has conducted research in the European Region examining the health impacts of certain housing risk factors by employing the Environmental Burden of Disease (EBD) approach. The results show that mould in homes leads to the loss of 40 Disability-Adjusted Life Years per year per 100,000 children (WHO, 2011). The WHO LARES study, conducted in eight European cities, reported there was evidence of mould growth in at least one room for 25% of all dwellings surveyed (WHO, 2007). The LARES study used data gathered during dwelling surveys by trained assessors. The European Community Respiratory Health Survey (ECRHS) used the self-reported method to investigate dampness in sample dwellings across 18 countries. Using data from this study, Zock et al (2002) reported evidence of mould or mildew in over 22% of the sample. In Ireland, Goodman et al (2011) used the self-reported method for a sample of older persons. Respondents were asked if they had damp, mould or black stains on walls, windows, doors, or ceilings of their home. Goodman et al reported 15% of the sample having damp and/or mould. In the UK, Baker & Henderson (1999) selected a random sample representative of women with children less than 1year. This study used the self-reporting method and reported 18.7% to 26.7% damp dwellings and 21.2% to 28.6% dwellings with mould growth.

2.1.4 Excess Winter Mortality

It has been well established by studies in many countries that there is higher levels of mortality in winter compared to summer. There are a number of causes of these excess winter deaths but cold weather and cold homes are significant contributing factors to increased respiratory and circulatory diseases during winter (Power et al, 2009). Excess winter mortality is not normally recorded as being from hypothermia, but cold weather interacts to trigger deaths from existing cardiovascular disease and/or respiratory conditions. The Marmot Review Team (2011) concludes that 40% of excess winter deaths are attributable to circulatory diseases, whilst 33% can be attributed to respiratory diseases.

Housing condition and indoor ambient temperature in the home are important considerations for excess winter deaths, particularly for the elderly. The WHO estimates that based on existing data, cold homes account for 30% of total excess winter deaths (WHO, 2011). The Marmot Review Team (2011) estimate that excess winter deaths are almost three times higher in the coldest quarter of housing than in the warmest quarter. This estimate is based on previous findings by Wilkinson et al (2001). Wilkinson et al (2001) found strong but not conclusive links between winter mortality, cold related mortality and suboptimal home heating. Clinch & Healy (2000) estimated that 40% of excess winter mortality in Ireland attributable to cardiovascular and respiratory diseases may be associated with poor housing energy efficiency.

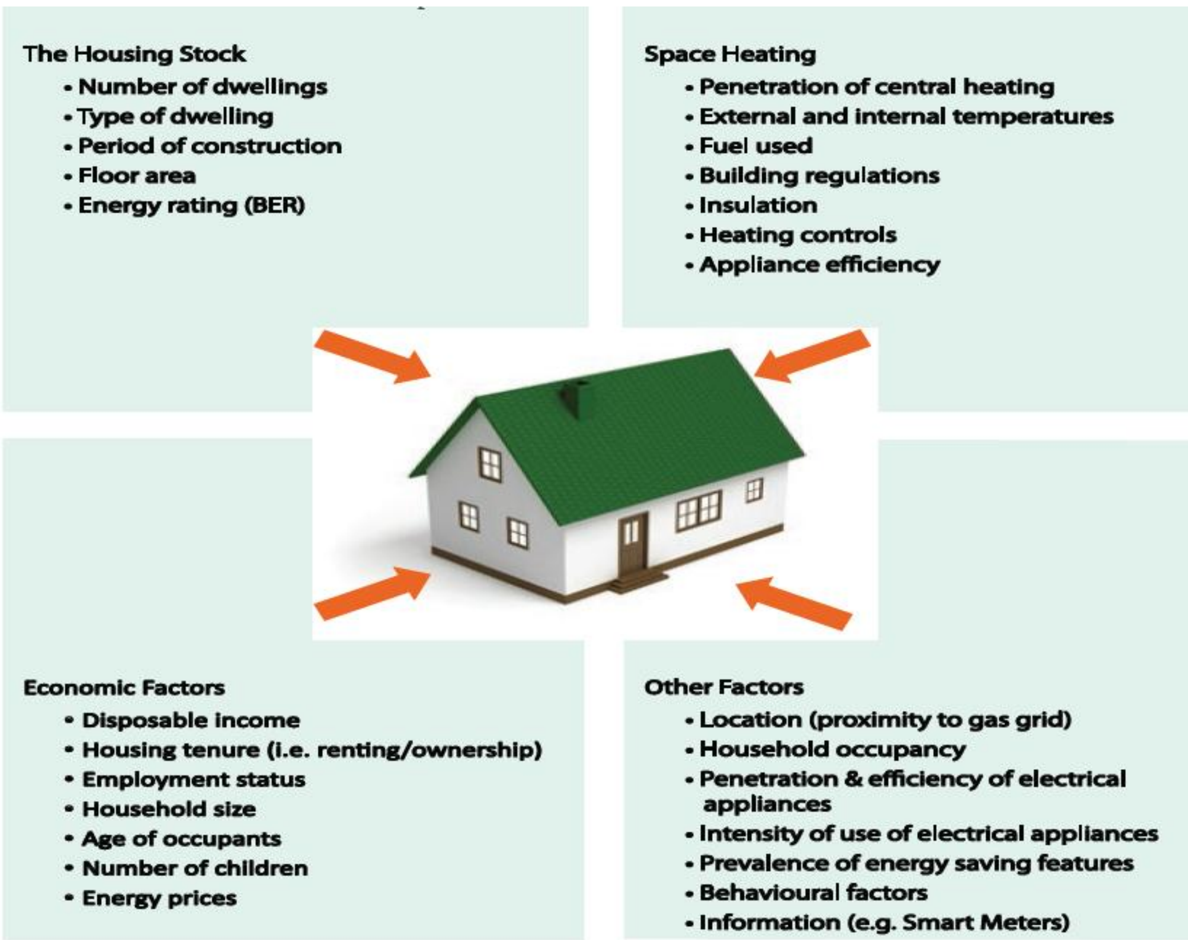
A temperature related mortality study in Dublin showed cold temperatures were associated with increased all cause mortality. Each 1°C decrease in temperature was associated with a 2.6% increase in total mortality over the subsequent 40 days. The effects were most acute for the elderly (Goodman et al, 2004). A reduction of 1°C in the living-room temperature of an elderly person is associated with rise of 1.3mmHg blood pressure, due to cold extremities and lowered core body temperature (Woodhouse et al, 1993). In London, Keatinge and Donaldson (2001) reported that every 1°C decrease in temperature corresponded to a 3% increase in total mortality over the subsequent 24 days. Keatinge & Donaldson (2000) estimate that half of excess winter deaths are attributable to indoor cold and half to outdoor cold.

2.2 Household Energy Use

The residential sector accounted for just over a quarter (27%) of all primary energy used in Ireland in 2011 and was the second largest energy using sector, after the transport sector. The residential sector was responsible for 27% (10.5 million tonnes) of energy related Carbon Dioxide (CO_2) emissions in 2011 (SEAI 2013). The number of permanently occupied dwellings in Ireland grew by 64% between 1990 and 2011 to 1.65 million dwellings. However despite this significant growth, energy usage in the residential sector only grew by 26%. In addition to energy price increases in recent years there has been a decrease in energy spend per household since 2008. The reasons for these reductions include improvements in energy efficiency, households being more aware of the environmental impact of energy use and the economic recession. The Central Statistics Office reported for 2009/2010, that the lowest earners (weekly income <€238) spent 13% of their disposable income on household energy, compared with 2% for the highest earners (CSO, 2012).

There are various driving factors that determine energy usage in the home. These factors can be categorised into four broad areas as detailed in figure 2.2 below.

Figure 2.2 Drivers of Energy Usage



Source: SEAI

2.2.1 Housing Stock

Owner occupancy, with or without a mortgage, remains the dominant tenure for older people in the Republic of Ireland. Only 8.4% of people aged 65 years and over occupy social housing in the Republic of Ireland. The most common form of accommodation occupied by older people in Ireland is a detached house, followed by semi-detached and terraced properties. Less than 5% of older people in the Republic of Ireland occupy flats/bedsits/apartments. In 2006 there were 121,157 older people living alone in the Republic of Ireland, of which nearly two thirds were women. Unsurprisingly, older people are far more likely to occupy older houses. Nearly half of all older people in the Republic of Ireland live in homes built before 1960 compared to one fifth of the general population occupying pre 1960 homes (Data from Census, 2006). Older properties are generally harder to heat and would be expected to use more energy per square metre than newer more energy efficient housing. The inclusion of energy efficiency standards in building regulations is a relatively recent phenomenon in Ireland, really only making an impact from the early 1990's. Older properties are more likely to be solid wall and may lack a central heating system or have the original older heating systems still in place. The cost of retrofit for such properties can be substantial.

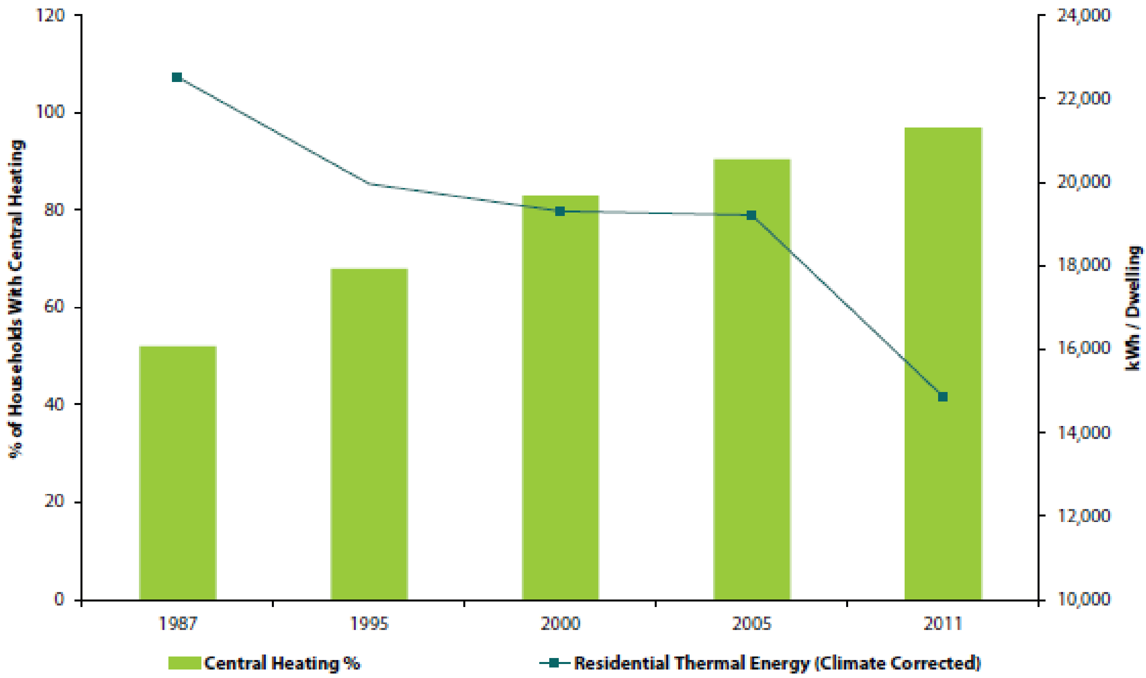
2.2.2 Space Heating

The type of space heating is a significant determinant of energy usage in the home. Central heating is more energy efficient than plug-in electric heaters or open fires, and therefore less energy would be expected to be used for a given space heating requirement. It is estimated that homes heated by central heating tend to be 2.5°C warmer than those heated by stand alone room heating systems (Department of Energy & Climate Change, 2013). However installation of central heating and similar energy efficiency improvements can result in the "take back" factor. This is where energy efficiency upgrades to existing dwellings often result in higher thermal comfort levels rather than lower energy consumption (Milne & Boardman, 2000).

The homes of older people are more likely to lack central heating than those occupied by persons less than 65 years. According to the Census 2006 in the Republic of Ireland (ROI), rates of no central heating were higher among social housing tenants and tripled for tenants renting from a private landlord, compared to owner occupiers. 19% of people aged 85 years and over lacked central heating with 20.2% of older people living in social housing lacking central heating and also older people living alone were more likely than other older people to lack central heating according to the Census 2006. Previous analysis of European Union Statistics on Income & Living Conditions (EU-SILC) ROI data from 2004 showed that older men were more likely than older women to lack central heating and hot water (Prunty, 2007). Lack of central heating has important implications for older people in heating their homes. Households lacking central heating are recognised as a high risk group for fuel poverty and are sometimes targeted in retrofitting programmes.

Figure 2.3 below examines the relationship between unit consumption (usage of energy per dwelling) and the penetration of central heating for selected years between 1987 and 2011. Figure 2.3 shows that with the penetration of central heating between 1987 and 2011, there was a decrease in the thermal unit consumption over the same period. There was a significant reduction in energy consumption between 2005 and 2011, which can be attributed to a number of factors. These factors include revised Building Regulations, energy efficiency upgrade schemes, energy price increases and economic recession.

Figure 2.3 Central Heating and Thermal Unit Consumption-Selected Years



Source: SEAI

Households in the Republic of Ireland with central heating are more likely than those without it to be very satisfied with their heat source type, ease of use and amount of heat available, control over the level of heat and running cost of the system (Watson and Williams, 2003).

2.2.3 Heating Degree Days

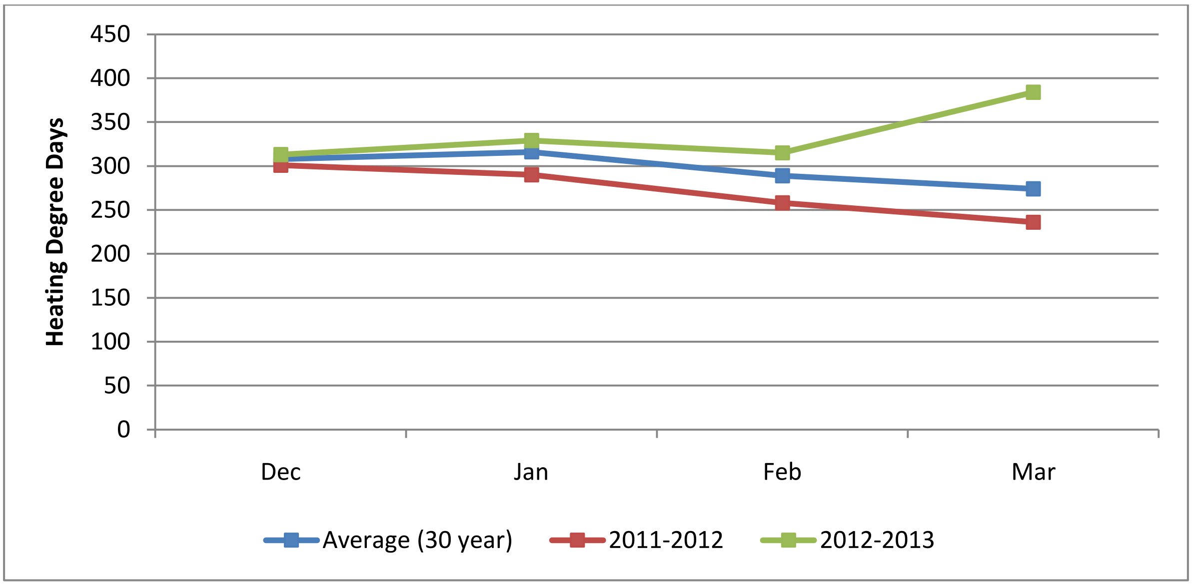
Degree days give a measure of the effect of the seasons' temperatures on crop growth and fuel requirements, especially in the case of a building which is continually heated. For each day that the average temperature is one degree above the base temperature, one degree day has accumulated. Probably the most widespread application of the degree day concept is the management of industrial and domestic heating. Heating degree days are indicators of household energy consumption for space heating. The air temperature in a building is on average 2°C to 3°C higher than that of the air outside. A temperature of 18° C indoors corresponds to an outside temperature of about 15.5°C.

If the air temperature outside is below 15.5°C then heating is required to maintain a temperature of about 18°C. The sum of the degree days over periods such as a month or an entire heating season is used in calculating the amount of heating required for a building. Degree Days are also used to estimate air conditioning usage during the warm season (Met Eireann, 2014).

Ireland does not experience the same range of temperatures throughout the year as more continental countries do. Although our inland stations show more variation, there is only about one day or less per year when the air temperature stays below freezing point. Minimum air temperature falls below zero on about 40 days per year at the inland stations, but on less than 10 days per year in most coastal areas. Air temperatures inland normally reach 18 to 20°C during summer days, and about 8°C during wintertime. It should be noted that the larger the number of heating degree days, the colder the weather and that the typical heating season in Ireland is October to May. If, for example, the outdoor temperature for a particular day is 10 degrees lower than the base temperature (15.5 degrees), this would contribute 10 degree days to the annual or monthly total (SEAI 2013).

Figure 2.4 below shows the average monthly heating degree days in Ireland for December to March for the last 30 years. It also shows the monthly heating degree days for the December to March period of 2011/12 and 2012/13.

Figure 2.4 Heating degree days in Ireland for December to March



Source: Met Eireann

It can be seen that it was warmer than average during the December to March period of 2011/12 with 8.6% less heating degree days than the 30 year average. In contrast there were 13% more heating degree days than average during December to March 2012/13, and therefore it was significantly cooler than the 30 year average.

The number of heating degree days in March 2013 is particularly striking with 40.1% more heating degree days than the 30 year average. This compares to 13.9% less heating degree days for March 2012 when compared with the 30 year average. This indicates that the March 2013 was significantly cooler than March 2012.

2.2.4 Fuel types

Fuel type is an important factor when considering energy usage in the home. The cost of different fuels can vary and therefore can greatly affect the energy costs for a household. Electricity can cost between 1.5 and 2 times more than other household fuels. Also the type of fuel affects the level of carbon emissions.

Home heating is the majority energy cost in Irish homes, with a smaller but significant cost attributed to lighting, cooking and other household appliances. On a weather corrected basis, the average dwelling in Ireland consumed almost 20,000 kilowatt hours (kWh) of energy in 2011. This comprised approximately 5,000 kWh of electricity and 15,000 kWh of non-electrical consumption. On this basis, households on average consumed 166 kWh per square metre per annum, comprising 124 kWh non-electrical and 42 kWh of electricity (SEAI 2013).

The majority of older people in the Republic of Ireland use oil or dual systems for central heating. 58.5% of those aged 65 and over use oil/dual systems, 25.1% mains gas and 16.4% other fuel types (Data from Household Budget Survey 2005). The protections offered by the regulation of gas and electricity and the provision of ‘free’ or subsidised units/social tariffs may be of great benefit those older people reliant on mains gas or electricity for their heating. However, these interventions will have limited use in helping those older people reliant on oil.

2.2.5 Energy Prices

There have been significant fluctuations in oil prices in recent years and this has impacted on other energy prices, in particular on natural gas and electricity. Further to approval by the energy regulator, upward prices in gas have directly affected prices in electricity since September 2011. Most international research in this area argues that energy prices are set to increase over the coming decade-price increases will be passed on to the consumer, irrespective of how many companies are in the Irish market. However despite this, recent research estimates that a 10% increase in electricity prices is associated with only a 0.7% decrease in consumption (Di Cosmo & Hyland, 2013). This means that it takes relatively large increases in fuel or carbon taxes to bring about significant reductions in consumption, and also that fuel price increases tend to lead to higher expenditure by households rather than decreases in demand.

Tables 2.4 and 2.5 below show the tax-inclusive electricity prices to households during the first semester of 2012 and 2013. Residential electricity prices in Ireland were above the EU average in all bands except band (DE). It is evident that the price per KWh for lower consumption bands is more expensive than the higher consumption bands. The higher price per kWh for the lower consumption bands is because the standing charges form a larger proportion of the costs. Whilst band (DD) with the largest share of consumers was only slightly above the EU average price, band (DB) was 23% to 30% higher than the EU average. It is evident that there was a decrease in price during the 1st semester of 2012 for the lower consumption bands but the price increased during the second semester of 2013 when compared with the previous semester.

Table 2.4 Residential Electricity Prices (all taxes included) - 1st Semester 2012

Household Electricity Band (kWh)	Band Share (%)	Ireland Price (c/kWh)	Relative to EU (%)	EU Rank (30)	Ireland Price Change (%)	EU Price Change (%)
DA (<1000)	2.3	36.95	132	5	-30.2	0.8
DB (1000-2500)	9.1	24.58	123	5	-1.8	0.9
DC (2500-5000)	20.4	21.45	115	6	2.8	1.2
DD (5000-15000)	49.3	18.89	106	7	1.9	1.0
DE (≥15000)	8.9	16.04	94	9	3.3	0.8

Source: SEAI

Table 2.5 Residential Electricity Prices (all taxes included) - 1st Semester 2013

Household Electricity Band (kWh)	Band Share (%)	Ireland Price (c/kWh)	Relative to EU (%)	EU Rank (29)	Ireland Price Change (%)	EU Price Change (%)
DA (<1000)	1.0	60.76	202	1	3.0	3.9
DB (1000-2500)	7.9	27.94	130	4	0.3	1.7
DC (2500-5000)	30.8	22.95	114	4	0.3	2.0
DD (5000-15000)	50.7	19.92	104	6	-1.2	1.5
DE (≥15000)	9.6	17.33	95	11	0.0	0.8

Source: SEAI

Tables 2.6 and 2.7 show the tax-inclusive gas prices to households during the first semester of 2012 and 2013. In contrast to electricity prices, gas prices in all consumption bands were below the EU average. The medium consumption band (D2) accounted for approximately 94% of consumers, whilst the lower consumption band (D1) accounted for approximately 4% of the market.

Table 2.6 Residential Gas Prices (all taxes included) - 1st Semester 2012

Household Gas Band (kWh)	Band Share (%)	Ireland Price (c/kWh)	Relative to EU (%)	EU Rank (30)	Ireland Price Change (%)	EU Price Change (%)
D1 (<5,556)	3.4	6.78	79	16	-5.7	-6.8
D2 (5,556-55,556)	94.5	6.14	97	13	-0.6	-2.0
D3 (≥55,556)	2.1	5.8	98	12	1.2	3.3

Source: SEAI

Similar to electricity, the price per KWh for gas was highest for the lower consumption bands, but the price for this band was significantly below the EU average. It is also evident that there was a significant reduction in price for band (D1) and to a lesser extent band (D2), during the first semesters of 2012 and 2013 when compared with the previous semesters.

Table 2.7 Residential Gas Prices (all taxes included) - 1st Semester 2013

Household Gas Band (kWh)	Band Share (%)	Ireland Price (c/kWh)	Relative to EU (%)	EU Rank (24)	Ireland Price Change (%)	EU Price Change (%)
D1 (<5,556)	4.5	7.12	80	17	-7.8	-11.2
D2 (5,556-55,556)	93.5	6.53	99	12	-2.8	-7.1
D3 (≥55,556)	2.0	6.25	99	10	1.1	0.0

Source: SEAI

2.2.6 Appliances

In the last 30 years there has been significant penetration of electrical appliances in our homes. Appliances such as clothes dryers, washing machines, dishwashers, microwave ovens, home computers and digital appliances are now common place. Although these newer appliances are much more energy efficient than their predecessors, appliances which are constantly turned on such as fridges, and digital appliances constantly left on standby, do use significant amounts of energy.

In the UK the "Powering the Nation" survey found that on average, 50% of the electricity consumption or more in the homes surveyed was used for appliances. The work suggested that 16% of household electricity powers cold appliances (fridges & freezers), 14% is used for wet appliances (washing machines & dishwashers), 14% for consumer electronics, and 6% for information and communication technology (Energy Saving Trust, 2012).

2.2.7 Behavioural Factors

The manner in which dwelling occupants behave can have a significant impact on energy usage. These behaviours can include heating practices and individual comfort needs, temperatures at which room and water thermostats are set, use of electrical appliances and use of ventilation including opening windows. This is just a small sample of such behaviours but all of these actions can vary from one household to the next and can even vary for occupants within the same household.

Morley & Hazas (2011) found that similarly sized households in similar properties consume widely ranging amounts of energy. The Household Electricity Use Survey in England reported that one person households used as much, and sometimes more, energy than typical families on particular appliances. In particular the cooking of lone dwellers matched or sometimes exceeded those of average family units (Energy Saving Trust, 2012).

As homes become more energy efficient, the behaviour of their occupants can play an increasingly important role in their energy consumption (Guerra-Santin & Itard, 2010). This goes back to the "take back" factor or rebound effect discussed earlier. Some of the more significant behaviours influencing energy usage are discussed separately within this chapter, including temperature management and energy efficiency.

2.3 Energy Efficiency

Energy efficiency is a way of managing and restraining the growth in energy consumption. Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. For example, when a compact florescent light (CFL) bulb uses less energy (one-third to one-fifth) than an incandescent bulb to produce the same amount of light, the CFL is considered to be more energy efficient (International Energy Agency, 2014). One area where energy efficiency has become very important is in our homes. An energy efficient home is one which uses less energy to achieve and maintain a comfortable temperature.

In Ireland 1.2 million dwellings were built prior to the introduction of the Draft Building Regulations in 1976 (that were never formerly implemented but were considered by some designers as being a good standard of construction), and 86% were built before the most stringent 1991 Building Regulations that came into force in 1992 (Department of Environment & Local Government, 1998). This implied that most of the housing stock in 1998 had some degree of inefficiency. Around the same time it was also reported that housing standards in Ireland were amongst the lowest in Northern Europe with regard to energy efficiency and heating systems (Brophy et al, 1999). However the introduction of regulations in the form of amendments to the Building Regulations and regulation on foot of EU Directive means that both new and existing buildings must meet certain criteria in relation to energy performance.

2.3.1 Building Regulations

The requirements regarding conservation of fuel and energy for dwellings are laid out in Part L of the Second Schedule to the Building Regulations 1997 (S.I. No. 497 of 1997) as amended by the Building Regulations (Part L Amendment) Regulations 2011 (S.I. No. 259 of 2011).

In the case of dwellings, an ambitious programme for upgrading the Regulations has been advanced over the past decade with the standards that pertained in 2005 being used as a benchmark for further improvements. The Regulations were upgraded in 2007 to achieve a 40% improvement in energy efficiency and a 40% reduction in associated carbon emissions relative to 2005 requirements. These Regulations also provided for the mandatory use of Renewable Energy Sources in new dwellings (a minimum of 10 kWh/m2/annum contributing to energy use for domestic hot water heating, space heating or cooling). These Regulations were further revised in 2011 to achieve an aggregate 60% improvement in energy efficiency and an aggregate 60% reduction in associated carbon emissions relative to 2005 requirements. The 2011 Regulations became fully operational (on the expiry of transitional planning-related exemptions) from 1 December 2013 (Department of Communications, Energy & Natural Resources, 2014).

For existing dwellings the requirements of Part L shall be met by:

(a) limiting heat loss and, where appropriate, maximising heat gain through the fabric of the building;
(b) controlling, as appropriate, the output of the space heating and hot water systems
(c) limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air
(d) providing that all oil and gas fired boilers installed as replacements in existing dwellings shall meet a minimum seasonal efficiency of 90% where practicable.

2.3.2 Energy Performance of Buildings

Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings was brought into force on January 4 2003. The Directive contains a range of provisions aimed at improving energy performance of residential and non-residential buildings, both new-build and existing through cost-effective measures. This Directive was adopted into Irish law in the form of the European Communities (Energy Performance of Buildings) Regulations 2006. There are four main aspects to the EPBD:

1. Implementation of a methodology for the calculation of the energy performance of buildings, taking account of all factors that influence energy use

2. Introduction of regulations that set minimum energy performance requirements for new buildings and for large existing buildings when they are refurbished

3. Energy performance certificate to be provided when buildings are constructed, sold or rented

4. Introduction of regulations to require inspections of boilers and heating systems

The EPBD does not specify a detailed calculation methodology for the calculation of the energy performance of buildings but it does state that the methodology includes the following as a minimum:

- Thermal characteristics of the building
- Heating installation and hot water supply, including their insulation characteristics
- Air-conditioning installation
- Ventilation
- Built-in lighting installation
- Position and orientation of buildings, including outdoor climate
- Passive solar systems and solar protection
- Natural ventilation

Dwelling Energy Assessment Procedure

The Dwelling Energy Assessment Procedure (DEAP) has been adopted in Ireland to calculate energy performance of dwellings and thus demonstrate compliance with the EPBD. DEAP is also used to demonstrate compliance with the Building Regulations Part L 2005, 2008 and 2011 for new buildings.

The Dwelling Energy Assessment Procedure (DEAP) is the Irish official procedure for calculating and assessing the energy required for space heating, ventilation, water heating and lighting, less savings from energy generation technologies. DEAP calculates the annual delivered energy consumption, primary energy consumption and carbon dioxide emission for standardised occupancy. DEAP compares the dwelling's Energy Performance Coefficient (EPC) and Carbon Performance Coefficient (CPC) to the Maximum Permitted Energy Performance Coefficient (MPEPC) and Maximum Permitted Carbon Performance Coefficient (MPCPC) for Building Regulations 2008 and 2011 Technical Guidance Document (TGD) L. DEAP also determines if the Building Regulations 2008 and 2011 TGD L renewable requirement is satisfied (SEAI 2012).

DEAP is based on the European Standard IS EN 13790: 2004 and draws heavily on the UK's Standard Assessment Procedure (SAP) 2005-2009. The DEAP method takes into consideration the factors which contribute to energy usage and the resultant CO_2 emissions which include dwelling dimensions, fabric and orientation, space heating, water heating, fuel type, ventilation, thermal storage capacity and solar gains. DEAP uses standard assumptions in relation to occupancy, heating demand temperatures and heating durations and the use of electrical appliances. It is assumed that for households the living room is heated to 21°C and the rest of the house to 18°C for 8 hours a day (7am to 9am & 5pm to 11pm). This method does therefore not allow for individual heating duration and usage, preferred demand temperature, efficiency of electrical appliances etc which are unique to every household.

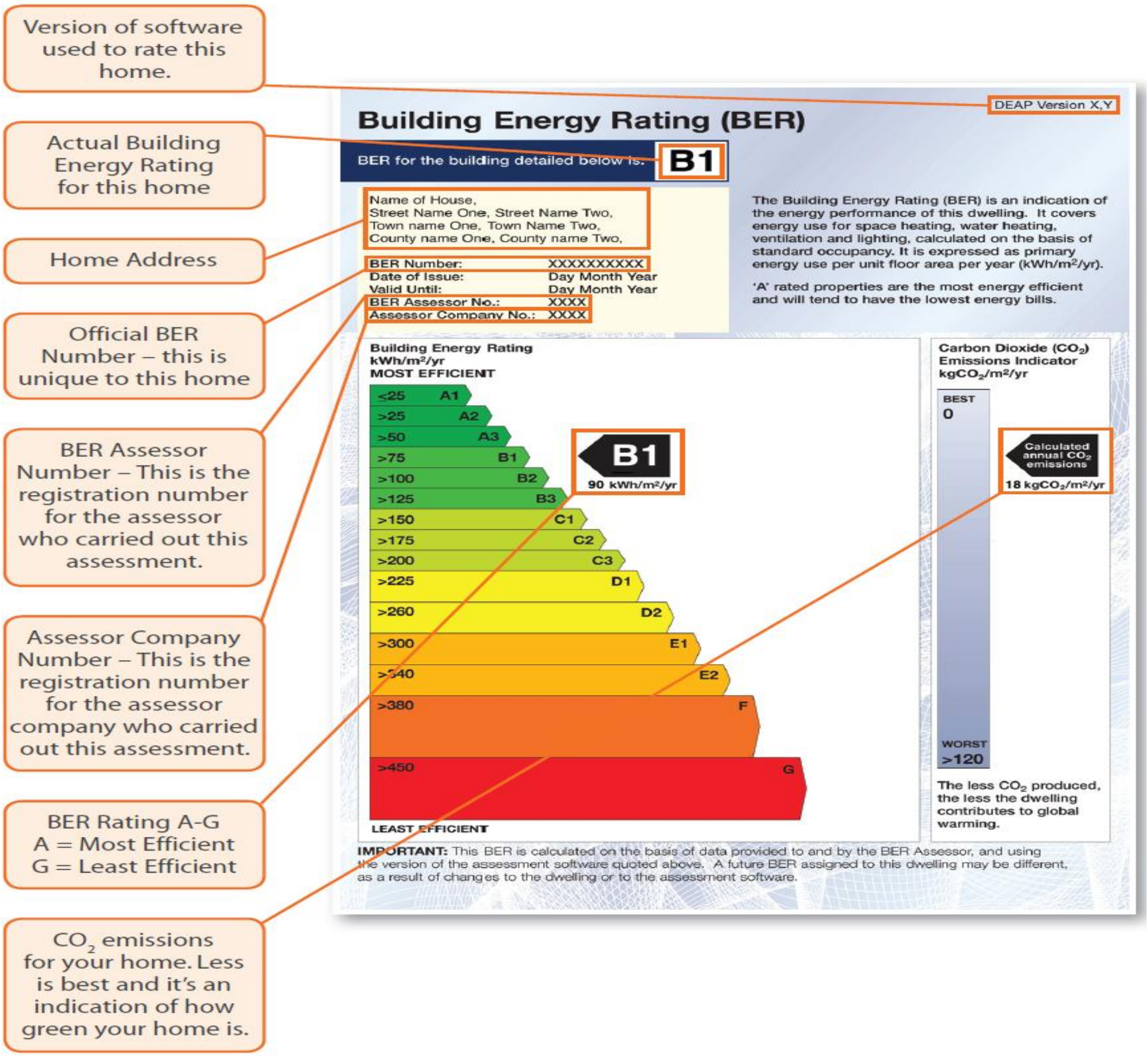
The procedure calculates and aggregates the monthly space heating energy balance for the October to May inclusive heating season. DEAP then calculates the hot water energy demand based on dwelling size and accounts for heating system control, responsiveness and efficiency characteristics, fuel type and calculated lighting energy (electricity) requirement to determine the overall results. A given dwelling specification will yield the same result in all parts of Ireland (SEAI 2012).

Building Energy Rating

The DEAP method is used to produce energy performance certificates as prescribed in the EPBD. The energy performance certificate in Ireland is known as the Building Energy Rating (BER) and has been a requirement for new dwellings since January 1st 2007 and for existing dwellings for sale or rent since January 1st 2009.

The energy performance is calculated using the DEAP method described above. These assessments can only be completed by trained assessors and a register of approved assessors is held by the SEAI. The BER uses a scale from A (lowest primary energy usage) to G (highest primary energy usage) to represent the primary energy use per unit floor area per year (kWh/m²/yr) This banding system allows all building types from carbon neutral to the poorest performing buildings to provide a broad indicator of the energy performance of the building. The BER provides a figure for the annual CO_2 emissions from the building which is expressed as kilograms carbon dioxide per metre squared per year ($kgCO_2/m^2/yr$). The BER is only an indication of the energy performance of the house. The actual energy usage will depend on the occupants of the house. The BER is accompanied by recommendations for cost effective improvements to the building. These improvements can vary from additional insulation measures to heating upgrades.

Figure 2.5 Sample BER Certificate

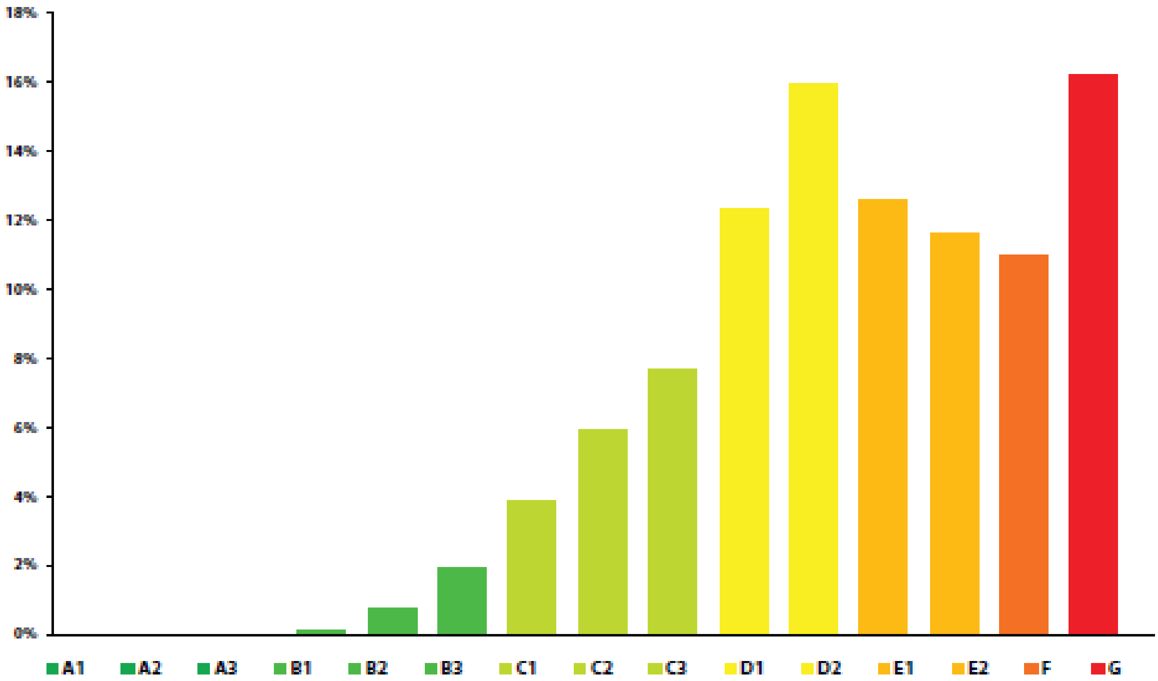


Source: SEAI

The EPBD obliges specific forms of information and advice on energy performance to be provided to building purchasers, tenants and users, and provides consumers with information regarding the energy performance of a building enabling them to consider this in property transactions. The BER fulfils this criteria and must be made available to the perspective purchaser, tenant etc.

There are just over 295,000 records for existing dwellings in the BER database, with the most frequently occurring being “D1” or “C3”, both categories accounting for 14% of all existing dwellings. This would suggest that actual heating periods, temperature levels or hot water usage in Irish homes may be below the standardised regimes applied in the DEAP software calculations used to generate BER certificates (SEAI 2013). The latest figures published in the National Energy Efficiency Action Plan, 2014; state that there are 436,000 registered domestic BER certificates as of February 2014. This figure represents1.6 million or one quarter of all dwellings in Ireland. Overall older properties are found more frequently in the lower BER band. As would be expected, dwellings using more efficient fuels including oil and natural gas have higher average ratings than dwellings using solid fuel space heating. Natural gas dwellings have an average rating of a “C1”. In contrast to the overall housing stock, apartments and flats built prior to 2000 show greater concentrations in the “D”, “E”, “F” and “G” categories.

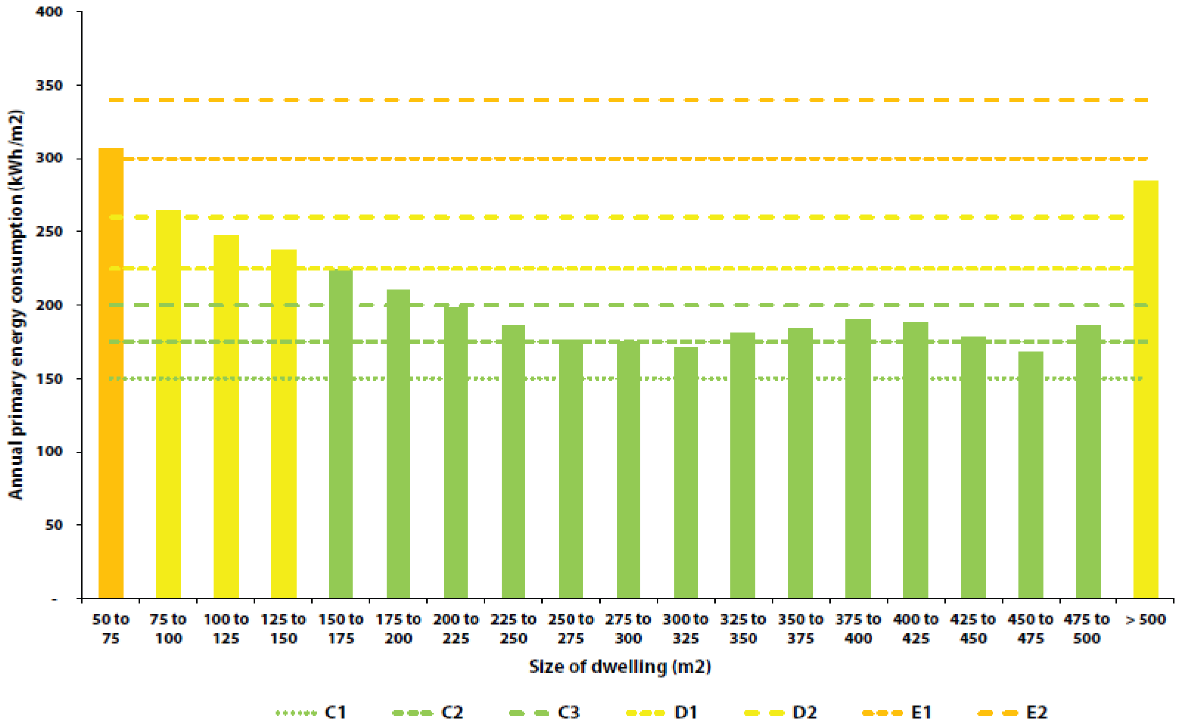
Figure 2.6 BER distribution of all apartments built prior to 2000 in the BER database



Source: SEAI

Figure 2.7 below shows the annual energy consumption of dwellings by floor area. It is evident that for energy usage per square metre, the smallest dwellings are the biggest consumers of energy. This is probably because there is a greater concentration of occupants in these smaller dwellings. It can also be noted that the bigger dwellings are not always the largest energy users. This may be explained by the fact the larger dwellings are likely to have been constructed more recently and therefore to a greater thermal efficiency standard. Another interesting finding from the BER database is that rented dwellings are on average more efficient than the overall housing stock, which is surprising considering rented properties are less likely to avail of energy efficiency upgrades.

Figure 2.7 Annual energy consumption of dwellings by floor area



Source: SEAI

2.3.3 Energy Efficiency and Older Persons Housing

There is limited data specifically on energy efficiency measures in older person's dwellings. Data on older person households was not presented distinctly in the published results of the Quarterly National Household Survey Recycling and Energy Conservation report (Central Statistics Office, 2007). However, the national data demonstrated significantly lower installation rates for energy conservation measures for dwellings built pre-1961 and rented dwellings. Nationally, 76.2% of households reported attic/loft insulation, 79.3% reported double glazing, 47% reported draught stripping, 78.3% reported a lagging jacket and 38.7% reported CFL light bulbs.

The data in the table below is based on self-reporting as part of a general household survey. However respondents to surveys in the Republic of Ireland have limited information on the structural features of their accommodation that are not directly visible (Watson and Williams, 2003). Overall, older people in the Republic of Ireland were less likely to have insulation/energy efficiency measures than the general population.

Table 2.8Energy efficiency/insulation measures in homes of older people (ROI)

Age group (years)	Attic/loft insulation	Double glazing	Draught stripping	Lagging jacket	CFL bulbs
65-74	73.6%	73%	48.6%	74.7%	36.4%
75+	58.5%	62.2%	45.1%	67.1%	25.2%
65 & over	**66.0%**	**67.9%**	**46.5%**	**70.9%**	**31.0%**

Source: Quarter 3 Recycling and Energy Efficiency Module of the Quarterly National Household Survey 2005. Presence of these measures = full or partial.

There were no figures for wall insulation available in the Quarterly National Household data. However, the Irish National Survey for Housing Quality 2002 has presented figures for wall insulation. These figures showed that older person households were the household type most likely to lack wall insulation. Over 45% of older person households reported no wall insulation, compared to 24% of all households (Watson and Williams, 2003). Data from the Republic of Ireland suggests a decline in the proportion of homes with attic/wall insulation with age within the over 65 year's group. It would appear that the oldest-old are more likely to live in energy inefficient and poorly insulated homes.

Republic of Ireland data suggests low levels of usage of simple low cost energy conservation methods such as CFL light bulbs and lagging jackets among older people. It is however notable that this data was collected in 2005, prior to the introduction of legislation on CFL bulbs, so figures should have increased since then.

2.3.4 Government Schemes

The Irish government's policy on energy efficiency is based on its legal responsibilities as an EU member state, and other obligations under international agreements, aimed at improving energy efficiency and reducing greenhouse gas emissions. The government submitted the first National Energy Efficiency Action Plan to the European Commission in 2007, and has submitted two further revisions in 2011 and 2014. The plan outlines the energy efficiency policies which will meet the target of 9% savings by 2016 as required by the EU Energy Services Directive (2009). The plan also details Irelands national target of 20% savings by 2020 i.e. 20% efficiency improvement, 20% increase in renewable energy, and 20% reduction in greenhouse gas emissions.

It has been recognised that improving the energy efficiency of the housing stock is the best way to target and assist low income households. The state administers a number of different energy efficiency programmes in the housing sector, through the SEAI and Department of Environment, Culture & Local Government.

Better Energy Programme

In 2011 the Home Energy Saving Scheme (HES), Warmer Home Scheme (WHS) and Greener Home Scheme (GHS) were merged to form the Better Energy Programme. These schemes aim to encourage people to improve the energy efficiency of their homes, reduce greenhouse gas emissions and improve thermal comfort.

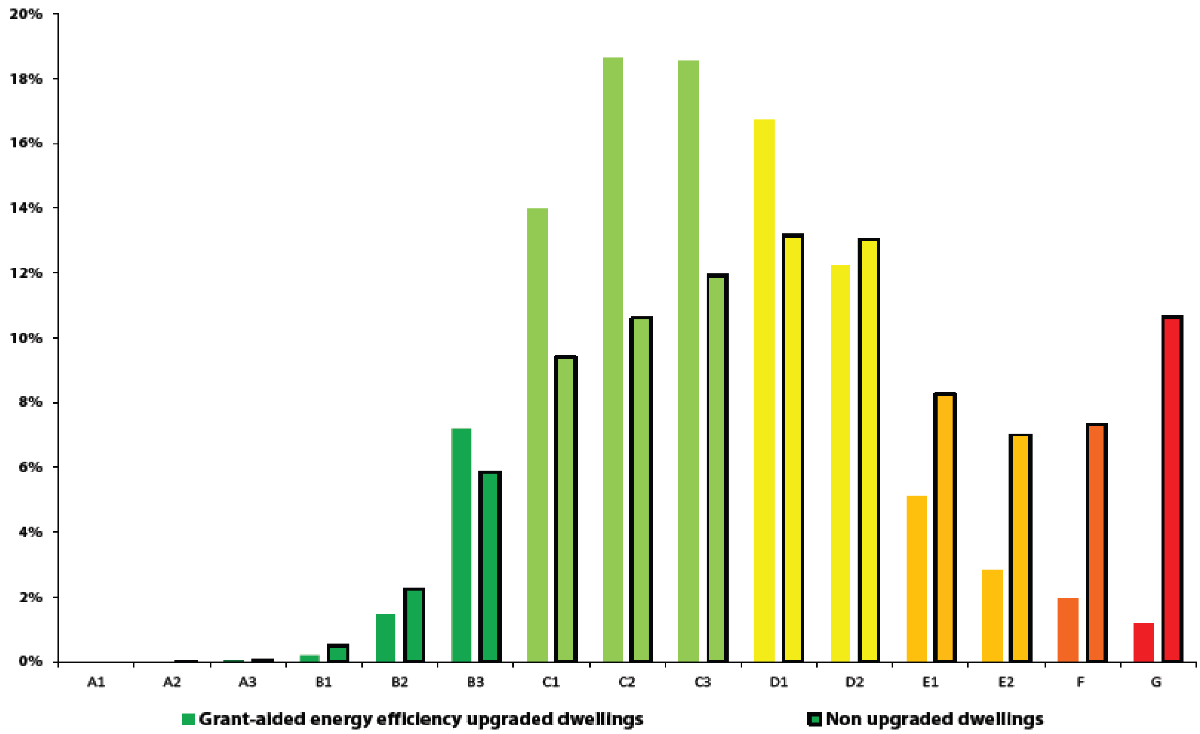
This Better Energy Warmer Homes Scheme targets low income households and those vulnerable to energy poverty. The energy efficiency upgrades include attic insulation, cavity wall insulation, draught proofing, lagging jackets and low energy light bulbs. The programme is administered by the SEAI and there is no cost to the household for the retrofit measures completed. In 2014 the government has committed €20 million to this scheme which will deliver energy efficiency improvements to an estimated 12,000 homes. The scheme has targeted over 104,000 homes since the year 2000.

Formerly the Home Energy Saving Scheme, the Better Energy Homes Scheme aims to encourage homeowners to improve the thermal efficiency of their dwellings. This scheme targets those who do not meet eligibility for the Better Energy Warmer Homes and is also available to landlords of private rented houses. The energy efficiency measures included in the programme include attic insulation, wall insulation, boiler and heating control upgrades, solar panel installation and completion of a BER. The scheme is administered through the SEAI who provide a range of fixed grants to homeowners depending on the upgrade measures being availed of. The Department of Communications Energy and Natural Resources reports that 20 million has been allocated to this scheme in 2014, which will lead to an estimated 70GWh in energy saving. The DCENR also reports that further to a grant aided investment of over 162 million since the commencement of this scheme, 387,870 energy efficiency measures have been completed in 155,283 homes.

A study examining changes in energy use for a sample of households which participated in the Better Energy Homes Scheme was conducted by the SEAI. The changes in gas consumption for the 210 sampled households were calculated using gas meter readings supplied by the gas utility providers. The gas usage for several years' pre upgrade (2008) and 1 year post upgrade (2010) was calculated for each dwelling. In addition a controlled sample for the general population of approximately 640,000 households was used, by obtaining gas meter readings from the gas providers over the same period.

The upgrade works included wall and attic insulation and boiler and/or heating control upgrades. The research concluded that each dwelling saved on average 21% on their annual gas bill. Households also experienced improved thermal comfort and there were significant improvements in the BER of the homes. Figure 2.8 below shows that prior to retrofit only 17% of the sample had a BER of C3 or better, while post retrofit 60% of the sample had a rating of C3 or better. The measured savings through the reduction in gas consumption showed a shortfall of 36 ± 8 %, when compared with the technical savings estimated for the energy efficiency upgrades completed. This shortfall includes the effects of direct and indirect rebound effects, variations in ex ante assumptions and achieved *u* values and efficiencies for upgraded dwellings (Scheer et al, 2013).

Figure 2.8 Comparison of upgraded dwellings to existing dwellings in the BER database



Source: SEAI

Energy Efficiency Programmes for Social Housing

Under the Social Housing Investment Programme (SHIP), Local Authorities are allocated funding by the DECLG to upgrade the thermal efficiency of their housing stock. Initially local authorities targeted void units for retrofit. The upgrade measures included insulation and installation of high efficiency condenser boilers. The targets during the first 3 years of the scheme between 2009 and 2012 were to achieve a BER of C1 post retrofit, where possible.

In 2013 the DECLG announced that there would be a change in focus away from just improving BER in voids, to include occupied dwellings also. The programme targets four main energy efficiency measures including attic insulation, cavity wall insulation, draught proofing and lagging jackets. These four items are recognised as the most cost effective way to improve the BER of a building. This programme in now referred to as "The Fabric Upgrade Programme" and refers exclusively to retrofitting the above four items to existing stock. Local Authorities utilise an area based approach for this programme as this is the most cost effective. A BER assessment is carried out pre and post retrofit so that energy efficiency gains can be documented.

In 2013 the DECLG also introduced the Job Stimulus Retrofitting Programme. This programme is similar to the Fabric Upgrade Programme, and the DECLG have indicated that the programme will operate from 2013 to 2015, with funding of 50 million over the three years. The main difference between the two programmes is that the eligible expenditure has been capped at €2,000 per unit for the Jobs Stimulus Retrofitting Programme (as opposed to €3,500 for the Fabric Upgrade Programme).

Table 2.9 Energy efficiency savings in social housing

Year	No. houses upgraded	Energy savings (GWh)	Carbon Savings (kt/CO2)
2009-2012	7762	31.2	10.2
2013	10100	24	4.8
2014	26,750(est)		

Source: DCENR

In addition to the programmes above local authorities can avail of SEAI Warmer Homes Area Based Programme which was introduced in 2013. Applications were invited from local authorities to participate in an €4 million competitive fund established to support targeted energy efficiency upgrades to energy poor households. The works associated with this programme are considerably more extensive and include such works as: installation of new high efficiency boilers and heating controls, cavity or wrap around wall insulation and double glazed windows where necessary.

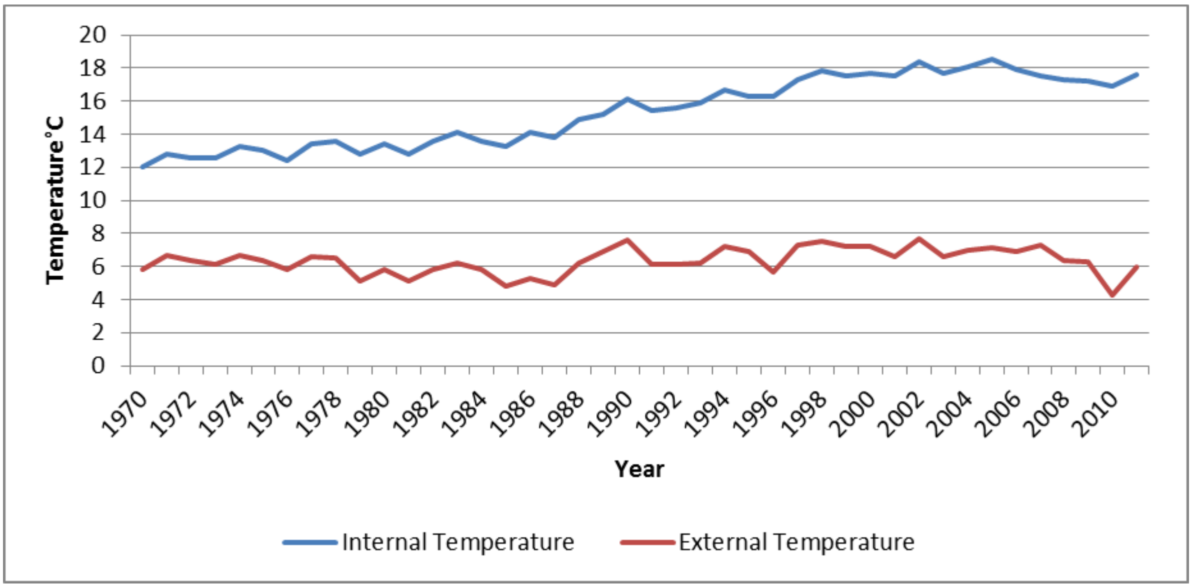
In 2014 the budget for retrofit of social housing will increase from approximately €10 million in 2013 to €25 million for occupied dwellings, with the number of homes also set to increase to 25,250 dwellings. It is anticipated that this will realise 60 GWh/yr in energy savings. There will be a further €15 million available for vacant properties in 2014. It is anticipated that this will enable a deep retrofit of a further 1,500 dwellings, realising savings of 20GWh/yr (DCENR, 2014).

2.4 Previous studies relating to thermal comfort, energy usage and fuel poverty

There is limited data available on temperature inside homes in Ireland but estimated temperatures are available for the UK. The Building Research Establishment (BRE) presents estimated temperatures inside UK dwellings over the last 40 years in the Housing Energy Fact File, 2013. The estimated temperatures which have been modelled using building data and energy consumption figures are presented in figure 2.8 below. It is clear that internal temperature in homes has risen significantly since 1970. The average winter internal temperature for homes with central heating has risen by 4°C from 13.7°C in 1970 to 17.7°C in 2013. The increase in winter temperature for homes without central heating is even more pronounced, with internal temperatures rising by 5.4°C from 11.2°C to 16.7°C during the period 1970 to 2013.

It is also clear from figure 2.9 below that the average winter internal temperature has increased significantly more than the average winter external temperature. The BRE attributes the widening gap between the average internal and external winter temperatures to the heating used to lift homes from the temperature outside to the indoor temperature that is now demanded in winter. This elevation in temperature has been achieved largely by burning fossil fuels, nowadays mainly by consuming gas. Even though average internal temperatures have risen by 4°C or more, much better insulation and more efficient heating systems have provided more comfort at the same time as cutting energy use per home (DECC, 2013). As Ireland has a similar climate to the UK and there have also been similar increases in the penetration of central heating in our housing stock, it is reasonable to make the assumption that Ireland may have experienced similar increases in average internal dwelling temperatures.

Figure 2.9 Modelled average internal & external winter temperatures in the UK



Source: UK Housing Energy Fact File 2013

Previous studies relating to Ireland

Healy & Clinch (2002) using data from a national household survey of the Republic of Ireland examined the relationship between fuel poverty and thermal comfort. They used both household occupant reported thermal comfort and monitored household living room temperatures. Yohanis & Mondol (2010) recorded internal temperatures in a sample of households in Northern Ireland. Although this was a small sample, the authors considered the sample to be a reasonable representation of the Northern Ireland housing stock based on house type. Bokenes et al. (2011) compared the indoor climate in a sample of houses with elderly occupants (≥60 years) in Dublin, Ireland and Tromso, Norway. The sample size was small and it identified a very specific household type.

Fuel poverty, thermal comfort and occupancy: results of a national household-survey in Ireland

Healy & Clinch (2002) using data from the Irish National Survey of Housing Quality (2001), examined the relationship between fuel poverty and thermal comfort. They used both subjective and objective measures of thermal comfort. Household occupants reported the thermal comfort of their home on a room by room basis, and indoor ambient temperature was recorded in the living room of 1500 surveyed homes during March 2001.

Healy & Clinch reported that fuel-poor households were more likely to be experiencing colder temperatures than other households. In total almost 30% of fuel-poor households had living room temperatures below 18°C and more than two thirds had living room temperatures below 20°C. Overall nearly half of all non-fuel-poor homes had living room temperatures below 20°C. In households with persons aged over 65 years, 16% had living room temperatures below 18°C and over 50% had temperatures below 20°C. On the other end of the scale over 5% of households occupied by persons over 65 years experienced living room temperatures of ≥24°C.

Table 2.10 Living room temperature for different household categories

	Fuel poor households (%)	Other households (%)	Households >65 years old (%)
<16°C	5.5	1.8	1.5
16-17.9°C	23.9	9.0	14.6
18-19.9°C	39.2	38.5	34.6
20-21.9°C	19.2	33.1	32.7
22-23.9°C	9.0	11.4	11.2
24-25.9°C	3.1	6.0	5.4

Source: Healy & Clinch (2002)

Using household occupant reported thermal comfort; Healy & Clinch found that both fuel-poor households and households with occupants greater than 65 years old had higher levels of thermal discomfort than other households. Over one quarter of fuel-poor households reported thermal discomfort in the living room and almost one third reported thermal discomfort in the master bedroom. This is compared with 9% in the living room and 7% in the master bedroom of other households. Healy & Clinch reported greater thermal discomfort in all rooms of households with persons aged over 65 years when compared with the other household's category. Nearly 13% reported thermal discomfort in the living room and for bedrooms it varied from 13% in the master bedroom to almost 29% in the third bedroom.

Healy & Clinch conclude that there are limitations with both the subjective and objective measures of thermal comfort used in this study. They state that while the temperatures recorded act as a good measurement of thermal comfort, living room temperature is by no means a flawless gauge of thermal comfort. They also conclude that there is a tendency to under declare the levels of thermal discomfort in the home when using the subjective method.

Annual variations of temperature in a sample of UK Dwellings (Northern Ireland Region)

Yohanis & Mondol (2010) recorded temperatures in a sample of 25 households in Northern Ireland over all seasons. In terms of house type the authors considered the sample to be a reasonable representation of the Northern Ireland housing stock. Temperatures were recorded in the living room, kitchen, bedroom and hallway.

Yohanis & Mondol reported that in 60% of homes sampled the average daily whole house temperature during winter was less than 19°C. There were 24% of homes with an average daily winter temperature of 19°C to 21°C, which was the "comfort range" set by the study and 16% of the sample had a temperature above 21°C. On a whole house basis 40% of the sample maintained average daily winter temperatures at or above the "comfort range". Almost one third of the sample maintained their living rooms within the "comfort range" and a further one third maintained the living room temperature above 21°C during the winter. It was also reported that for 12% of homes, the living room temperature ranged between 13°C & 16.5°C in winter.

Yohanis & Mondol found that the highest temperatures in houses were in the evening after 8pm which corresponded to periods of occupancy. The peak bedroom temperatures occurred between 10pm and midnight and again in the morning after 8pm. It was also reported that temperatures in single occupancy dwellings were lower than those dwellings with large families. Surprisingly the lowest recorded temperatures were in terraced houses and the highest in semi-detached houses for the winter period. It is suggested by the authors that the lower temperatures in terraced houses may be due to lower occupancy.

Table 2.11 Daily average temperature distribution for bedroom, living room, hall & kitchen in winter

	Temperature (°C) & Households (%)		
	<19°C	19-21°C	>21°C
Bedroom	65.4	15.4	19.2
Living room	38.5	30.8	30.8
Hall	69.2	15.4	15.4
Kitchen	53.8	15.4	30.8
Whole house	60	24	16

Source: Yohanis & Mondol (2010)

Table 2.12 Daily average winter temperatures by house type & occupancy for bedroom, living room, hall & kitchen

	Temperature (°C)				
House type	**Bedroom**	**Living**	**Hall**	**Kitchen**	**Average**
Terrace	17.4	18.8	16.9	17.5	17.7
Semi-detached	20.1	20.8	17.4	20.9	19.8
Detached	18.2	18.8	17.5	20.7	18.8
Bungalow	18.7	20.2	19.3	19.2	19.3
Occupancy					
1	16.2	15.7	15.6	13.7	15.3
2	17.2	17.4	17.4	17.3	17.9
3	18.8	17.9	17.9	19.6	18.7
4	18.2	16.5	16.5	19.4	18.1
4+	20.5	19.1	19.1	22.2	20.9
Daytime occupancy					
0	17.8	18.2	16.0	19.3	17.8
1	19.1	19.6	18.9	18.1	18.9
2	17.0	19.9	17.5	18.1	18.1
2+	17.1	18.3	17.8	19.3	18.1

Source: Yohanis & Mondol (2010)

Yohanis & Mondol concluded that there was a significant correlation between indoor and outdoor temperature in the sample dwellings. They also concluded that households with a high average daily temperature maintain a steady temperature over the year, while households with lower average daily temperatures tend to fluctuate significantly over the year.

Annual variations in indoor climate in the homes of elderly persons living in Dublin, Ireland and Tromsø, Norway

Bokenes et al. (2011) compared the indoor climate in a sample of houses with elderly occupants (≥60 years) in Dublin, Ireland and Tromso, Norway. The average external temperatures in Dublin during the survey period were 6.7°C in January and 15.4°C in July. In Tromso the average external temperatures in January and July of the study period were 4.4°C and 12°C. The Dublin study was conducted between April 2002 and 2003 and the Tromso study between April 1999 and April 2000. The Dublin study consisted of 25 dwellings and 37 subjects and Tromso study 19 dwellings and 29 subjects.

Bokenes et al. found that despite the higher outside air temperatures in Dublin that the indoor temperatures recorded in the living room, kitchen and bathroom were significantly lower in homes of the elderly in Dublin. The difference in bathroom temperature was significant with Dublin bathrooms being up to 10°C colder.

The pattern of seasonal changes in kitchen, bathroom and bedroom temperatures for the Dublin group was found to be similar to seasonal changes in the outside temperature. Relative humidity values for both the living room and bathroom were significantly higher in the Dublin houses with levels higher by 23% in the living room and 11% in the bathroom when compared with the Tromso sample. Despite significant variations in both outdoor and indoor temperatures between Dublin and Tromso, participants in both samples were satisfied with their housing from both a climatic and health point of view.

Bokenes et al. found that all rooms in the Tromso houses with the exception of the bedroom, generally maintained constant temperatures and were not significantly influenced by the external temperature. It is suggested that this is due to better house quality, cheaper heating cost and higher standard of living. However in Dublin homes, all rooms with the exception of the living room seem to be significantly influenced by the external temperature. It is suggested that this may be due to a combination of poor insulation and higher energy costs. Bokenes et al. found that the bedroom temperature in both groups mirrored changes in the external temperature. It is again suggested that poor insulation is the cause of the significant correlation between bedroom temperature and external air temperature in Dublin houses, whilst Bokenes et al. suggests use of additional ventilation in Tromso bedrooms.

Previous studies in the UK

A number of temperature monitoring studies have been undertaken in the UK and have given some insight into indoor temperature including thermostat settings and heating patterns in dwelling houses.

The first major study was in 1978 and the spot measurements of internal temperatures in 1000 UK dwellings (Hunt & Gidman 1982). Spot temperature measurements were taken in the living room, kitchen and bedroom and interviews were conducted with a household member to obtain data on heating patterns and thermal comfort. The average recorded dwelling temperature was 15.8°C. Hunt and Gidman found that the type and operation of heating system, time of day, and age of dwelling all influenced the temperature patterns. It was found that the living room was not as influenced by the above factors as other rooms. However this study was limited to spot temperatures and not mean temperatures.

One of the main sources of nationally representative data on temperature inside dwellings in the UK is the English House Conditions Survey (EHCS). A national temperature survey was incorporated as part of the EHCS in 1986. In addition detailed questions on heating patterns and a fuel consumption survey were also introduced. The temperature study also formed part of the EHCS in 1991 & 1996.

Table 2.13 Temperature in homes and health effects, England 1996

Indoor Temperature (°C)	Assumptions of physiological effect	Living rooms at these temperatures (million)	Halls/stairs at these temperatures (million)
24+	Risk of strokes & heart attacks	0.4	0.3
21-24	Increasing discomfort	3.5	2.1
18-21	Comfortable temperature	8.8	6.3
16-18	Discomfort, small health risk	4.1	4.6
12-16	Risk of respiratory disease	2.5	4.7
9-12	Risk of strokes, heart attacks	0.2	0.9
<9	Risk of hypothermia	0.1	0.7
Unhealthy cold (<12°C)		2.8	6.3
Total cold homes (<16°C)		6.9	10.9

Source: Richard Moore, pers.comm.

The temperature study measured spot temperatures in the living room and hallway in a nationally representative sample of houses. The 1996 EHCS found that 6.9 million homes (28%) had living rooms below 16°C and 10.9 million (44%) had hallways below16°C. Despite the temperatures recorded being associated with physiological discomfort and danger to health, 80% of those interviewed claimed that they were satisfied with the temperature in their home (DETR 2000).

The temperature data from the 1996 EHCS has been used in studies of excess winter mortality (Wilkinson et al., 2001) and (Rudge and Gilchrist, 2007). However the data recorded is only one spot temperature per house and only gives us a single temperature for a particular point in time. In addition it does not take into consideration the time of day, heating usage and the outside temperature. The EHCS has not included any temperature survey since 1996.

More recent studies on internal dwelling temperature in the UK have been on a smaller scale and have been non-representative samples. As part of the Carbon Reduction in Buildings project a survey of 160 low energy homes was undertaken in Milton Keynes Energy Park in 1989/90. Summerfield et al (2007) monitored temperatures in a sub-sample of 29 dwellings. A follow-up study was commenced in 2005 and consisted of 15 dwellings from the original sample. The final sample for analysis used by Summerfield et al. for both 1989/90 and 2005 was 13 dwellings.

Living room temperature in 2005 was 20.1°C and 19.5°C for the bedroom. This was similar to the 1990 survey results with the exception of the main bedroom evening temperatures (6pm-11pm) which had decreased by 1.3°C. Summerfield et al. found higher average internal temperatures than in previous studies and states that this is consistent with expectations for well insulated and centrally heated homes. The study also found that the internal dwelling temperatures were well maintained as external temperatures reached mid-winter levels. This is again consistent with expectation for well insulated homes. Summerfield et al. calculated a drop of 1°C for every 5°C drop in external temperature.

Oreszczyn et al. (2006) investigated winter indoor temperatures in a sample of over 1600 low income households who were receiving the Warm Front energy efficiency grant. 64.4% of the houses sampled had an occupant 60 years or older and it was found that the dwellings occupied by older persons tended to have warmer living rooms and colder main bedrooms. Oreszczyn et al. established that dwellings which received both heating and insulation measures through the Warm Front scheme resulted in daytime living room temperatures 1.6°C higher than pre-intervention dwellings and night time bedroom temperatures 2.8°C higher. A summary of the mean temperatures recorded in this study and other UK studies are detailed in table 2.14.

Unlike many previous studies which recorded only spot temperatures this study has provided results for continuous monitoring at regular intervals over a period of time. It has also allowed for the external temperature when calculating standardised temperatures. However the houses sampled were all in the lower income category and therefore cannot be considered to be nationally representative.

There were a number of other related studies with the purpose of measuring the effectiveness of the Warm Front scheme. Hong et al (2009) investigated the effect of The Warm Front scheme on the thermal comfort of 2519 low income dwellings.

Self-reported thermal comfort and indoor temperatures were recorded. Hong et al. used a survey design based on cross-sectional comparisons between pre and post improvement households measured during the same winter.

Hong et al. found that in the pre intervention dwellings the mean self reported comfort vote for all groups except for the living room and evening to be in the “comfortably cool” category. The lowest mean indoor temperatures were recorded in the bedroom at 16°C and in the morning time at 16.3°C. The living room and the evening were the only groups in the “comfortable” category and had mean temperatures of 18.3°C and 17.9°C.

Hong et al. found that in post intervention dwellings there was improved thermal condition across all groups and their mean values. The greatest improvement was seen in the households with an elderly occupant who had gas central heating installed, with an increase in mean indoor temperature of 2.3°C to 19.1°C. Hong et al. concluded that the introduction of insulation measures and gas central heating results in higher indoor temperatures and greater thermal comfort clearly demonstrating the process of take-back i.e. occupant desire for increased temperature to achieve thermal comfort. The combination of both central heating and insulation was found to be the most effective in achieving the desired thermal comfort.

Hong et al. (2006) aimed to determine the effect of the Warm Front scheme on space heating fuel consumption. A sample of 1372 house was used for this study and included the recording of indoor temperatures and collection of property utility data. Hong et al concluded that energy efficiency improvements from the installation of insulation and improved heating systems have not been evident, and there appears to have been no reduction in fuel consumption despite the increased post-intervention temperatures. Hong et al. states that it is not unusual for energy improvements in buildings to not deliver the potential reduction in fuel consumption and attributes this to the “comfort factor”

Kane et al. (2011) investigated the relationship between house type and indoor temperature by measuring temperatures in 300 dwellings in Leicester.

Table 2.14 Mean indoor temperature (living room °C) for February 2010 measured in 292 dwellings

	Whole Day	Morning (7:00-9:00)	Day (9:00-17:00)	Evening (17:00-23:00)	Night (23:00-7:00)
All dwellings (n=92)	18.4	17.5	18.2	19.4	18.1
Detached (n=29)	17.6	16.3	17.2	18.6	17.1
Semi-detached (n=130)	18.5	17.5	18.2	19.6	18.2
End terrace (29)	18.2	17.6	18.2	19.5	18.2
Mid terrace (n=70)	17.9	17.1	17.8	18.9	17.7
Flats (n=34)	19.6	19.1	19.6	20.2	19.3

Source: Kane et al (2011)

Kane et al. calculated mean temperatures for the month of February 2010. Mean temperatures for the whole sample was 18.4°C. This mean temperature is lower than reported in previous studies but Kane et al. states that the mean outside temperature during February 2010 was 2.5°C which is lower than the 5°C standardised temperature reported in other studies. Flats had the highest average temperatures of 19.6°C and detached dwellings had the lowest average temperatures of 17.6°C. It was found that flats had higher temperatures throughout the day and cooled slower during unheated periods compared to other house types. Kane et al. showed that the relationship between house type and indoor temperature is statistically significant for all periods except the evening. Kane et al. suggests that when the heating system is not in use the heat loss through the building is related to house type but during heated periods the influence of house type is less significant.

Shipworth et al. recorded temperatures inside 358 dwellings as part of the Carbon Reduction Buildings (CaRB) survey of home energy use. This study used a nationally representative sample and did include building, technical and behavioural data including occupant reported central heating thermostat settings. Using these temperature measurements Shipworth et al. estimated average thermostat settings and average daily hours of central heating use. Calculations were based on the living room temperatures from 1 November 2007 to 31 January 2008.

Shipworth et al. found significant variations in both estimated and reported thermostat settings with standard deviations of 2.5°C and 3°C respectively. Although both the mean and median thermostat settings were 21°C, it was found that 30% of the sample had settings of less than 20°C and 40% had settings of 22°C or higher. No correlation was found between estimated and reported thermostat settings, even when selecting the more energy efficient dwellings. Significant variation was also found in the reported number of hours per day that the central heating is on with a standard deviation of 5.4 hours. However Shipworth et al. found much less significant variation in the estimated number of hours per day that the central heating is active with a standard deviation of 1.5 hours per day. The study also found that detached houses were heated for significantly longer than mid terrace houses with significant difference in the mean number of hours for both estimated and reported active heating hours.

Shipworth et al. concludes that households that use central heating controls do not have demand temperature that are any lower or heating durations that are any shorter than households that do not use controls. As this study shows that the use of heating controls did not reduce either maximum living room temperature or duration of operation, Shipworth et al. suggest that policy makers need to revise their assumptions that adding controls will reduce energy usage. Also as this study shows that detached houses are heated for longer than any other house type Shipwoth et al. states that detached houses should be prioritised for targeting in energy efficiency programs. Shipworth et al. concludes by stating that building energy models that inform energy policies require greater real world data to improve policy effectiveness.

Table 2.15 Summary of previous indoor temperature studies in UK dwellings

Reference	No. dwellings	Sample type	Monitoring	Mean temperature (°C)
Hunt & Gidman (1978)	1000	Nationally representative	Spot temps Living-room, kitchen & bedroom	Whole house 15.8 Living-room 18.3 Kitchen 16.7 Bedroom 15.2
EHCS (1996)	16,100	Nationally representative	Spot temps Living-room & hallway	28% living room <16 44% hallway <16
Milton Keynes Energy Park Summerfield et al (2006)	13	Low energy homes	Every hour over 2 separate years 1989/90 & 2005 Living-room & bedroom	Livingroom 20.1 (2005) Bedroom 19.5 (2005) Similar temps to 89/90 except bedroom in evening-1.3 degree decrease
Warm Front Study Oreszczyn et al (2006)	1604	Lower income qualifying for receipt of Warm Front Grant	Every 30 minutes for 2-4 weeks over winter of 2001/02 & 2002/03 Living-room & bedroom	Living-room daytime 19.1 (+1.6 post intervention) Bedroom nigh-time 17.1 (+2.8 post intervention)
Warm Front Study Hong et al (2009)	2519	Lower income qualifying for receipt of Warm Front Grant	Twice daily at 8am & 7pm for 11 consecutive days over winter of 2001/02 & 2002/03 Whole house (living-room & bedroom)	30.2% <16 pre intervention 7.2% <16 post intervention Elderly households: 16.8 pre intervention 19.1 post intervention
Kane et al (2011)	300	City of Leicester	Every 30 minutes Feb 2010 Whole house (living-room & bedroom)	All dwellings 18.4 Flats 19.6
Shipworth et al (2011)	358	Nationally representative	Every 45 minutes Nov 07 to Jan 08 Living-room	Mean & median thermostat setting 21 30% <20 & 40% >22

A summary of the findings from all the studies outlined can be found in Table 2.15. The majority of these studies identified specific sample groups i.e. low income households, low energy households, households in specific geographical areas etc. These studies do not provide the necessary data on indoor temperature, heating patterns and heating usage which could be considered to be nationally representative. It can be argued that the only nationally representative temperature monitoring study inside households in the UK since the English Housing Conditions Survey was by Shipworth et al. (2011).

Previous studies in New Zealand

The Household Energy End-Use Project (HEEP) was conducted in New Zealand between 1999 and 2005. The HEEP project holds data on 397 houses from the far north (Kaikohe) to the far south (Invercargill) giving a statistically representative sample of New Zealand (Stoecklein et al 2001).

Living room and bedroom temperatures were monitored as part of the project. Temperatures were recorded at 10 minute intervals in the living room and main bedroom for approximately 1 year. Technical information relating to the building including house construction and heating and water systems was recorded and also relevant information relating to the occupant was obtained (French et al 2007).

French et al. analysed the living room temperature data recorded over the winter months (June-August) from the sample of 397 houses. They found that over this period living rooms were below 20°C for 83% of the time. The mean and median living room temperature was 17.9°C. The evening time was the warmest period and this was also the most common heating period.

It was established that the living room temperature was influenced by heating type, climate and the age of the dwelling. French et al. used the measured energy and temperature data to calculate the heating schedules and seasons which matched closely to the occupant reported heating schedules. However previous HEEP analysis (e.g. Isaacs et al 2004) was based on occupant reported heating months, but it had been found that there was a statistically significant difference, with occupants reporting on average 1.1 months less heating than actually occurred.

In conclusion French et al. analysis of data from the HEEP Project showed that New Zealand houses were cold compared to other temperate climate regions. French et al. suggests that this may be explained by the fact that New Zealanders tend to only heat the room they are in and only while they are in it. In addition the majority of homes in the HEEP Project were of timber construction and only 5% of houses sampled had central heating. This means that as the housing stock in New Zealand is so different to that in Ireland and the United Kingdom, that these research findings are not as relevant as studies conducted in the UK in particular.

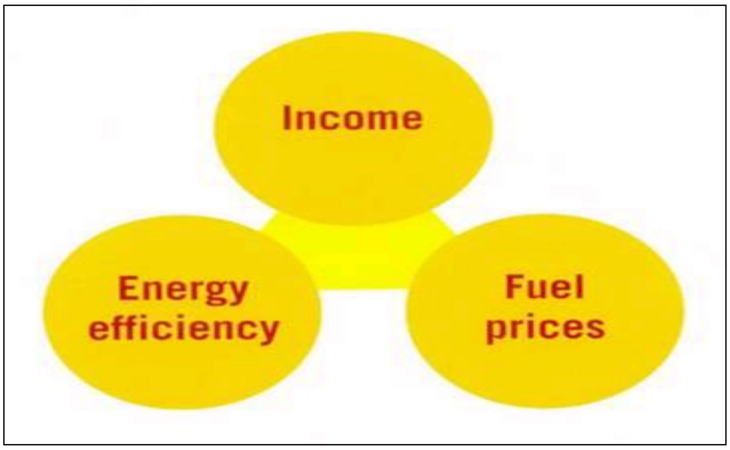
2.5 Fuel (Energy) Poverty

Fuel poverty is perhaps the strongest adverse social impact resulting from the inefficient consumption of energy in the domestic sector (Healy & Clinch, 2002). Fuel poverty or energy poverty refers to a situation when someone is unable to afford to heat their home to a level that is healthy and safe. A level that is healthy and safe is generally recognised as 21°C in living-rooms and 18°C in bedrooms i.e. the WHO guideline temperatures for thermal comfort in the home.

An important aspect of fuel poverty among older people is the requirement that people go without other essentials in order to keep warm. Fuel poor households simply do not have enough income to afford to heat their home adequately. The consequences are multiple debts, the forgoing of other essential needs, ill health and mental stress due to the difficulty of paying bills (Energy Saving Trust, 2005).

Fuel poverty is caused by the interaction of high fuel prices, low income and poor energy efficiency in the home. A government definition of energy poverty has been set out in Warmer Homes – A Strategy for Affordable Energy Poverty in Ireland (Department of Communications, Energy and Natural Resources), 2011. This definition states that a household is considered to be energy poor if it is unable to attain an acceptable standard of warmth and energy services in the home at an affordable cost.

Figure 2.10 Determinants of fuel poverty



2.5.1 Fuel Poverty and Energy Efficiency

It can be argued that the most important determinant of fuel poverty is the energy efficiency of the house. Houses which are well insulated and have efficient heating systems are less likely to house fuel poor occupants, even if the occupants are in the lowest income categories. Affordable heating is achievable for the vast majority of families, no matter what their family income, provided they live in decent, well-insulated and energy efficient homes (Liddell, 2008).

Fuel poor households frequently occupy inefficient housing which can also be cold and damp (Energy Research Group & Environmental Institute, 1999). Improvements to the energy efficiency of the housing stock has been identified as priority for tackling fuel poverty. Improving the energy efficiency of the home has been shown to have both health and environemental benefits. In the UK, the National Centre for Social Research surveyed a sample of children over five years. It was reported that 15% of children who lived in cold homes had respiratory problems, compared to 7% of children living in energy efficient homes, and 16% of children living in damp homes had respiratory problems compared with 6% living in energy efficient homes (Barnes et al, 2008). Liddell & McKeegan (2008) reported that older people report significantly better mental health further to improvements in the energy efficency of their home and in particular, less anxiety in relation to heating costs.

Although fuel poor households will absorb 40% to 100% of savings post-retrofit as improved thermal comfort (Milne & Boardman, 2000; Heyman, Harrington & Heyman, 2011), there are environemtal benefits also. Clinch & Healy (2000) estimated that a programme aimed at improving the energy efficiency of the housing stock in Ireland would reduce energy use by a quarter and reduce CO_2 emissions by 28%. Liddell (2008) carried out a cost benefit analysis of the Warmer Homes-Northern Ireland Fuel Poverty Strategy. The savings to the National Health Service as a result of fewer people needing treatment for respiratory problems and mental health was estimated at 42% of the capital cost of the Warmer Homes Scheme. In Ireland it was estimated that increased thermal comfort as a result of energy efficiency upgrades to the housing stock could be worth €461 million in savings to households (Clinch & Healy, 2003).

2.5.2 Measuring Fuel Poverty

There are various methods of measuring fuel poverty. The most common method of measuring fuel poverty is the expenditure method i.e. a household is considered to be experiencing fuel poverty if it is spending more than 10% of its income on energy, including heating and lighting. This method is common in both the Republic of Ireland and Northern Ireland. The expenditure method is also used in the Warmer Homes-A strategy for Affordable Energy Poverty in Ireland, 2011. However the strategy references the severity of energy poverty with a greater than 10% spend on energy services meaning a household is in energy poverty, greater than 15% spend is defined as “severe” energy poverty and a greater than 20% spend is defined as “extreme” energy poverty. The strategy suggests that an estimated one-fifth of households in Ireland are likely to experience some form of energy poverty, while about 10% of households are likely to be experiencing severe energy poverty (DCENR, 2011).

In the Republic of Ireland, national survey data from the Household Budget Survey 2005 has been used to calculate levels of fuel poverty.

Projections based on this data estimated that 19.4% of all Irish households (n= 301,368) were fuel poor in 2008 (Scott et al, 2008). In Northern Ireland data from the National House Condition Survey is used, employing a more complex formula which directly assesses a range of factors including household energy efficiency. National House Condition Surveys are operated in each of the UK jurisdictions, allowing broad comparisons of fuel poverty levels on a UK basis. The 2011 House Condition Survey estimated that 42% of household were in fuel poverty in Northern Ireland (Northern Ireland Housing Executive, 2011).

The ‘subjective method’ of measuring fuel poverty is based on self-reporting of difficulties with keeping the home adequately warm. In the Republic of Ireland this is measured annually through the European Survey of Income and Living Conditions (EU-SILC) by asking respondents whether they are able to keep the house adequately warm or whether they have had to go without heating in the last year because they could not afford it. The 2012 EU-SILC survey reported that 8.5% of households in Ireland were unable to keep their house adequately warm. This is an increase of 5% since 2007. The 2012 EU-SILC survey also revealed that 12. 9% of households went without heating at some stage in the last year, which is an increase of 6.9% since 2007 (CSO, 2014).

On examination of the EU SILC figures for 2009 in table 2.16 below, it is clear that older people living alone in the Republic of Ireland were more likely than other older person households to report that they went without heating in the last year. Older people living alone were also twice as likely to report that they were unable to keep the home adequately warm.

Table 2.16 EU-SILC measures of fuel poverty for older people living alone and other older person households (Republic of Ireland, 2009)

	Household-1person aged >65yrs (%)	Household-2 or more persons at least 1 aged >65yrs (%)	All households (%)
Went without heating in last year	7.2	4.2	7.3
Unable to keep the home adequately warm	5.1	2.5	4.1

Source: European Survey of Income & Living Conditions, 2009

There are limitations to the use of subjective measures of fuel poverty among older people. In Northern Ireland as across the UK, it is observed in the house condition surveys that older people tend to report their housing condition and comfort of their home very favourably with limited agreement with objective measures (Northern Ireland Housing Executive, 2009).

Rising fuel prices, combined with the economic recession have contributed to increased levels of fuel poverty in the Republic of Ireland in recent years, particularly for vulnerable households. The Household Budget Survey 2009-2010 reports that the average weekly expenditure on fuel and light was 15.3% higher than five years earlier. This increase was mainly due to increased expenditure on electricity and gas. As a proportion of total household expenditure, households in the lowest income decile (≤€238) spent more on fuel and light than households in the highest income decile i.e. 7% compared with 2.5%. The survey also reported that retired people spent more on fuel and light than any other group, and households at risk of poverty spent a greater proportion of their income on fuel and light than those households not at risk of poverty (CSO 2012).

2.5.3 Fuel Poverty and Government Policy

Traditionally tackling fuel poverty has been a two pronged approach i.e. improving thermal efficiency of the housing stock and state subvention through household fuel payment schemes. The various energy efficiency programmes implemented in Ireland have been detailed earlier in this chapter. In relation to state subvention to alleviate fuel poverty, the winter fuel allowance payment under the National Fuel Scheme is available to people reliant on long-term social welfare and those unable to provide their own heating needs. The fuel allowance is €20 a week and is paid for 26 weeks. In addition, the majority of those households in receipt of the fuel allowance payment will also be eligible for the Household Benefits Package, which includes €35 a month towards electricity or gas (Department of Social Protection, 2014).

There has been research which has demonstrated the health benefits of winter fuel payments. A 5 city study in the USA compared two groups of low income children, one group in households receiving a winter fuel payment and the other in households that were not. It was found that those living in homes not receiving the winter fuel payment were 30% more likely to be admitted to hospital in their first three years of life (Frank et al, 2006). In a follow-on study it was reported that children in households not receiving the winter fuel payment consumed 10% less calories which demonstrated the "heat or eat" phenomenon which is often associated with fuel poverty (Child Health Impact Working Group, 2006).

Healy & Clinch (2004) suggested that fuel allowance payments in Ireland were not sufficient to meet the cost of heating the home due to energy inefficient housing and low incomes. However, this was based on data from over 10 years ago and may or may not be applicable today. In recent years the government has made significant strides in tackling fuel poverty. The National Energy Efficiency Action Plan (NEEAP) 2009-2020, the National Action Plan for Social Inclusion (2007-2016) and Delivering a Sustainable Energy Future for Ireland (2007-2020) have all demonstrated a commitment to dealing with fuel poverty.

A Strategy for Affordable Energy Poverty in Ireland (Department of Communications, Energy and Natural Resources), 2011 is the first government strategy aimed at making energy affordable for low income houses. The strategy recognises that energy (fuel) poverty is a complex issue and that an integrated policy approach to addressing energy (fuel) poverty is needed. Energy efficiency, fuel prices and household income are all factors that have to be considered both individually and collectively. The strategy sets out the following objectives:

- Improving the efficiency of low income homes.
- Maximising the quality of people's lives through implementation of practical initiatives.
- A partnership approach including government departments and agencies, local authorities, energy utilities, health and social services providers, non-government organisations and community based organisations.
- Promote social inclusion and target social need.
- Be integrated within emerging anti-poverty national policy.
- Deliver cost effective approaches to addressing energy poverty.
- Be consistent with the government's climate change policy.

The strategy aims to achieve these objectives by ensuring greater access to energy efficiency measures and reforming eligibility for these schemes. This should allow low income houses who are more likely to live in energy inefficient housing to benefit. In addition the strategy aims to review the National Fuel Scheme and Households Benefits Scheme to examine the feasibility of aligning income supports with the energy efficiency and income of the home.

2.5.4 Fuel Poverty and Older People

Goodman et al (2011) carried out a review of existing government survey data from Republic of Ireland and Northern Ireland relating to fuel poverty, with a particular focus on older people.

Goodman et al concluded that older people on the island of Ireland, as in many other countries, experience a 'dual burden' in terms of fuel poverty. They are more likely to experience fuel poverty and are also particularly vulnerable to health and social harm as a result of this experience. The higher levels of fuel poverty recorded for older people on the island of Ireland appeared to be driven by all aspects of the fuel poverty model - poor housing condition, energy inefficient housing, rising fuel prices and low income.

The interface between fuel poverty and tenure, living alone, rural location, and chronic illness or disability was explored through the survey data. Older people living alone emerged as a particularly vulnerable group in terms of low income, poor housing condition and lower energy efficiency compounded by low occupancy.

Also, there was a concentration of risk factors for fuel poverty among the older age groups (75+) in terms of lacking central heating, poor housing condition and less adoption of energy efficiency measures.

A summary of the main findings are outlined below:

- Older people experience a ‘dual burden’ in terms of fuel poverty. They are more likely to experience fuel poverty and are also particularly vulnerable to health and social harm as a result of this experience.

- The higher levels of fuel poverty recorded for older people were driven by poor housing condition, energy inefficient housing, rising fuel prices and low incomes.

- The numbers of older people vulnerable to ill-effects from cold homes will increase as part of significant increases in the numbers of people aged 80 years and over and those living with chronic illness or disability.

- Self-reported ‘subjective’ measures of fuel poverty and levels of debt/arrears should be interpreted with caution in the context of older people. Expenditure based methods may have greater validity for this age group.

Goodman et al concludes that population ageing and the increasing number of older-old people has implications for fuel poverty policy. Older people are especially vulnerable to harm from cold temperatures, and particularly when there is associated illness or disability. Older people living alone have been identified as being at particular risk of income poverty and housing deprivation in the Republic of Ireland and Northern Ireland (Layte et al, 1999).

CHAPTER 3
PILOT STUDY
“ANALYSIS OF TEMPERATURE DATA FROM DATA LOGGING THERMOMETERS”

3.1 Introduction

This pilot study was completed and published in 2011 as part of the report: Fuel Poverty Older People and Cold Weather: An all-island analysis. Rather that embark on a full scale monitoring of temperatures and humidity in dwellings of older people, it was decided to conduct a small pilot study to test the feasibility of the equipment and the information generated, which it was proposed would be used for a larger scale follow on study.

This chapter details the temperature monitoring and relative humidity and dew point monitoring which was conducted at 13 local authority senior citizens sheltered housing dwellings within the Dublin area. The results are presented in both table and graph outputs. The results of this study give us an indication of the temperatures, relative humidity and dew point of the housing environment in which the occupants are living over a period of time, and how these parameters fluctuate within that period. For the purposes of this study we will focus on the temperature results.

Overall the temperature results were satisfactory. However it must be considered that these readings were taken during the spring/summer months. The limitations of the survey are obvious in that it was a small sample taken from a specific geographical area and at a time of the year when outside temperatures are at their highest. In addition the placing of the loggers in occupied homes meant it could not be guaranteed that loggers would not be interfered with and therefore results affected.

3.2 Research design and methods

The research was carried out in 13 Dublin City Council senior citizens sheltered housing dwellings. All dwellings surveyed were within sheltered housing complexes which varied in age, design and heating systems. The dwellings surveyed within each complex were either 1 bed or studio.

The information was gathered using data loggers which measured temperature (°C), relative humidity (%RH) and dew point (°C). Dew point is the temperature at which moisture (dew) begins to appear on a solid surface when the temperature of this surface is falling and there is water vapor in the atmosphere (Oxford University Press 2007). The logger used was the OM-EL-USB 2 Series pictured below.

The loggers were programmed to record temperature (°C), relative humidity (%RH) and dew point (°C) at 30 minute intervals. Once programmed the logger was placed in each dwelling to be surveyed. In the case of a studio dwelling the logger was placed in the studio area and in the case of a 1-bed dwelling the logger was placed in the main living area or the room most frequently occupied by the tenant. The dwelling occupant in each case was requested not to interfere with the data logger.

Figure 3.1: Data Logger

The temperature (°C), relative humidity (%RH) and dew point (°C) parameters were monitored over a long period of time, as continuous monitoring was necessary to show the ranges in readings over the period. The temperature was measured by a thermistor sensor in the data logger and the relative humidity was measured by a capacitive senor within the data logger. The period of monitoring varied between 3 and 4 months depending on the dwelling surveyed. When the data loggers were removed from the surveyed dwellings, the recording function was stopped and the data collected was then downloaded and exported into microsoft excel. Once the data was exported to excel only the readings recorded within the period the loggers were in the dwellings was analysed.

3.3 Results

The results for the mean, maximum and minumum values for the parameters measured at all 13 sites is presented in the table below. The full set of data for 7 of the sites is presented below in graph form. These sites were selected for further analysis as they gave an overview of varying temperature, relative humidity and dew point patterns within the dwellings over the monitoring periods. These 7 sites also included dwellings of varying ages. It was not the intention of this study to carry out detailed analysis of results for each dwelling. For such analysis to be worthwhile, additional information including occupant behaviours would be required. As stated above for the purposes of this study we will focus on the temperature readings.

The logger was set to record the temperature (°C) at 30 minute intervals over a period of 3-4 months depending on the site surveyed. The recording was carried out between April and August 2011. The logger has a temperature range of -35 to 80°Cand an accuracy of ±0.5°C. The logger has a memory of 16000 temperature readings and a battery life of 1 year.

Table 3.1: Results of readings for remperature, relative hunidity & dew point for all sites

	Temperature °C			Relative Humidity % rh			Dew Point °C		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Site 1	18.9	23.0	16.5	65.4	84.5	47.5	12.3	19.3	6.7
Site 2	23.0	26.0	7.5	49.8	64.5	41.5	11.9	15.6	-3.5
Site 3	19.8	22.5	16.5	58.7	77.0	44.5	11.4	17.3	6.2
Site 4	20.4	23.0	17.5	54.6	67.5	40.5	10.9	16.5	5.3
Site 5	23.8	30.0	18.5	44.9	60.0	25.5	11.0	16.8	4.5
Site 6	21.0	25.0	17.0	53.4	70.5	35.5	11.0	16.6	4.7
Site 7	21.3	27.5	18.0	53.0	81.0	33.0	11.3	21.8	4.1
Site 8	22.4	24.5	19.0	52.1	68.0	35.0	12.1	17.1	4.5
Site 9	21.0	29.5	18.0	54.6	80.5	33.3	11.4	18.5	5.6
Site 10	20.0	22.5	18.0	73.8	85.5	56.0	15.2	18.8	9.4
Site 11	21.2	26.0	17.0	56.5	75.5	43.0	12.2	17.2	6.8
Site 12	19.9	32.5	15.0	57.4	82.5	27.0	11.1	17.4	2.1
Site 13	20.9	25.5	18.0	53.1	76.0	33.0	11.0	17.7	4.1

The average temperatures for each site surveyed varied from 18.9ºC at site 1 to 23.8ºC at site 5. The differences in average temperatures recorded between sites 1 and 5 may be partially explained by the fact that site 1 was built over 30yrs ago, whilst site 5 was built 2 yrs ago and would have been constructed to required energy rating standard. In general it was found that the higher average tempertures were recorded at the more recently constructed sites. Sites 2, 5 and 8 had the highest average temperatures recorded and were all built in the last 2-3 yrs.

The highest recorded temperature was 32.5 ºC at site 12. This is looked at in more detail below with reference to the graph. The lowest recorded temperature was 7.5 ºC at site 2. This does not make sense but it may be the case that the logger was interfered with by the occupant. The loggers were placed in locations where it was hoped they would not be disturbed and the occupant was requested not to interfere with them. The lowest temperature recorded excluding that at site 2 was 15 ºC at site 12.

Table 3.2: Data logging period for all sites surveyed

Site 1	**15/04/11-9/08/11**	**Site 8**	**20/04/11-09/08/11**
Site 2	**28/04/11-11/08/11**	**Site 9**	**07/05/11-08/08/11**
Site 3	**14/04/11-09/08/11**	**Site 10**	**07/05/11-09/08/11**
Site 4	**19/04/11-10/08/11**	**Site 11**	**07/05/11-09/08/11**
Site 5	**19/04/11-10/08/11**	**Site 12**	**07/05/11-09/08/11**
Site 6	**20/04/11-09/0811**	**Site 13**	**07/05/11-16/08/11**
Site 7	**05/05/11-16/08/11**		

Despite this being a small sample there was quite a bit of variance between sites monitored. It is evident from looking at the graphs for sites 1, 2, 3 and 10 that the temperature did not significantly fluctuate but sites 5, 9 and 12 do show significant changes in temperature over the period of monitoring. Site 12 in particular shows both significant fluctuations in temperature and a large range in temperature with the maximum recorded value 32.5ºC and the minumum value 15ºC. It is difficult to determine the reason for the significant variance in temperature at site 12 as we are not familiar with the occupant. However it may be that the temperature is being significantly affected by the heating being turned on and off.

Figure 3.2: Temperature, relative humidity & dew point readings for site 1

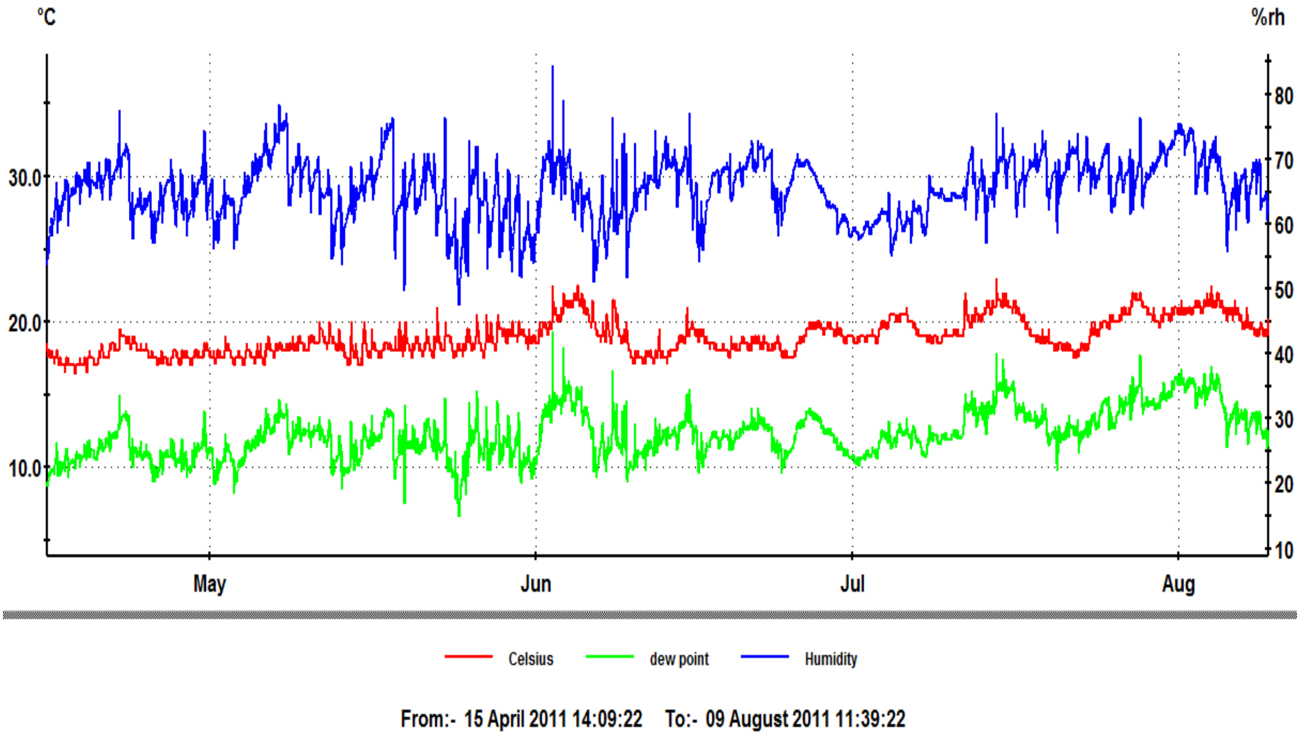


Figure 3.3: Temperature, relative humidity & dew point readings for site 2

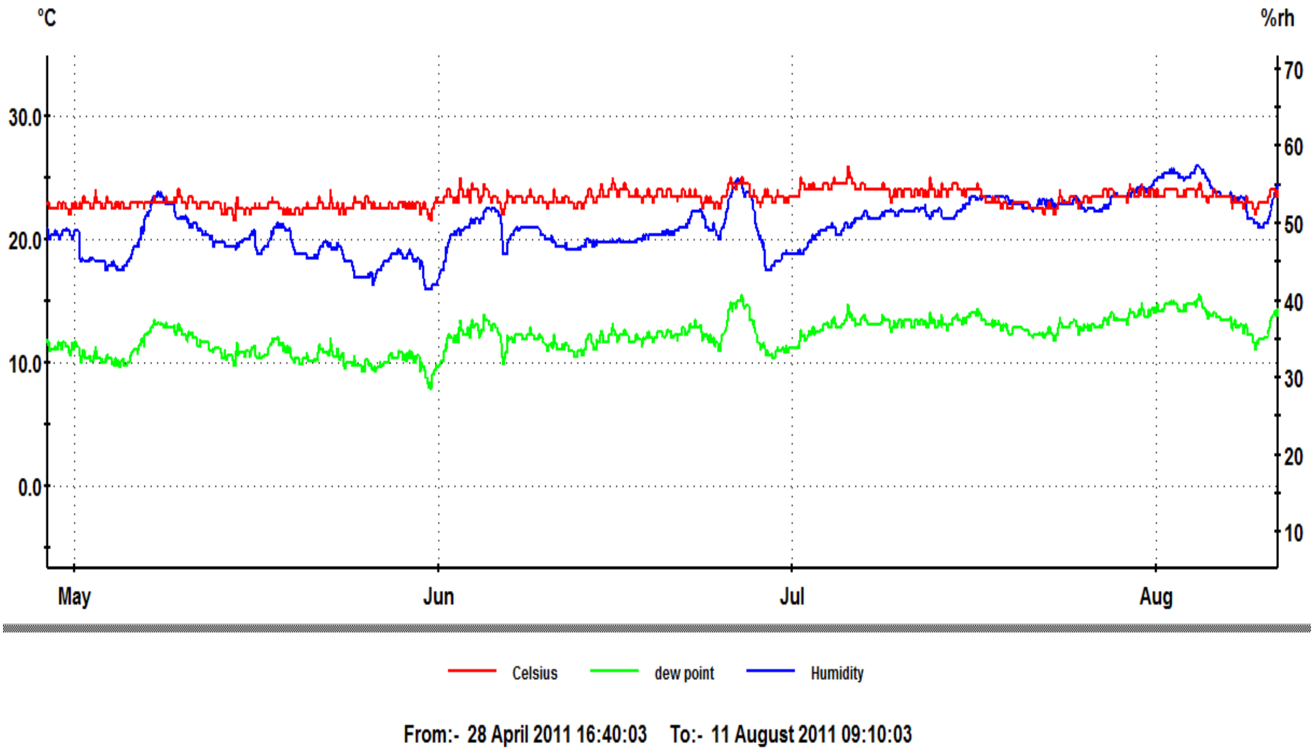


Figure 3.4: Temperature, relative humidity & dew point readings for site 3

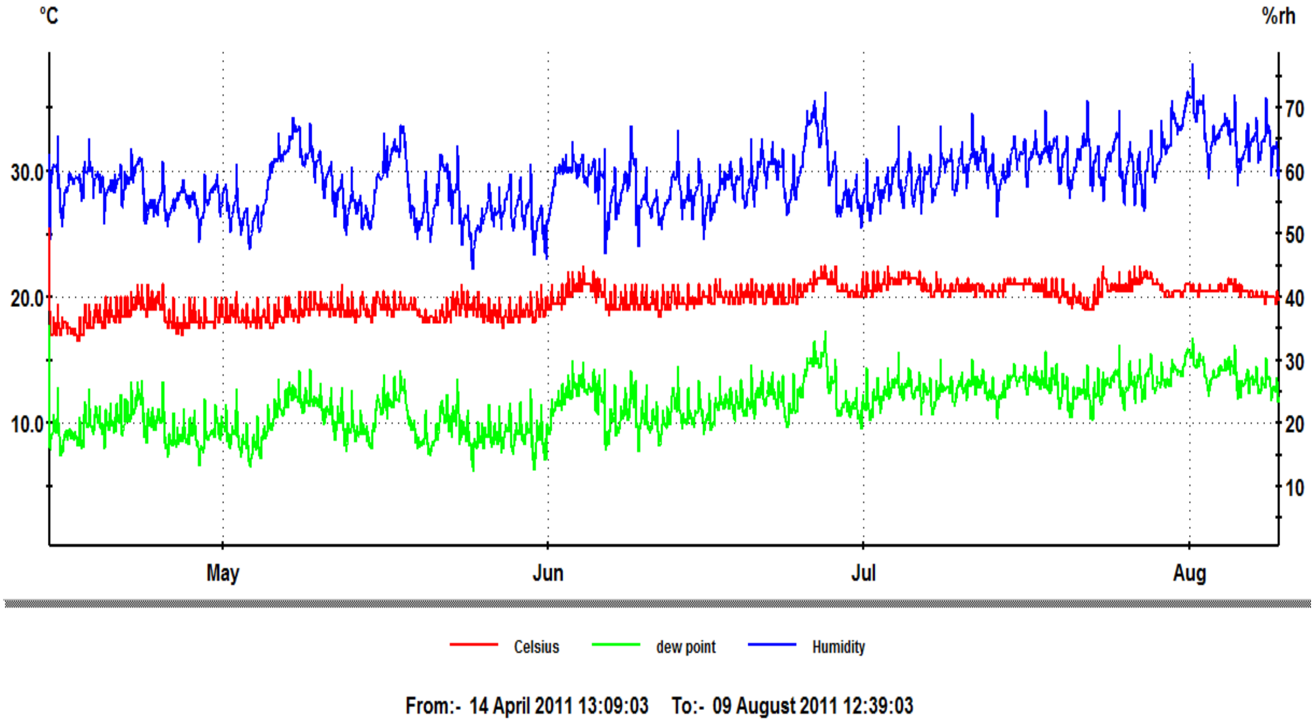


Figure 3.5: Temperature, relative humidity & dew point readings for site 5

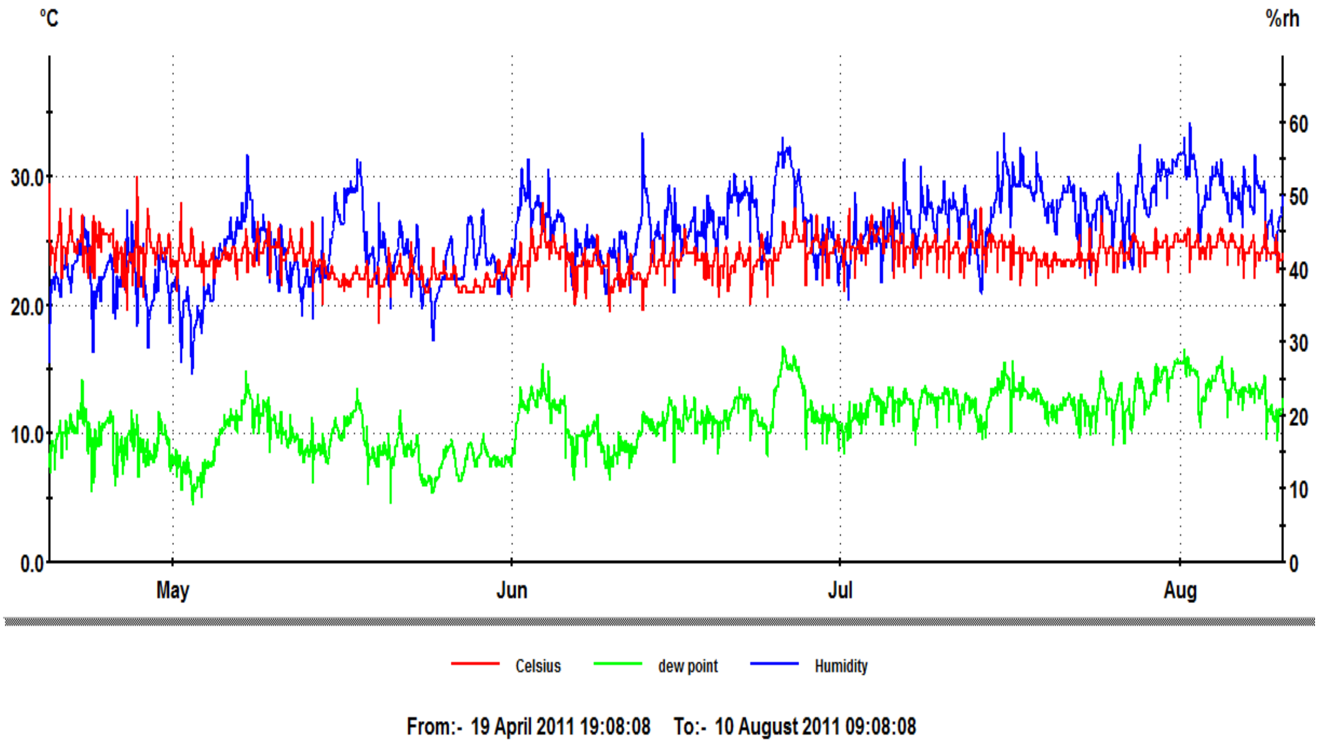


Figure 3.6: Temperature, relative humidity & dew point readings for site 9

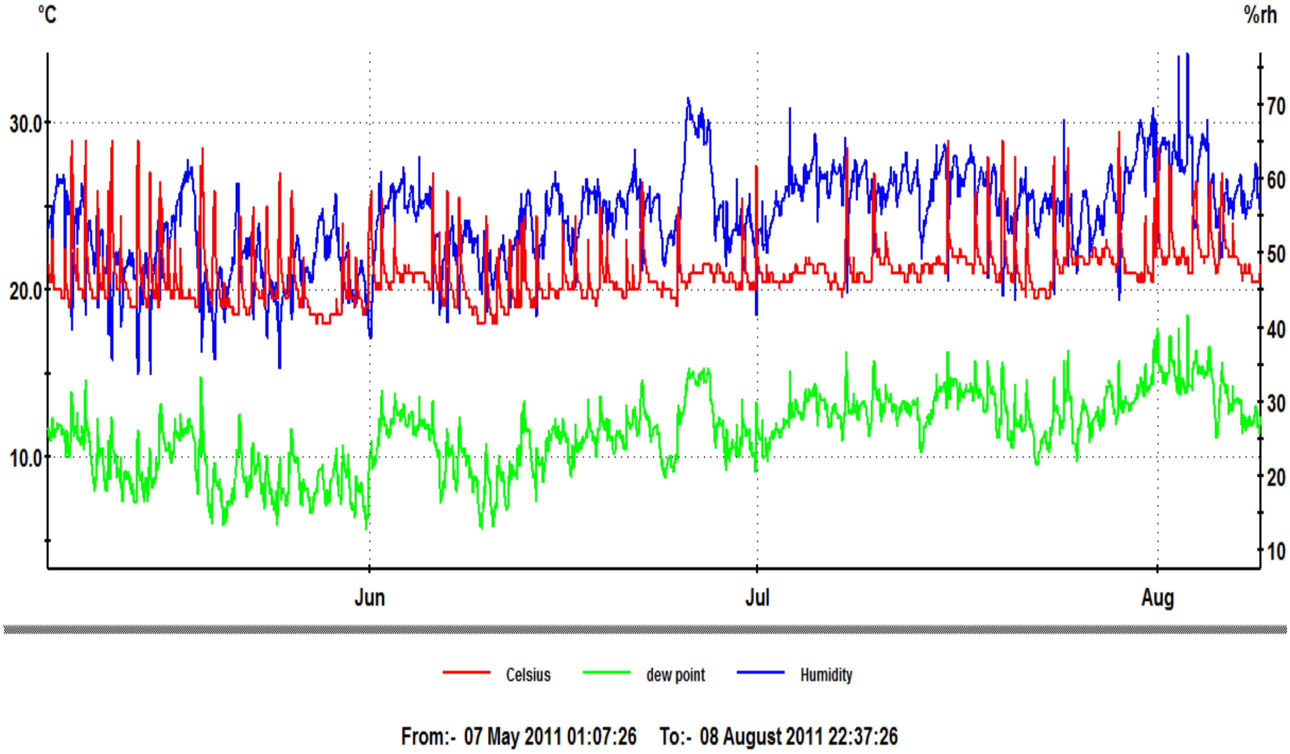


Figure 3.7: Temperature, relative humidity & dew point readings for site 10

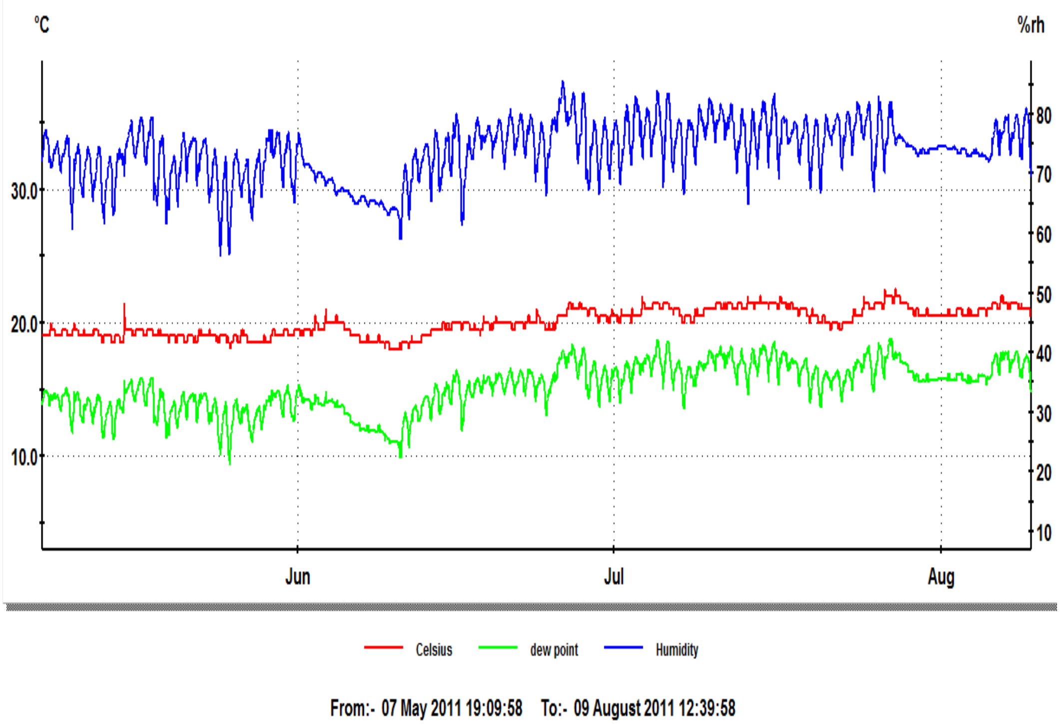
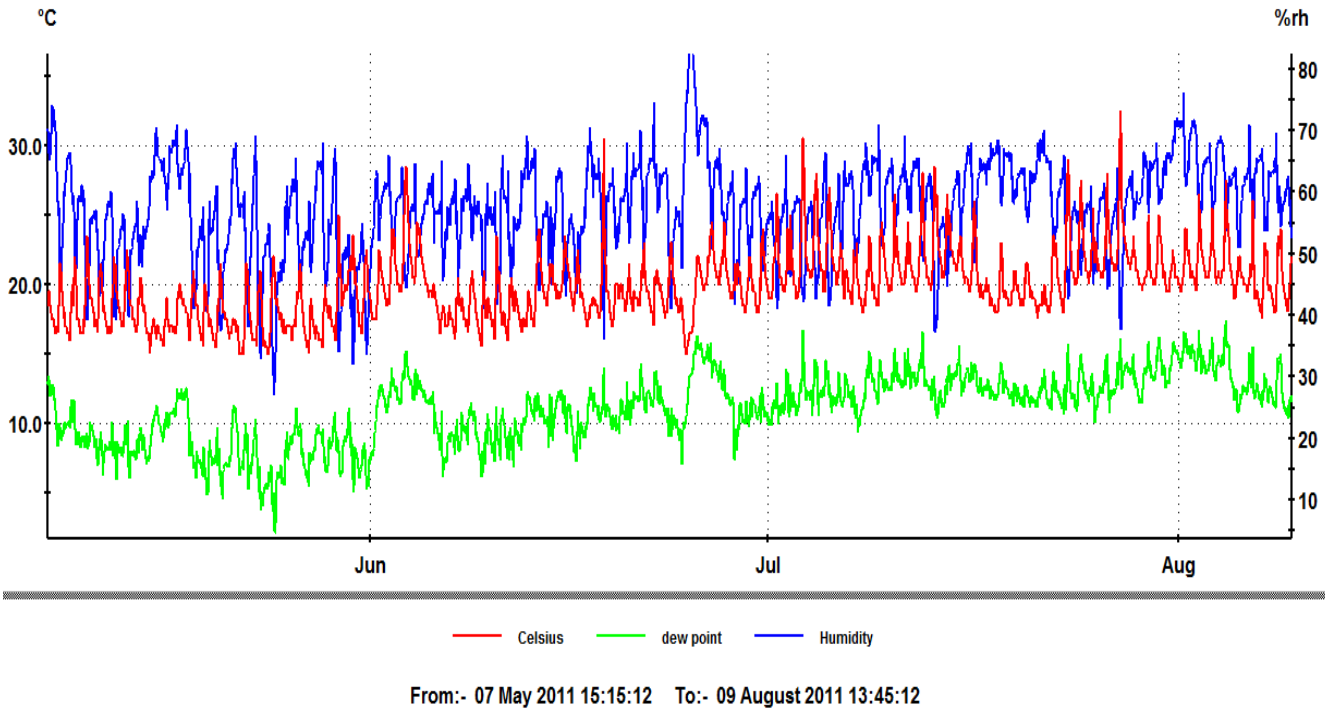


Figure 3.8: Temperature, relative humidity & dew point readings for site 12



3.4 Conclusions

The WHO states that an indoor environment between 18 ºC and 24 ºC offers little thermal threat to appropriately clothed individuals. However it has been recommended that dwellings inhabited by elderly people should be 2-3 ºC higher than for young people. Whilst based on the WHO recommendation, the temperatures recorded at the sites surveyed would appear to be reasonably adequate it must be remembered that we have not monitored during the winter period.

In truth we cannot draw too many conclusions from this survey with regard to the average ambient temperatures recorded as a newly built house constructed to the current energy efficiency standards could potentially maintain an average ambient temperature within the recommended range whilst using very little heating during the summer months.

It can be concluded from the results that people are reacting differently to the outside weather conditions. In some cases the temperature remains relatively constant while in other sites the temperature appears to fluctuate significantly. Whilst the temperatures appear to be affected by the age, design and construction of the building, the habits of the occupants also seem to have an impact on the variances in the temperatures recorded i.e the degree to which they are occupying the house and the degree to which they are using their heating.

3.5 Recommendations

This was only a pilot study, but it has clearly demonstrated the usefulness of the equipment and that it can play a role in providing quantitative data on temperatures in dwellings over a long period of time.

The Large Analysis & Review of European Housing and Health Status (LARES) carried out by the WHO in a number of countries throughout Europe identified indoor temperatures as one of the most prominent housing issues. A substantial amount of the surveyed population reported frequent problems in all seasons with cold temperatures, although 47% of all households reported too cold temperatures in winter and/or the transient season.

It is clear from LARES that the problem of cold temperatures in the home is not confined to any particular season but that it is more prominent during the winter. Overall it would be recommended that a more comprehensive survey should be carried out. The survey should cover various housing stock including private, local authority, voluntary and private rented. The survey should cover a larger geographical area, should be ideally carried out during the winter and for a minimum period of 3 months. The monitoring should also include relative humidity and dew point to give a greater indication of the overall impact on the health of the occupant and the housing and health link.

Studies carried out in Britain have shown the average temperature inside the home during the winter rose from 12°C in 1970 to 18°C in 2006. This was measured against the average external temperature which remained relatively constant over the same period. These changes are thought to be associated at least in part with the installation of more efficient and extensive heating and insulation (Uttley & Shorrock, 2008). It would be recommended that a study would include obtaining the external temperatures from Met Eireann over the period of monitoring and cross-referencing these with the indoor air temperatures.

The UK's Warm Front evaluation looked at temperatures in the home before and after retrofit. Prior to retrofit householders maintained daytime temperatures of around 19°C and 17°C in living rooms and bedrooms respectively. After retrofit, temperatures increased to 21°C and 20°C in living rooms and bedrooms respectively. Even so, post-retrofit temperatures lower than 16°C prevailed in 21% of living rooms and almost 50% of bedrooms (Oreszczyn, et al., 2006). This shows the importance of knowledge of both the housing surveyed and the occupants. It is therefore recommended that in order to fully utilise the data collected and develop links with potential fuel poverty, health impacts etc, it will be necessary to collect or have access to data relating to the housing surveyed and the occupants.

CHAPTER 4
STUDY OVERVIEW
AND
RATIONALE

4.1 Study Rationale Overview

This research was conducted in 29 Dublin City Council senior citizen sheltered housing dwellings. The dwellings were within sheltered housing complexes which varied in age, design and size. The majority of the dwellings surveyed were either studio flats with the living and sleeping areas within one room and a separate kitchen or one bedroom flats with a separate living room and kitchen. The dwellings surveyed varied in size from 25m² to 40m². The principal component of the research was the monitoring of temperature and relative humidity in the dwellings over two separate monitoring periods during the winter months of 2011-2012 and 2012-2013. The research undertaken involved both primary and secondary research methods.

There were four components to the primary research:

1. Measurement of temperature (°C) and relative humidity (% RH) inside all dwellings using data loggers over two separate monitoring periods of four months during the winter.
2. Recording electricity and gas meter readings at the start and end of the monitoring periods to calculate energy usage in the home.
3. Dwelling occupant questionnaire to obtain relevant technical, social and behavioural data and establish the prevalence of fuel poverty amongst the sample.
4. Researcher dwelling survey to confirm presence of supplementary heating, energy efficiency measures, dampness problems etc.

There were two components to the secondary research:

1. Obtaining the outside ambient temperature data for both the monitoring periods.
2. Establishing the Building Energy Rating (BER) and the age, design and heating systems in each dwelling.

The inside air temperatures recorded using the data loggers was the principal element of the research but the dwelling occupant questionnaire and the information on the physical building gave greater scope to allow a better understanding of the data logger results.

The inside dwelling temperatures and relative humidity data was used to assess thermal comfort in the sample dwellings. The recording of the electricity and gas meter readings allowed an energy usage to be calculated for each dwelling which could then be cross referenced against both the inside temperature data and the BER for the dwelling. The outside air temperature data was compared with the inside air temperatures and the patterns investigated as well as looking at the link with the energy efficiency of the dwelling.

4.2 Sample Size

The sample size was 29 dwellings. The 29 dwellings sampled were within 16 Dublin City Council senior citizen sheltered housing complexes. The main reason for the small sample size was the funding provided for this project allowed the purchase of 30 data loggers only. The data loggers were necessary for the recording of temperature and relative humidity in the dwellings.

The other reason for the small sample size was difficulty in identifying people willing to participate in the survey. The survey involved the dwelling occupant allowing the data logger to be installed in their home over the winter periods, their electricity and gas meter readings to be recorded and a questionnaire to be completed.

4.3 Property Selection

The properties selected for this project were all within Dublin City Council senior citizen sheltered housing complexes. All dwellings surveyed were studio, one bedroom or two bedroom flats/houses, and all but one dwelling had single occupancy.

These properties were selected for a number of reasons:

- Target sample of older persons i.e. aged 60yrs and over.
- Assistance of Liaison Officers within the Community Development Section of Dublin City Council to provide access to tenants within Dublin City Council sheltered housing units who were willing to participate in the research project. A number of these tenants had participated in the pilot project during the spring/summer of 2011.
- Geographical spread of sheltered housing complexes throughout Dublin City.
- Smaller housing units which meant one data logger per dwelling was sufficient
- Housing which varied in age, size and energy efficiency.
- Access to data relating to energy efficiency of the dwellings sampled, via the Housing Maintenance Section of Dublin City Council.

It was decided to target the older housing complexes with potentially poorer energy efficiency measures. With the exception of one, all of the dwellings surveyed had their own individual gas boiler and all received their own individual gas bill. The newer housing complexes were not targeted primarily because the majority of them have communal heating facilities. As the cost of heating in communal facilities is a fixed amount and is included in the tenants rent the tenant does not have to worry about how much gas they use. The newer housing complexes were also likely to have greater energy efficiency measures in place due to regulation in this area in recent years. Within this sample of older sheltered housing complexes it was intended to select the best geographical spread and the greatest variety of properties available.

The properties selected were spread across the Dublin City region both on the north and south sides of the city. The majority of the dwellings selected were within complexes that comprised of two-storey blocks of studio flats with living and sleeping areas provided in one room and a separate kitchen, and one bedroom flats with a separate living room and kitchen. There was one two bedroom flat with a separate living room and kitchen in the sample. Seventeen of the dwellings surveyed were studio flats and had an average floor space of 25m². Eight of the dwellings comprised of one bedroom flats with a separate living room and kitchen and had a floor space of 35 to 40m². The sample included flats on both the ground and first floors and both mid-terrace and end-terrace. Three dwellings surveyed were within complexes comprising of single storey semi-detached and terraced houses. Two of these houses had one bedroom with a separate living room and kitchen and the other had a studio area with separate kitchen. The number of dwellings surveyed within each complex varied from one to three. In complexes where more than one dwelling was surveyed, dwellings on different levels and different locations within the building were selected where possible.

As there was only 30 data loggers available for this project, the properties selected ensured the maximum number of dwellings could be surveyed with the monitoring equipment available. All dwellings surveyed with the exception of one were either studio or one bedroom and therefore one data logger per dwelling was sufficient. Two data loggers were used in one dwelling surveyed during monitoring period 1. It was felt that any dwelling with two bedrooms or more would require more than one data logger to get an accurate picture of the temperature throughout the house.

4.4 Primary Research

Recording of Temperature (°C) and Relative Humidity (% RH) using data loggers

Temperature (°C) and relative humidity (%RH) was measured inside each of the 29 dwellings surveyed using the OM-EL-USB 2 Series data logger. The aim of the data loggers was to provide qualitative data on the environment inside the dwellings surveyed.

The temperature (°C) and relative humidity (% RH) parameters were monitored over a long period of time, as continuous monitoring was necessary to show the ranges in readings over the period. There were two separate monitoring periods. The first monitoring period was between December 2011 and March 2012 and the second monitoring period was between December 2012 and March 2013. The same dwellings were used for both monitoring periods. The data logger procedures are detailed in chapter 5.

Recording Energy Usage

The energy usage for all dwellings was recorded for both monitoring periods. This allowed a total energy usage to be established for each dwelling during both monitoring periods. The data gathered allowed the investigation of the interactions and relationships between energy usage and the temperatures recorded inside the dwellings, and also the relationship between energy usage and the energy efficiency of the dwellings. The procedure for recording of the dwellings energy usage is detailed in chapter 5.

Dwelling Occupant Questionnaire

The aim of this questionnaire was to learn about the lived experience during cold weather periods of the occupants of the 29 dwellings in which the data loggers were placed. The pilot study in the previous chapter concluded that in order to fully utilise and understand the data collected using the loggers; you must have access to relevant data relating to the occupants. As discussed in chapter 3, a questionnaire was considered the most appropriate method of obtaining information about dwelling occupant's behaviours during cold weather. The questionnaire was adopted from the questionnaire used as part of the 2011 survey: Fuel Poverty Older People and Cold Weather: An all-island analysis. The questionnaire was modified to include a number of questions looking at different behaviours between the cold winter of 2010/11 and the milder winter of 2011/12. A number of questions were also removed e.g. tenure and type of property as this information was already known.

The aim of the survey was to establish the following:

- How occupants dealt with cold weather periods.
- What fuels occupants used in their homes and how they are managing their heating systems – if they need supplementary heat sources, efficiency of these systems and the financial implications of the need to keep warm.
- Establish the prevalence of fuel poverty amongst the sample
- Type of housing and energy efficiency measures occupants have.
- Demographic information; to include health and disability.

Dwelling Surveys

A survey of each dwelling was carried out by the researcher. The main reason for this survey was to cross reference the survey findings with information provided by the dwelling occupant questionnaire. The checklist included the following detail:

- A list of the main electrical appliances in the dwelling.
- Presence of supplementary heating.
- Presence of energy saving light bulbs.
- Presence of hot water cylinder lagging jacket.
- Presence of door draft excluders.
- Evidence of dampness and/or mould growth.
- Evidence of vents being closed or blocked.

4.5 Secondary Research

Outside Air Temperatures

It was decided that as indoor temperatures are likely to be influenced by external meteorological conditions, that external air temperature data would be needed for the survey. Outside air temperatures were necessary to provide a baseline for analysis of the temperatures recorded inside the house. This data also allowed analysis of how outside temperature influenced inside temperature at different times of the monitoring periods and in different dwelling types.

The outside temperatures were recorded at Met Eireann's Dublin airport station for the periods December 2011 to March 2012 and December 2012 to March 2013. The data was provided in excel format and consisted of average daily temperatures for both of our study monitoring periods.

Building Energy Rating and information on age, design and heating systems

The pilot study identified the importance of having knowledge of the housing surveyed. Similar to having knowledge of the occupants of the dwelling, the knowledge of the housing surveyed is important in trying to interpret the temperature data recorded inside the home.

The Housing Maintenance Section of Dublin City Council provided information relating to the BER for each dwelling surveyed. They also provided information in relation to the age, size and heating systems in all housing complexes used in the survey. All relevant information available in relation to improvements to make houses more energy efficient was provided. This type of data was also supplied via the dwelling occupant questionnaire but it was felt the tenant/occupant knowledge of the energy efficiency measures in particular may be limited. This method allowed the responses supplied in the questionnaires to be cross referenced against the information supplied by the Housing Maintenance Section.

4.6 Limitations

There are a number of limitations to this type of study. The sample size is small and this makes analysing of sub-samples difficult. Analysis by dwelling type, dwelling size etc must be interpreted with caution due to the small sample size. The dwellings surveyed are all very similar. However the pilot study showed significant variances in temperature patterns inside the houses surveyed despite the size, layout and design of the properties being quite similar.

There were also limitations in relation to the equipment used. The data loggers have proven to be quite robust but after the first monitoring period one of the data loggers failed to record any readings. This logger had the battery replaced for the second monitoring period. During the second monitoring period there was one logger which failed to record data for part of the monitoring period. It was also not possible to ensure that data loggers were not tampered with by dwelling occupants during the monitoring periods.

There were study limitations regarding the dwelling occupants. During the second monitoring period one of the dwellings was vacant for a period of 3 months. This unoccupied period related to the occupant being taken into a care facility. The temperature and relative humidity recorded in this dwelling could therefore only be used for the occupied period.

The household energy usage data had limitations. This data provided the overall dwelling energy usage for the monitoring periods and this allowed an average daily energy usage to be calculated for each dwelling. However unlike the temperature data, this did not provide real time energy usage. Real time daily energy usage would provide greater scope for analysing the relationship between the dwelling temperatures, energy usage and heating patterns. There were also limitations regarding establishing household energy spend over both monitoring periods. An estimate of the energy spend could be calculated using the energy usage data but it would be preferable to have access to household energy utility bills.

As the questionnaire was completed by the researcher whilst interviewing the dwelling occupant every effort was made not to lead the individual in answering a question. However it is difficult not to lead the interviewee when asking particular questions and therefore, the responses given may vary in some cases to that of a self completed questionnaire.

CHAPTER 5

STUDY PROCEDURES AND DATA COLLECTION

5.1 Data Loggers

An OM-EL-USB-2 data logger was placed by the researcher in each of the 29 dwellings surveyed. The same data loggers were placed in each dwelling during monitoring period 1 (December 2011 to March 2012) and monitoring period 2 (December 2012 to March 2013). The loggers were programmed to record temperature (°C) and relative humidity (% RH) at 30 minute intervals for the duration of the survey periods. Approximately 12000 data points per dwelling of temperature, and relative humidity were recorded for each monitoring period.

Logger Placement

In the case of a studio dwelling, the logger was placed in the studio area i.e. the room for both living and sleeping. In the case of a one or two bedroom dwelling the logger was placed in the living room as this was the room most frequently occupied by the dwelling occupants in all cases. During monitoring period 1, two loggers were used in one dwelling with one logger in the living room and one in the bedroom. In as far as reasonable practicable, the loggers were consistently placed in a location within the room that was not directly beside a heat source or an external wall and at a height approximately half way between floor and ceiling. Loggers were often placed on a shelf or cabinet unit. The location of the data loggers was recorded for all dwellings and the loggers were placed in the same location within the dwelling during both monitoring periods.

Controls and Calibration

Once the data loggers were installed in the dwellings by the researcher, the dwelling occupants were requested not to interfere with the data logger. On removing the data loggers the researcher checked to see if there was any evidence that the logger had been tampered with or moved from its original location. Also all data loggers were checked before and after monitoring periods to make sure they were in proper working order and where necessary batteries were replaced.

All data loggers were tested prior to each monitoring period to ensure consistency between loggers. This procedure involved all the data loggers being placed in a desk drawer for a period of 24 hours. The data loggers were programmed to record at 30 minute intervals for the 24 hour period. After the 24 hour period, the loggers were stopped and the data was uploaded and exported to excel. The average temperature over the 24 hour period was then calculated for each data logger. For the data loggers tested before monitoring period 1, there was a difference of 0.8°C between the data logger with the lowest average temperature and the data logger with the highest average temperature. The data loggers tested before monitoring period 2 showed a difference of 0.7°C between the data logger with the lowest average temperature and the data logger with the highest average temperature. The test results show that all loggers were operating within a satisfactory range of each other during both monitoring periods.

As the same data loggers were used in the same dwellings during both monitoring periods, it was possible to compare performance between the tests carried out before monitoring periods 1 and 2 respectively. It was evident that there was a consistency between the data logger's performance when tested before monitoring period 1 and monitoring period 2.

Data logger calibration was carried out before both monitoring periods. As the controls described above demonstrated that all data loggers were operating within a satisfactory range of each other, it was only necessary to complete a calibration test for one of the data loggers.

A calibrated mercury thermometer was used to measure the air temperature in the room. The temperature reading displayed on the mercury thermometer was recorded every minute for a period of thirty minutes. At the same time, the data logger recorded the room temperatures every minute for a period of thirty minutes. An average temperature was then calculated for both the mercury thermometer readings and the data logger readings. The data logger was found to be operating within 0.5°C of the mercury thermometer prior to both monitoring periods.

Data Retrieval

The data loggers were removed from the dwellings by the researcher after each monitoring period. When the data loggers were removed from the surveyed dwellings, the recording function was stopped. The data collected was then uploaded by plugging each logger into a laptop via a USB port. The data was saved and stored on a secure server. The OM-EL-USB-2 software generated graphs of the data once uploaded and the data was exported to Microsoft Excel for further analysis.

5.2 Recording and Calculating Energy Usage

Electricity and gas meter readings were taken for each dwelling by the researcher. The readings were taken when the data loggers were installed and again when the data loggers were removed for both monitoring periods during the winters of 2011-2012 and 2012-2013.

The total number of electricity and gas units used by each dwelling during both monitoring periods was calculated, by subtracting the meter readings at the start of the monitoring periods from the meter readings at the end of the monitoring periods. The total electricity and gas unit figures were then divided by the number of days between meter readings to give an average daily electricity and gas usage for each dwelling. Both the daily average electricity and gas units were converted to kilowatt hours (kWh) in order to calculate a total daily energy usage for each dwelling.

5.3 Dwelling Occupant Questionnaire Completion

The questionnaire was completed after the first monitoring period. A shortened questionnaire was also completed after the second monitoring period. On collecting the data logger from each dwelling the researcher interviewed and completed the questionnaire with the dwelling occupants. It was decided that self-completion of a questionnaire that appeared to be long may have been off-putting for certain respondents, in particular people with eyesight, literacy or concentration limitations.

As the researcher completed the questionnaire by interviewing the dwelling occupant this also meant that the majority of questions were answered and not skipped over as the researcher was able to explain any questions not fully understood by the respondent.

The majority of the questions were multi-choice but free text was provided if people wanted to include their own comments. The questionnaire took approximately 20 minutes to complete. The final page of the questionnaire was perforated for respondents to tear out and keep and included details of different services and schemes they may find useful.

The questionnaire included a confidentiality guarantee and this was brought to the attention of all respondents before completing the questionnaire. In addition ethical approval was sought and granted from the DIT ethics committee.

5.4 Dwelling Surveys

A survey of each dwelling was carried out by the researcher after the second monitoring period. The survey consisted of a 1 page checklist and was based on a visual inspection of the dwelling. In relation to establishing the presence of dampness in a dwelling, a calibrated moisture meter was used to measure moisture levels where there was visual evidence on a surface of a possible dampness issue.

5.5 Outside Temperature Data

The outside temperatures were recorded at Met Eireann's Dublin airport station for the periods December 2011 to March 2012 and December 2012 to March 2013. This data was supplied in an excel spreadsheet with daily average temperature data provided in degrees Celsius (°C).

Using the Met Eireann data the average daily outside ambient temperature for both of the study monitoring periods was calculated. The average monthly temperatures for both monitoring periods were also established using the Met Eireann data.

CHAPTER 6
DATA SUMMARY

6.1 Overview

This chapter provides a summary of the data results including:

- A profile of the sample dwellings including type, size, age, construction, heating types, insulation measures and energy efficiency.
- A profile of the dwelling occupant's demographics and characteristics including health, occupant reported condition of the home, occupant heating practices and occupant cold weather behaviours.
- Dwelling temperature data recorded over two monitoring periods inside the sample dwellings including average, maximum and minimum temperatures, average monthly temperatures and average temperatures by time of day.
- Dwelling relative humidity data recorded over two monitoring periods inside the sample dwellings including average, maximum and minimum relative humidity.
- Outside ambient air temperatures recorded over two monitoring periods including average, maximum and minimum temperatures.
- Energy usage including both gas and electric usage recorded over two monitoring periods in the sample dwellings.

6.2 Profile of Dwellings

The findings in this section are taken from the researcher dwelling survey and technical data provided by the Housing Maintenance Section of Dublin City Council. There is also some data extracted from the dwelling occupant questionnaire.

Dwelling Type and Size

The majority of the dwellings selected were within complexes that comprised of two-storey blocks of studio flats with living and sleeping areas provided in one room and a separate kitchen, and one bedroom flats with a separate living room and kitchen. There was one two bedroom flat with a separate living room and kitchen in the sample. Three dwellings surveyed were within complexes comprising of single storey terraced and semi-detached houses and were either studio or one bedroom.

Figure 6.1: Dwelling type

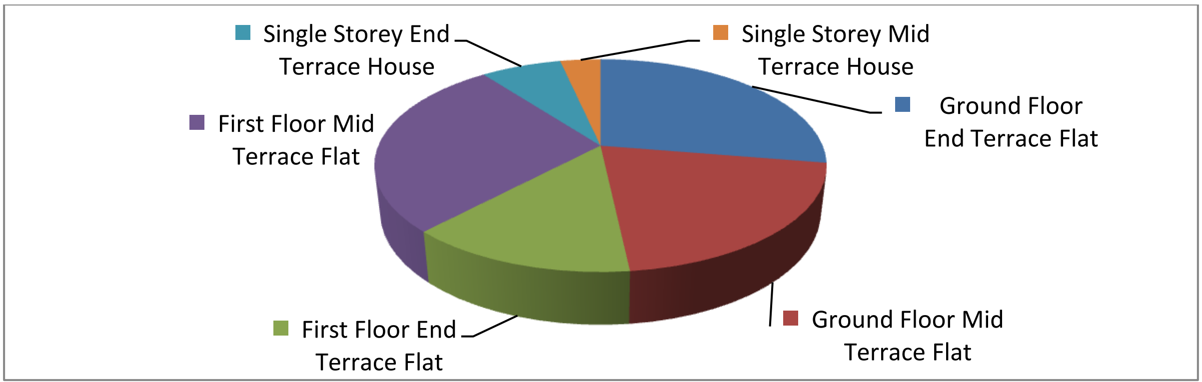
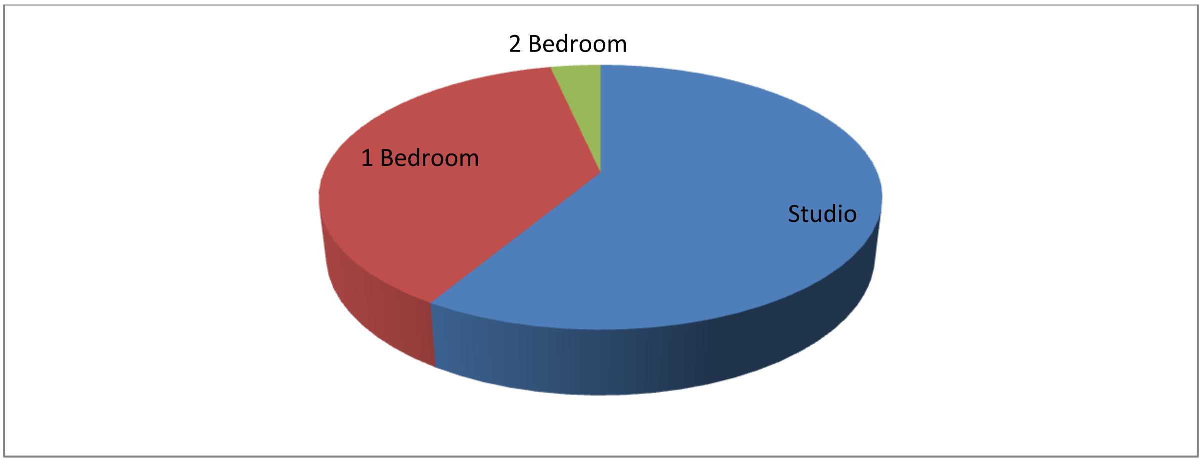


Figure 6.2: Dwelling size



Dwelling Age, Construction and Insulation Measures

All of the dwellings were constructed between 1969 and 1988, with one built in the 1960's, six in the 1970's and sixteen in the1980's. The majority of the dwellings built in the 1960's and 70's were solid wall construction, whilst all the dwellings completed in the 1980's were cavity wall construction. In total twenty six of the sample dwellings had double glazed windows. There were three dwellings with single glazed windows and all three were located in the same complex. All of the dwellings surveyed had both water cylinder lagging jackets and thermostatic radiator valves. Approximately half of the sample dwellings had door draft excluders with this measure being most common in dwellings constructed in the 1980's. There were four dwellings which had undergone significant energy efficiency upgrades and all of the upgraded dwellings were constructed in the 1980's.

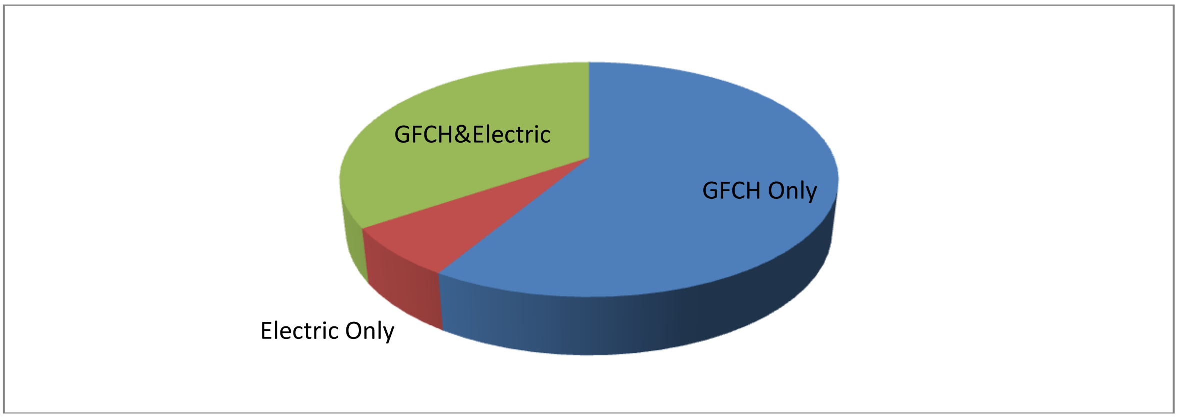
Table 6.1: Dwelling age & energy efficiency measures

	Number of dwellings (total sample)		
Dwelling age	**1969 (n=1)**	**1975-1979 (n=12)**	**1983-1988 (n=16)**
Double glazed windows	1	9	16
Single glazed windows	0	3	0
Cavity wall insulation	0	0	5
Water cylinder lagging jacket	1	12	16
Door draft excluders	1	7	10
Thermostatic radiator valves	1	12	16
Energy efficiency upgrade	0	0	5

Dwelling Heating Types

All of the dwellings with the exception of two used a gas fired central heating system with their own individual gas boiler. These two dwellings had gas fired central heating available but chose not to use it. In total, ten of the sample were using electric heaters as a supplementary heat source in most cases. The space heating types are outlined in Figure 6.3. In relation to water heating 14 respondents stated they used the GFCH to heat their water, 6 used an immersion, 6 used both GFCH and immersion and 1 used GFCH and the kettle.

Figure 6.3: Dwelling space heating type



Dwelling Building Energy Rating (BER)

The BER for the sample dwellings ranged from C1 to F. Over two thirds of the sample dwellings had a BER of E or F. The remaining dwellings had a BER of C or D. In total 4 of the sample dwellings had undergone energy efficiency upgrades in recent years, including cavity wall insulation, attic insulation where applicable and heating control upgrades. In the case of two sample dwellings, these upgrade works were completed between monitoring period 1 and 2, and therefore results could be compared before and after retrofit.

Figure 6.4: Dwelling BER (Monitoring Period 1)

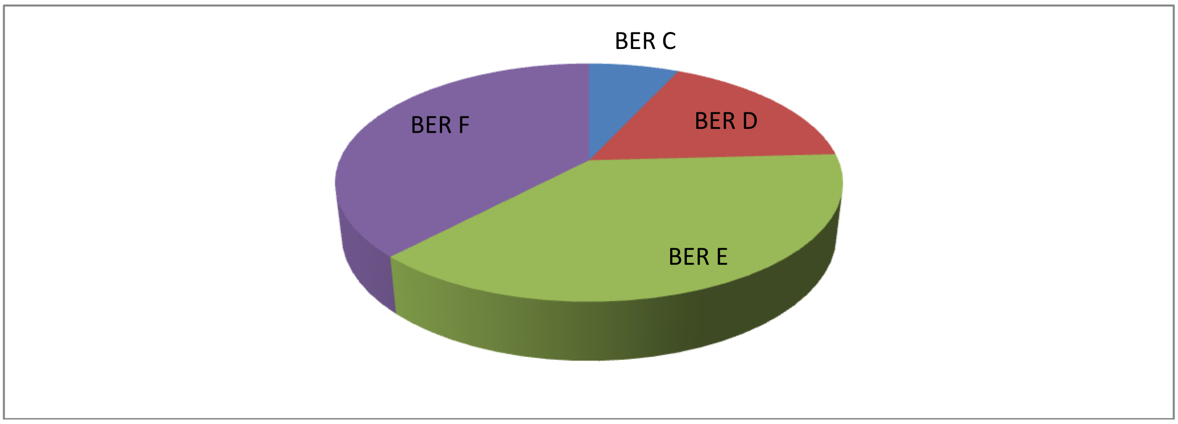
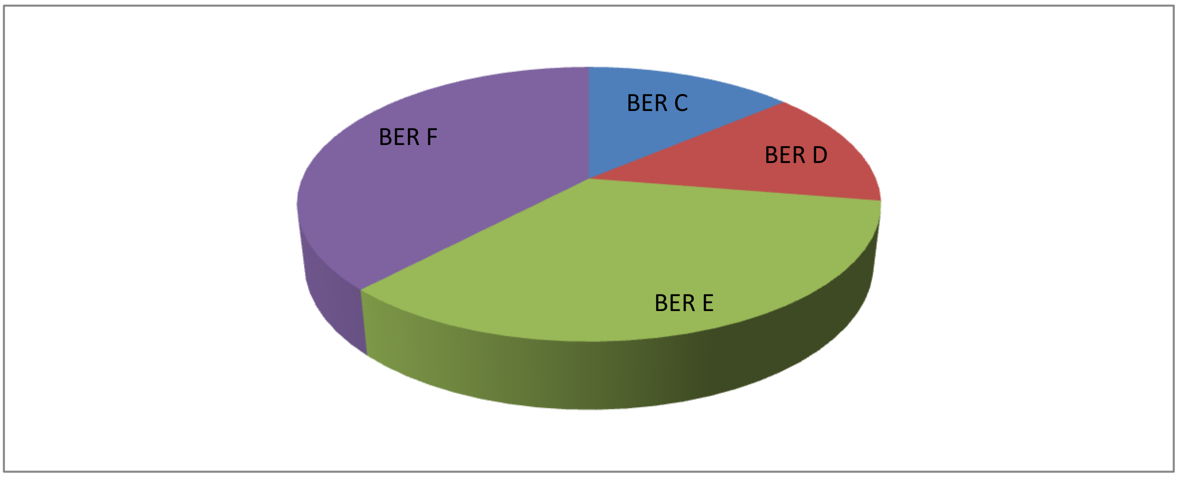


Figure 6.5: Dwelling BER (Monitoring Period 2)



The BER profile of the sample changed for monitoring period 2 as two dwellings underwent energy efficiency upgrades. Site 2 was upgraded from a BER E1 to C3 and site 17 was upgraded from a BER D2 to C1.

Condition of the Dwelling

The dwelling occupant questionnaire revealed that draughts, dampness and mould were concerns among the sample. In total 17 respondents recorded having dampness and/or draughts in their home. The dwelling surveys conducted by the researcher found that 7 of the sample dwellings had evidence of dampness and/or mould growth. The dwelling surveys also established that all of the sample dwellings had permanent ventilation in habitable rooms. However it was found that in the case of 7 of the sample dwellings vents were either blocked or closed at the time of the survey.

6.3 Profile of Dwelling Occupants

The questionnaire completed by all dwelling occupants provides an overview of respondent's demographics and characteristics including health. The questionnaire was completed by dwelling occupants after both monitoring period 1 and 2.

Age and Sex

The age range of respondents was from age 57 to age 89 (mean: 75.5 years old). There was only 1 person under age 60. There were 16 male and 14 female respondents.

Occupancy and Marital Status

All of the respondents lived alone with the exception of 1 dwelling which had 2 occupants. The marital status of the occupants is outlined in Table 6.2.

Table 6.2: Marital Status

Widowed	Married	Single	Divorced/separated
13	2	10	5

Income

Respondents were asked to state the weekly household income after tax. The majority of respondent's household incomes were at State pension level.

Table 6.3: Household income

Weekly income (after tax)	Number (total sample)
€151-€200	3
€201-€220	1
€221-€250	20
€251-€350	2
€351-€450	2
€451-€600	1

Social Connectivity

Respondents were asked to state how many times a fortnight they engaged in various activities listed in Table 6.4 below.

Table 6.4: Social connectivity

How many times a fortnight…	Never	1-2 times	3-4 times	over 4 times	Totals
Have visitors in your home (friends, family, etc)	13	8	3	4	28
Go out to visit friends	19	6	0	3	28
Go out to visit family	10	15	0	3	28
Go out for hobbies/ social activities	10	8	1	8	27
Go out for meals/ eat out	19	8	0	2	29
Go to a day centre	23	2	1	3	29

Health Status

Respondents were asked to self rate their health status and provide details on health problems.

Table 6.5: Self rated health status

Health Status	Number (total sample)
Very good	1
Good	8
Fair	16
Bad	1
Very bad	3

The majority of respondents described their health status as fair to very good (25), despite all but two of the respondents stating they had long term health problems. In total 22 of the sample listed between one and three long term health problems. A further 5 reported four to six long term health problems and two respondents reported 7 long term health problems. Arthritis was the most common long term health problem with 16 of the total sample stating they had it. Circulation problems were also common and reported by 13 respondents. In relation to mobility 12 of the sample respondents stated they used a walking aid and 10 of the respondents identified mobility when asked if they had a disability. In total almost half of the respondents (14) stated their health problems were affected by cold weather.

Occupant Thermal Comfort, Heating Practices and Cold Weather Behaviours

The questionnaire revealed that approximately half of the sample respondents were content with the temperature of their home with the other half stating their home was too cold. Respondents who stated their home was "too cold" gave varying reasons as to why this was the case. In the "too cold" sample 9 respondents stated draughts, dampness or poor insulation were the cause of their home being too cold, 2 respondents stated heating was too expensive, 1 stated their house was old and another that their house was end terrace as the causes.

Table 6.6: Dwelling occupant perception of thermal comfort in the home

	Period 1	[1]Period 2
Just right	15	13
Too cold	14	14
Too warm	0	1

[1]*No questionnaire completed for site 25 for period 2 as occupant was no longer in situ*

The dwelling occupant questionnaire included the ESRI indicators of deprivation. There were two of the indicators which were of particular relevance to this study and the findings are detailed in Table 6.7.

Table 6.7: Dwelling occupant self rated ability to keep home warm & dwellings that had to go without heating

	Keep home warm		Go without heating	
	Yes	No	Yes	No
Period 1	24	5	4	25
Period 2	21	7	4	24

During the first winter monitoring period, respondents tended towards keeping their heating on during the daytime for at least six hours (17), while a further 5 respondents stated that they kept their heating on for between four and six hours. This echoed the length of time spent indoors over the same period with 23 of the sample respondents stating they spent most to all of the day inside their homes. The results for monitoring period 2 were similar to period 1.

Table 6.8: Dwelling occupant reported heating hours

	Number of dwellings (Period 1)	Number of dwellings (Period 2)
1-2hrs	3	4
2-4hrs	4	2
4-6hrs	5	6
6-10hrs	12	8
More than 10hrs	5	8

Table 6.9: Dwelling occupant reported time spent indoors

	Time indoors (Period 1)	Time indoors (Period 2)
1-2hrs	0	2
2-4hrs	3	2
4-6hrs	3	5
Most of day	20	15
All day	3	4

Respondents were asked about their reactions to cold weather; people were most likely to keep warm by staying active indoors with the heating on, eating hot food and having hot drinks and using extra clothing layers and bed covers. Approximately one quarter of the sample stated that they went to bed earlier to keep warm. Table 6.10 details the dwelling occupant reported responses to cold weather.

Table 6.10: Responses to cold weather

Number of respondents (Period 1)	Number of Respondents (Period 2)	
25	27	I used my heating system/fire more than usual
17	14	I stayed inside my home
9	9	I used a hot water bottle/electric blanket(s)
12	10	I wore a coat or used a blanket indoors
2	1	I blocked vents
8	7	I went to bed earlier to keep warm
3	2	I heated only 1 or 2 rooms in the home
1	2	I slept in the living room because the bedroom was too cold
20	23	I used extra covers on my bed
26	27	I had at least one hot meal everyday
20	25	I drank hot drinks throughout the day
1	1	I drank alcohol to keep warm
4	2	I went somewhere else to keep warm and save on heating costs
14	14	I kept active indoors

Profile of Energy Usage and Costs

Respondents were asked to state the approximate cost of their bi-monthly energy bills during cold weather. In total 16 of the dwelling occupant respondents stated they had free units for their gas or electric bill with 11 of these respondents stating the free units covered the total cost of the bill.

Table 6.11: Bi-monthly bills

	Gas bill x 2 months		Electricity bill x 2 months
Free units covers bill	5	Free units covers bill	6
€0-50	4	€0-50	8
€51-100	9	€51-100	11
€101-150	10	€101-150	2
		Pre-pay meter	1

With regard to costs, respondents were asked if the price of heating their homes worried them, and also if they worried about being cut off. Tables 6.12 and 6.13 show that though worried about price, the majority of respondents were not worried about being cut off.

Table 6.12: Worry re: Price of heating the home

	Number of respondents (period 1)	Number of respondents (period 2)
I am very worried about the price	3	7
I am somewhat worried about the price	12	9
It's not something I think about	6	5
I am not very worried	6	7
I am not at all worried	1	0

Table 6.13: Worry re: electricity or gas being cut off due to not being able to pay bill

	Number of respondents (period 1)	Number of respondents (period 2)
I am very worried	3	2
I am somewhat worried	3	5
It's not something I think about	0	0
I am not very worried	5	4
I am not at all worried	17	17

Table 6.14 details the electric and gas appliances in the dwellings. This data was gathered using the occupant questionnaire and researcher dwelling survey. All or nearly all of the sample dwellings had a kettle, toaster and television. In relation to clothes washing facilities, only 4 of the dwellings had washing machines with the remainder of the sample availing of communal clothes washing facilities. There were 12 dwellings with stand-alone mobile electric space heaters with all but one of these dwellings having just one electric space heater. There were 12 dwellings in which the dwelling occupant stated they used their immersion to heat water and 15 dwellings had between one and five energy saving light bulbs.

Table 6.14: Dwelling electric & gas appliances

Appliance	Number of dwellings
Gas cooker	11
Electric cooker	17
Fridge-freezer	16
Fridge only	12
Kettle	28
Toaster	26
Microwave	20
Washing machine	4
Television	28
Electric space heater	12
Immersion water heater(in use)	12
Energy saving light bulbs	15

6.4 Dwelling Temperatures

Temperature (°C) was measured inside each of the 29 dwellings from December 3rd 2011 to March 31st 2012 (monitoring period 1) and from December 3rd 2012 to March 31st 2013 (monitoring period 2). The temperature was recorded by a single data logger in each dwelling. The data logger was located within the main living area of the dwelling and the data loggers recorded the temperature inside the dwellings at half hour intervals. The temperature data includes the results for all sites monitored over both monitoring periods.

Table 6.15: Average, average minimum & average maximum indoor temperatures recorded at all sites for monitoring period 1 & 2

	Temperature °C – Period 1			Temperature °C – Period 2		
	Average (±0.5°C)	Average Min(±0.5°C)	Average Max(±0.5°C)	Average (±0.5°C)	Average Min(±0.5°C)	Average Max(±0.5°C)
Site 1	21.3	19.9	24.4	18.3	16.3	21.8
Site 2	19.4	17.4	22	20	18.3	22.1
Site 3	N/a	N/a	N/a	14.8	13.1	17.9
Site 4	20.2	17.9	22.8	20.1	17.3	22.8
Site 5	21.1	19.2	23.6	20.8	18.7	23.6
Site 6	17.7	15.8	21.1	17.2	14.6	21.5
Site 7	18.3	15.8	22.6	15.3	12.7	20.2
Site 8	19.9	18.3	21.4	20	18.2	21.8
Site 9	22.3	19.7	24.7	21.8	20.1	23.1
Site 10	20.6	19.4	23.5	19.8	18.1	23.2
Site 11	17.5	16.4	19.7	17.2	16	19.8
Site 12	19.4	18	21.8	18.4	16.7	21.1
Site 13	17.5	16.6	19.3	17.6	16.2	21.1
Site 14	16.5	15.5	18.7	17.2	15.6	20.3
Site 15	17.8	16.4	20.8	17.6	15.8	20.9
Site 16	18.5	16.9	20.3	18.3	16.1	20.3
Site 17	24.3	20.4	28.4	23.7	19.8	27.1
Site 18	16.5	16	17.2	15	14.1	15.7
Site 19	18.5	17	20.4	18.3	16	20.6
Site 20	18.8	17.5	21	18	16.5	20.2
Site 21	20.8	20.1	21.8	20.5	19.7	21.8
Site 22	16.6	16.2	17	15.7	15.1	16.2
Site 23	17.7	17.1	18.5	17.6	17	18.4
Site 24	19.5	16.3	22.6	18.1	14.6	21.3
Site 25	19.4	18.5	20.6	18.7	17.8	19.8
Site 26	19.4	17.8	22.4	19	17.2	22
Site 27	22.6	19.9	25.7	23	20.3	25.1
Site 28	19.8	17.8	22.5	19.4	17	22.8
Site 29	17.2	16.1	19.4	16.2	14.9	18.7

There was no temperature data recorded at site 3 for monitoring period 1 due to a data logger recording failure. The data logger at site 12 did not record temperature data after January 15th 2013 during monitoring period 2 due to a recording failure. The dwelling located at site 25 was vacant from January 1st 2013 during the second monitoring period and therefore only the data recorded up until December 31st 2012 i.e. when the dwelling was occupied, was used for the purposes of this study.

For the purposes of this study the day was divided into four separate time periods i.e. morning (0700-0900hrs), day (0900-1700hrs), evening (1700-2300hrs) and night (2300-0700hrs) The average temperatures were calculated for these four daily time periods over the duration of monitoring period 1 and 2.

Table 6.16: Average inside temperature between defined hours at all sites for periods 1 & 2

	Average Temperature (±0.5°C) (Period 1)				Average Temperature (±0.5°C)(Period 2)			
	Morning 7-9hrs	Day 9-17hrs	Evening 17-23hrs	Night 23-7hrs	Morning 7-9hrs	Day 9-17hrs	Evening 17-23hrs	Night 23-7hrs
Site 1	20.8	20.3	22.9	21.1	17.4	17.2	20.0	18.3
Site 2	17.7	19.3	20.6	19.1	18.6	19.7	20.9	19.9
Site 3	N/a	N/a	N/a	N/a	13.9	14.8	15.0	15.0
Site 4	18.3	19.7	21.8	19.9	17.7	19.8	21.7	19.7
Site 5	20.6	19.9	22.4	21.6	20.0	19.4	22.6	21.1
Site 6	17.9	17.3	19.5	16.9	17.6	16.6	19.7	15.8
Site 7	16.4	17.1	21.4	17.7	13.3	13.8	19.0	14.7
Site 8	18.6	20.3	20.8	19.1	18.6	20.5	20.9	19.2
Site 9	22.0	21.9	23.5	21.8	21.9	21.8	22.5	21.4
Site 10	19.9	20.0	21.7	20.7	18.7	18.8	21.2	19.9
Site 11	17.2	17.4	17.1	18.0	16.8	16.8	17.1	17.7
Site 12	19.3	19.0	20.6	19.0	18.5	17.8	19.8	17.8
Site 13	17.1	17.0	18.2	17.5	16.8	16.8	19.1	17.5
Site 14	16.3	16.2	17.3	16.2	17.4	16.8	18.3	16.6
Site 15	16.7	17.4	18.7	17.7	16.2	17.5	18.4	17.4
Site 16	19.1	18.1	19.2	18.3	18.9	17.8	19.2	17.9
Site 17	21.1	24.0	27.1	23.2	20.6	24.7	25.7	22.1
Site 18	16.2	16.5	16.8	16.4	14.8	15.1	15.1	14.9
Site 19	17.9	18.4	19.2	18.3	16.7	18.1	19.6	17.8
Site 20	18.4	18.4	19.7	18.5	17.2	17.6	19.2	17.5
Site 21	20.6	20.7	21.3	20.6	20.2	20.4	21.2	20.3
Site 22	16.7	16.4	16.7	16.7	15.7	15.5	15.8	15.8
Site 23	17.6	17.5	18.0	17.7	17.6	17.3	17.8	17.7
Site 24	16.7	19.9	21.3	18.6	15.2	18.5	20.2	16.8
Site 25	18.9	19.4	19.8	19.1	18.6	18.7	19.1	18.6
Site 26	18.0	19.0	21.2	18.9	17.7	18.8	20.4	18.4
Site 27	21.5	22.7	24.4	21.5	22.3	22.8	24.1	22.5
Site 28	18.3	20.1	21.0	19.0	17.5	20.1	20.8	18.1
Site 29	16.5	17.1	17.9	16.9	15.3	16.1	17.0	15.7

Average monthly temperatures were calculated for each of the months during which temperature data was recorded. The average monthly temperatures for all sites during both monitoring period 1 and 2 are presented in Table 6.17.

Table 6.17: Average monthly indoor temperatures recorded at all sites for monitoring period 1 & 2

	Average Temperature(±0.5°C) (Period 1)				Average Temperature (±0.5°C) (Period 2)			
	Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar
Site 1	21.4	21.0	21.3	21.4	18.7	18.3	18.3	17.8
Site 2	20.3	18.9	18.9	19.6	19.4	19.1	21.0	20.5
Site 3	N/a	N/a	N/a	N/a	16.4	14.4	14.5	14.1
Site 4	19.8	20.1	19.8	21.0	19.9	20.2	20.2	20.1
Site 5	20.4	21.4	21.4	21.4	20.5	21.0	21.2	20.6
Site 6	17.0	17.9	17.2	18.7	17.4	17.2	16.9	17.3
Site 7	17.9	18.3	18.2	18.8	16.2	16.0	15.2	13.9
Site 8	19.1	19.4	20.2	20.8	20.0	19.8	19.6	20.7
Site 9	20.9	22.8	22.9	22.4	21.9	21.8	22.1	21.7
Site 10	20.4	20.7	20.9	20.6	20.0	20.1	19.6	19.3
Site 11	17.2	17.5	17.2	18.1	17.3	17.1	17.4	16.9
Site 12	17.7	19.8	20.5	19.6	17.9	19.3	N/a	N/a
Site 13	17.4	17.8	17.2	17.3	17.1	17.9	18.0	17.4
Site 14	14.9	17.4	16.0	17.5	18.7	18.0	14.7	17.2
Site 15	17.3	17.5	17.7	18.5	17.0	18.0	17.5	17.8
Site 16	18.3	18.4	18.7	18.8	18.7	18.5	18.3	17.6
Site 17	22.6	26.3	24.5	23.5	23.9	23.7	23.7	23.6
Site 18	16.2	15.8	16.2	17.8	15.5	15.5	13.1	15.7
Site 19	14.7	17.8	20.2	21.2	17.4	19.8	18.2	17.5
Site 20	17.5	18.9	18.7	19.9	17.6	17.9	18.1	18.2
Site 21	20.0	20.8	20.9	21.6	19.9	20.9	21.0	20.3
Site 22	16.2	16.2	16.3	17.7	16.0	15.8	15.9	15.1
Site 23	16.5	18.0	18.1	18.0	17.8	17.7	17.7	17.3
Site 24	17.4	18.4	20.9	21.5	18.9	18.9	17.2	17.2
Site 25	19.5	18.1	19.4	20.4	18.7	N/a	N/a	N/a
Site 26	18.6	19.2	19.7	20.2	18.4	19.2	19.2	19.1
Site 27	22.4	22.3	22.6	23.3	22.9	22.9	23.4	23.0
Site 28	18.7	19.8	20.1	20.7	19.4	19.1	19.3	19.8
Site 29	17.2	17.3	16.7	17.4	15.6	16.2	16.3	16.4

Table 6.18 and 6.19 show a breakdown of the temperature distribution for all dwellings during monitoring period 1 and 2. The tables display the percentage of time i.e. the number of half hourly temperature readings within a defined temperature range during each monitoring period. The temperature values used are significant from both a thermal comfort and health perspective.

Table 6:18: Percentage (%) of time that dwelling temperature was within defined ranges during monitoring period 1

	Percentage (%) of time in defined temperature ranges					
	<12°C	<16°C	<18°C	<20°C	20-24°C	>24°C
Site 1	0	0	0.2	18.7	74.1	7.2
Site 2	0	3.3	18.4	57	42	1
Site 4	0	0.2	8.6	40.2	59.5	0.3
Site 5	0	0	0.8	18.2	79.5	2.3
Site 6	0	16	48.7	84.8	15.1	0.1
Site 7	0.1	13.1	47.2	72	28	0
Site 8	0	0	8.4	42.8	57.2	0
Site 9	0	6.4	10.8	17	55.8	27.2
Site 10	0	0	0	27.1	72.8	0.1
Site 11	0	7.8	62.1	95.6	4.4	0
Site 12	0	7.6	14.7	52.7	47.2	0.1
Site 13	0	0.1	31.7	88.6	11.4	0
Site 14	0	31.7	79.9	95.5	4.5	0
Site 15	0	7.7	52.6	88.6	11.4	0
Site 16	0	0.7	25.5	83.9	16.1	0
Site 17	0	1.5	2.5	6.9	47.1	46
Site 18	0	27.3	83.1	99.4	0.6	0
Site 19	5.7	21.7	36.4	54	45.5	0.5
Site 20	0	3.7	26.6	73.2	26.8	0
Site 21	0	0	0	13	87	0
Site 22	0	24.5	84.9	100	0	0
Site 23	0	2.5	46.5	99.4	0.6	0
Site 24	0.6	10.9	27.2	51.3	44.3	4.4
Site 25	0	0.4	17.8	54	46	0
Site 26	0.6	0.9	12.8	62.4	37.5	0.1
Site 27	0	0	0.2	7.5	64.3	28.2
Site 28	0	0.9	12.2	49.5	50.1	0.4
Site 29	0	15.6	70.7	93.7	6.3	0
Total Sample	0.3	7.3	29.7	58.8	37.0	4.2

Table 6:19: Percentage (%) of time that dwelling temperature was within defined ranges during monitoring period 2

	Percentage (%) of time in defined temperature ranges					
	<12°C	**<16°C**	**<18°C**	**<20°C**	**20-24°C**	**>24°C**
Site 1	0	6	45.8	78.2	21.6	0.2
Site 2	0	5.1	15.9	41.2	57.6	1.2
Site 3	3.8	71.2	88.5	98.3	1.7	0
Site 4	0	1.8	11.9	41.3	58.5	0.2
Site 5	0	0.4	3	30.6	65.5	3.9
Site 6	0	31	62	85.1	14.9	0
Site 7	9.4	60.7	76.7	88.8	11.2	0
Site 8	0	0	4.4	39.9	59.9	0.2
Site 9	0	3	5.5	12.7	86.7	0.6
Site 10	0	0.3	7.3	62.5	37.4	0.1
Site 11	0	9.8	72.1	95.8	4.2	0
Site 12	1.5	17.4	34.6	69	30.9	0.1
Site 13	0	6.3	63.7	89.4	10.5	0.1
Site 14	0	28.8	63	84.2	15.3	0.5
Site 15	0	9.6	61.9	86.5	13.5	0
Site 16	0	3.7	36.9	83.7	16.3	0
Site 17	0	0	0.6	8.2	43.6	48.2
Site 18	15.7	60.5	87.4	96.9	3.1	0
Site 19	0	14.8	42.9	69.8	30.2	0
Site 20	0	6.1	46.1	88.5	11.5	0
Site 21	0	0	2.4	18.4	81.6	0
Site 22	0	47.5	99.7	100	0	0
Site 23	0	2.5	60.1	99.4	0.6	0
Site 24	2.8	22	42.8	66.4	33.6	0
Site 25	0	3.1	31.3	68.9	31.1	0
Site 26	1.6	2.1	18.5	70.2	29.8	0
Site 27	0	0.1	0.8	3.4	70.5	26.1
Site 28	0	1	24.6	61	37.1	1.9
Site 29	0	47	84.1	94.7	5.2	0.1
Total Sample	1.2	15.9	41.2	66.7	30.5	2.9

6.5 Outside Ambient Temperatures

The outside ambient temperatures for monitoring period 1 from December 2011 to March 2012 and for monitoring period 2 from December 2012 to March 2013 were recorded by Met Eireann at their Dublin airport weather station. The Met Eireann data used consisted of daily temperature recordings for both monitoring periods.

An average outside ambient temperature over the duration of both monitoring periods and average monthly temperatures over both monitoring periods were calculated and are detailed in Table 6.20 below.

Table 6.20: Average monthly outside ambient temperature for monitoring period 1 & 2

	Average Temperature (° C)				
	December-March	December	January	February	March
Monitoring period 1	6.6	5.9	6.1	6.5	8
Monitoring period 2	4.4	5.5	4.9	4.2	3.1

6.6 Relative Humidity

Relative humidity (% rh) was measured inside each of the 29 dwellings using the data loggers during monitoring period 1 and period 2. There was no relative humidity data recorded at site 3 during period 1 due to a data logger failure. The data logger at site 12 did not record relative humidity data after January 15th 2013 during period 2 due to a recording failure. The dwelling located at site 25 was vacant from January 1st 2013 during period 2 and therefore only the data recorded up until December 31st 2012 i.e. when the dwelling was occupied, was used for the purposes of this study.

Table 6.21: Average, average maximum & average minimum relative humidity recorded at all sites for monitoring period 1 & 2

	Relative Humidity (%rh)-Period 1			Relative Humidity (%rh)-Period 2		
	Average (±3% RH)	AverageMin(±3%RH)	Average Max(±3%RH)	Average (±3% RH)	Average Min(±3%RH)	Average Max(±3%RH)
Site 1	42.6	39.3	46.4	48.7	45.2	51.8
Site 2	62.5	55.5	69	57.2	51.3	61.6
Site 3	N/a	N/a	N/a	63.6	57.8	68.8
Site 4	45.9	41.3	50.9	43.7	39.5	48.8
Site 5	55.6	52	58.5	53.1	50.4	55.3
Site 6	60.8	54.8	67.6	58.9	52	66.2
Site 7	50	44.1	56.4	52.0	44.8	59.6
Site 8	53.5	49.7	59.1	49.5	45.5	54.8
Site 9	43	38.6	48.2	41.2	37.8	45.9
Site 10	51.9	45.5	57	54.2	47.2	59.4
Site 11	55.7	51.7	59.9	54.9	52.2	59.4
Site 12	52	47.6	59.7	53.0	48.6	59.9
Site 13	59.7	57	64.1	60.1	55.7	64.2
Site 14	74.1	69.1	77.7	71.5	66.2	75.2
Site 15	54.5	50.1	59.5	50.6	46.6	55.2
Site 16	56.3	50.1	61.8	52.8	47.3	58
Site 17	35.4	30.6	40.9	32.7	28.8	37.8
Site 18	63.2	57.5	67.8	58.9	54.7	62
Site 19	53.4	49.5	57	53.0	49	56.7
Site 20	65.4	59.7	70.9	68.8	64.2	73.1
Site 21	53.6	49.5	59.9	52.8	49.1	57.7
Site 22	53.3	50	57.4	57.6	54.9	61.6
Site 23	69.7	65.8	72.7	63.8	60.2	66.9
Site 24	58.2	52.1	64.1	58.6	51.2	66
Site 25	60.6	56	64.7	56.4	52.2	60.8
Site 26	49.4	45.3	55.1	50.5	47.1	55.4
Site 27	42.8	37.1	48.4	37.6	33.6	42.1
Site 28	47.8	42.9	54.1	46.8	42.2	51.9
Site 29	60.4	56.4	68.2	61.9	57.8	68.4

Table 6.22 shows a breakdown of the relative humidity distribution for all dwellings during monitoring period 1 and 2. The table displays the percentage of time i.e. the number of half hourly relative humidity readings within a defined relative humidity range. The relative humidity values used are significant from both a thermal comfort and health perspective.

Table 6:22: Percentage of time that dwelling relative humidity was within defined ranges during monitoring period 1 & 2

	Percentage of time in defined relative humidity ranges-Period 1				Percentage of time in defined relative humidity ranges-Period 2			
	<25%rh	<40%rh	>60%rh	>70%rh	<25%rh	<40%rh	>60%rh	>70%rh
Site 1	0	28	0	0	0	6	1	0
Site 2	0	0	69	4	0	0	32	0
Site 3	N/a	N/a	N/a	N/a	0	0	72	20
Site 4	0	14	0	0	0	26	0	0
Site 5	0	0	11	0	0	1	10	0
Site 6	0	0	53	5	0	1	46	5
Site 7	0	3	3	0	0	2	9	0
Site 8	0	0	9	0	0	11	5	0
Site 9	0	32	3	0	0	41	1	0
Site 10	0	1	1	0	0	2	14	0
Site 11	0	0	22	0	0	1	21	0
Site 12	0	1	7	0	0	0	11	0
Site 13	0	0	44	0	0	0	48	3
Site 14	0	0	99	76	0	0	99	59
Site 15	0	0	15	0	0	4	8	0
Site 16	0	0	26	0	0	2	7	0
Site 17	6	72	0	0	5	91	0	0
Site 18	0	0	67	13	0	2	47	9
Site 19	0	1	14	1	0	0	14	0
Site 20	0	0	83	18	0	0	96	40
Site 21	0	0	5	0	0	2	5	0
Site 22	0	0	11	0	0	0	34	1
Site 23	0	0	96	51	0	0	80	9
Site 24	0	0	37	6	0	2	46	4
Site 25	0	0	51	4	0	0	33	2
Site 26	0	2	2	0	0	4	5	1
Site 27	0	29	0	0	1	69	0	0
Site 28	0	6	2	0	0	13	2	0
Site 29	0	0	53	6	0	0	59	11
Total Sample	0	7	28	7	0	10	28	6

6.7 Energy Usage

Electricity and gas meter readings were taken for each dwelling by the researcher. The readings were taken when the data loggers were installed and again when the data loggers were removed for both monitoring period 1 and 2. The total number of electricity units and the total number of gas units used during both monitoring periods was then calculated and this was further broken down into an average daily usage for both electricity and gas. The average daily energy usage for each dwelling i.e. electricity and gas was calculated by converting all energy units to kilowatt hours (KWh). Table 6.23 below details the energy usage recorded for all sites.

Table 6.23: Average daily gas, electric & total energy unit usage recorded at all sites for monitoring period 1 & 2

	Energy Units KWh (Period1)			Energy Units KWh (Period 2)		
	Gas	Electric	Total	Gas	Electric	Total
Site 1	23.3	3.1	26.5	29.3	2.7	32.0
Site 2	23.9	9.0	32.9	23.4	9.1	32.5
Site 3	0.0	8.6	8.6	0.0	9.2	9.2
Site 4	24.6	5.0	29.6	40.7	5.2	45.9
Site 5	20.0	0.4	20.4	24.6	0.4	25.0
Site 6	8.0	0.9	8.8	10.7	1.0	11.7
Site 7	30.4	4.5	34.9	27.6	4.1	31.7
Site 8	30.6	6.2	36.8	39.1	7.7	46.8
Site 9	34.0	8.1	42.2	46.8	4.9	51.7
Site 10	21.3	3.0	24.4	27.0	3.2	30.2
Site 11	5.3	2.1	7.4	8.6	1.9	10.5
Site 12	22.7	3.9	26.6	14.7	5.6	20.3
Site 13	14.9	3.1	18.1	17.2	3.0	20.2
Site 14	0.4	5.8	6.2	0.7	11.1	11.8
Site 15	21.2	4.4	25.6	28.8	4.1	32.9
Site 16	45.6	7.2	52.8	54.0	5.1	59.1
Site 17	49.4	2.9	52.3	49.3	2.5	51.8
Site 18	N/a	14.6	14.6	N/a	10.1	10.1
Site 19	15.6	6.9	22.5	23.8	8.4	32.2
Site 20	12.1	6.4	18.5	16.1	5.7	21.8
Site 21	16.8	5.8	22.6	20.3	5.3	25.6
Site 22	0.4	2.8	3.2	0.5	3.4	3.9
Site 23	3.5	2.2	5.7	3.8	2.3	6.1
Site 24	28.7	7.2	35.9	35.4	4.2	39.6
Site 25	19.4	3.8	23.2	25.0	6.5	31.5
Site 26	16.7	4.3	20.9	16.4	3.8	20.2
Site 27	50.4	6.0	56.4	67.1	7.3	74.4
Site 28	22.8	5.2	28.0	25.6	5.2	30.8
Site 29	11.2	2.7	13.8	13.2	3.0	16.2

6.24: Rankings for average daily energy usage & average temperature for all sites during monitoring period 1 & 2 (Ranked by highest to lowest for energy usage & temperature)

	Energy Usage Rank		Temperature Rank	
	Period 1	Period 2	Period 1	Period 2
Site 1	12	11.0	4	12.0
Site 2	8	9.0	12	7.0
Site 3	25	27.0	N/a	27.0
Site 4	9	6.0	8	6.0
Site 5	19	17.0	5	4.0
Site 6	24	24.0	21	20.0
Site 7	7	12.0	19	25.0
Site 8	5	5.0	9	7.0
Site 9	4	4.0	3	3.0
Site 10	14	15.0	7	9.0
Site 11	26	25.0	23	20.0
Site 12	11	19.0	12	N/a
Site 13	21	20.0	23	17.0
Site 14	27	23.0	27	20.0
Site 15	13	8.0	20	17.0
Site 16	2	2.0	17	12.0
Site 17	3	3.0	1	1.0
Site 18	22	26.0	27	26.0
Site 19	17	10.0	17	12.0
Site 20	20	18.0	16	16.0
Site 21	16	16.0	6	5.0
Site 22	29	29.0	26	24.0
Site 23	28	28.0	21	17.0
Site 24	6	7.0	11	15.0
Site 25	15	13.0	12	N/a
Site 26	18	20.0	12	11.0
Site 27	1	1.0	2	2.0
Site 28	10	14.0	10	10.0
Site 29	23	22.0	25	23.0

CHAPTER 7

DATA ANALYSIS

AND

DISCUSSION

7.1 Thermal Comfort, Temperature and Energy Usage

For the purposes of this study air temperature was primarily used as the metric to identify an objective level of thermal comfort. The World Health Organisation (WHO) recommends an ambient air temperature in the home of between 18°C and 24°C (WHO, 1984). The WHO however recommends a minimum indoor temperature of 20°C for the elderly (WHO, 1987). In this study, thermal comfort is defined in accordance with WHO guidelines for those aged 65 years and over in the range 20°C to 24°C.

The average daily temperature recorded in all dwellings was 19.3°C during monitoring period 1 (Dec'11 to March'12) and 18.5°C during monitoring period 2 (Dec'12 to March'13). The average daily temperature measured in each dwelling varied from 16.5°C to 24.3°C during period 1 and from 14.8°C to 23.7°C during period 2. These figures demonstrate occupant need for very different comfort temperatures. The average minimum daily temperature recorded in all all dwellings was 17.6°C during period 1 and 16.7°C during period 2. The average maximum daily temperature recorded in all dwellings was 21.6°C and 21.1°C during period 1 and 2 respectively. This data is displayed in Table 6.15.

In over 70% of the dwellings during both monitoring periods, the average daily indoor temperature was below 20°C, which is the lower limit recommended by the World Health Organisation for the elderly. Over half of the dwellings surveyed had temperatures below 18°C for 25% of the half hourly readings recorded during period 1 and 41% of half hourly readings recorded during period 2. These results show that occupants were being exposed for long periods of time to temperatures that are known to be uncomfortable and potentially a health risk. The WHO estimates that based on existing data, cold homes account for 30% of total excess winter deaths (WHO, 2011). These findings are even more alarming when you consider 68% of the dwelling occupants stated they spent "most to all of their day" inside the home.

Although almost 60% of the sample dwellings were studio flats with living and sleeping facilities in one room, the temperatures recorded in this study are considered living room temperatures. Similar living room temperatures were recorded by Yohanis and Mondol (2010) who reported an average temperature of 19.4°C for a sample of 25 dwellings in Northern Ireland. Oreszczyn et al. (2006) investigated winter indoor temperatures in a sample of 1600 low income households and found an average daytime living room temperature of 19.1°C. Almost two thirds of the houses sampled had an occupant 60 years or older and it was found that the dwellings occupied by older persons tended to have warmer living rooms. The temperatures recorded in our study are lower than those found by Summerfield et al (2007) who monitored temperatures in a sample of 13 low energy dwellings. Summerfield et al reported an average living room temperature of 20.1°C but this higher temperature would be expected in energy efficient homes.

The results in our study compare less favourably with a nationally representative sample using data from the Irish National Survey of Housing Quality (2001). Using this data Healy & Clinch (2002) reported that for households with an occupant ≥65 years old, 16% had living room temperatures below 18°C. This figure is significantly less than the 28.6% (n=8) and 41.4% (n=12) of dwellings with temperatures below 18°C during periods 1 and 2 in our study. Only just over one quarter of the sample dwellings in our study had average temperatures above 20°C during both monitoring periods, which compares with almost 50% of dwellings reported by Healy & Clinch to be achieving average temperatures above 20°C. It must be remembered however that the temperatures reported by Healy & Clinch are for March only and not December to March as in this study. The March temperatures are examined in more detail later in this chapter. Any comparisons with the findings reported by Healy and Clinch must be interpreted with caution due to the small sample size in our study. For analytical purposes the dwellings surveyed were categorised according to the average daily temperatures as illustrated in Table 7.1.

Table 7.1: Number of dwellings by temperature group for periods 1 & 2

Dwelling Group	**[2]Period 1** **Dec 2011 to Mar 2012 (% dwellings)**	**Period 2** **Dec 2012 to Mar 2013 (% dwellings)**
Group 1 (<18°C)	n=8 (28.6%)	n=12 (41.4%)
Group 2 (18-19.9°C)	n=12 (42.8%)	n=9 (31%)
Group 3 (≥20°C)	n=8 (28.6%)	n=8 (27.6%)

Group 1 maintained average daily temperatures of less than 18°C. These dwellings used considerably less energy units than any of the other dwelling groups but fell well below the temperatures required to achieve thermal comfort. During period 2, there were four dwellings (14%) which maintained average daily temperatures of less than 16°C. Indoor temperatures below 16°C are known to impair respiratory function (Marmot Review Team, 2011). Average daily temperatures of 18°C to 19.9°C were recorded in group 2. Although these dwellings used considerably more energy units than those in group 1 during periods 1 and 2, they still failed to achieve thermal comfort. Group 3 dwellings had average daily temperatures of 20°C and greater. All but one of the group 3 dwellings maintained average daily temperatures within the WHO recommended guideline of 20°C to 24°C and therefore achieved thermal comfort. This dwelling group was the largest consumer of energy. The average daily energy usage for each dwelling group is presented in Table 7.2.

[2]Temperatures were only recorded at 28 dwellings for period 1 due to a data logger failure at Site 3

Table 7.2: Average daily energy usage by dwelling temperature group for periods 1 & 2

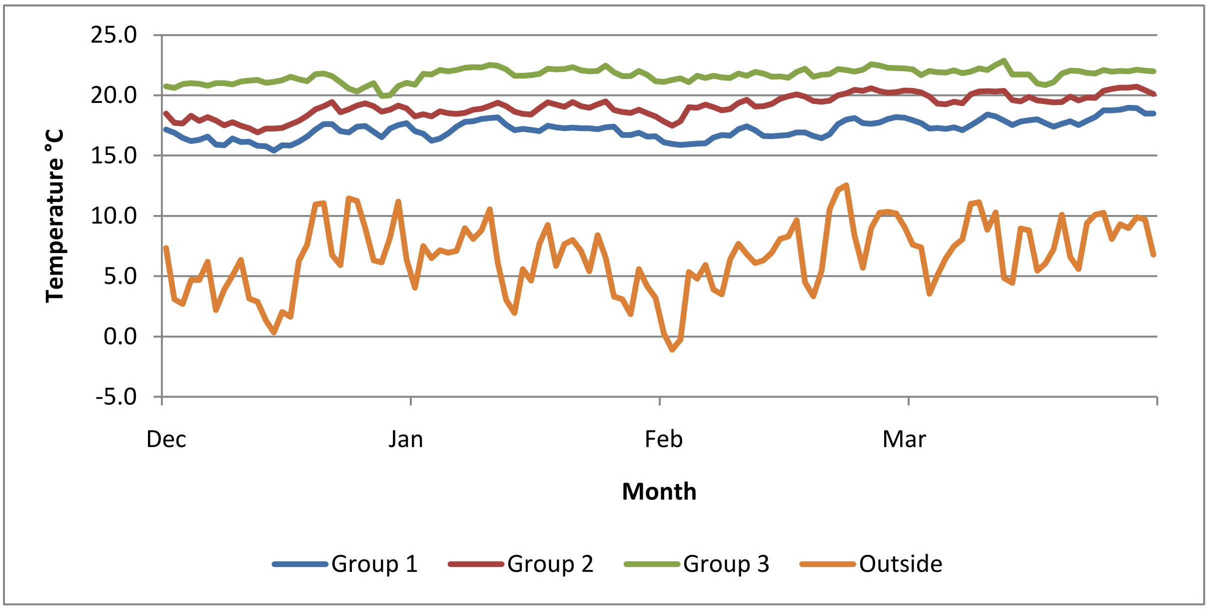
Dwelling Group	Daily Energy Usage (kWh)	
	[3]Period 1	Period 2
Group 1 (<18°C)	10.7 (n=8)	15.5 (n=12)
Group 2 (18-19.9°C)	29.3 (n=12)	32.9 (n=9)
Group 3 (≥20°C)	34.3 (n=8)	44.2 (n=8)
Total Sample	25.4 (n=28)	28.8 (n=29)

Site 17 was the only dwelling in group 3 which maintained an average daily temperature above 24°C during period 1. Site 17 had an average daily temperature of 24.3°C and 23.7°C during periods 1 and 2 respectively. This dwelling had the highest temperature and third highest energy consumption over both monitoring periods indicating an occupant need for a high comfort temperature and/or wasteful energy behaviour. Site 17 had temperatures above 24°C for 46% of the half hourly readings during period 1 and 48% of the readings recorded during period 2. This dwelling also had temperatures greater than 28°C for 18% of the half hourly recordings during period 1. The Chartered Institution of Building Service Engineers in the UK uses a comfort threshold limit of 28°C for living-rooms (Porritt et al, 2013). This demonstrates that this household was being exposed to overheating which can be equally detrimental to health as the cold temperatures in groups 1 and 2.

Figure 7.1 and 7.2 show the average daily inside temperatures for all dwelling groups and the average daily outside temperatures for period 1 and 2. It might be expected to see the dwellings with the higher average temperatures maintain a more steady temperature over the whole monitoring period. Although the group 3 dwellings maintain a slightly more steady temperature than the other groups, it is clear that all dwelling groups show similar fluctuations in temperature over both periods. This may be explained by the fact that all of the dwellings are of similar size, layout, construction and energy efficiency. This is contrary to the findings of Yohanis & Mondol(2010) who reported that households with a high average daily temperature maintain a steady temperature over the year, while households with lower average daily temperatures tend to fluctuate significantly over the year. However, these temperatures were recorded over all seasons and in various house types. The results in our study clearly show varying energy usage patterns for each dwelling group and they indicate that dwelling occupant behaviours including occupancy and heating practices have a significant influence on indoor air temperature.

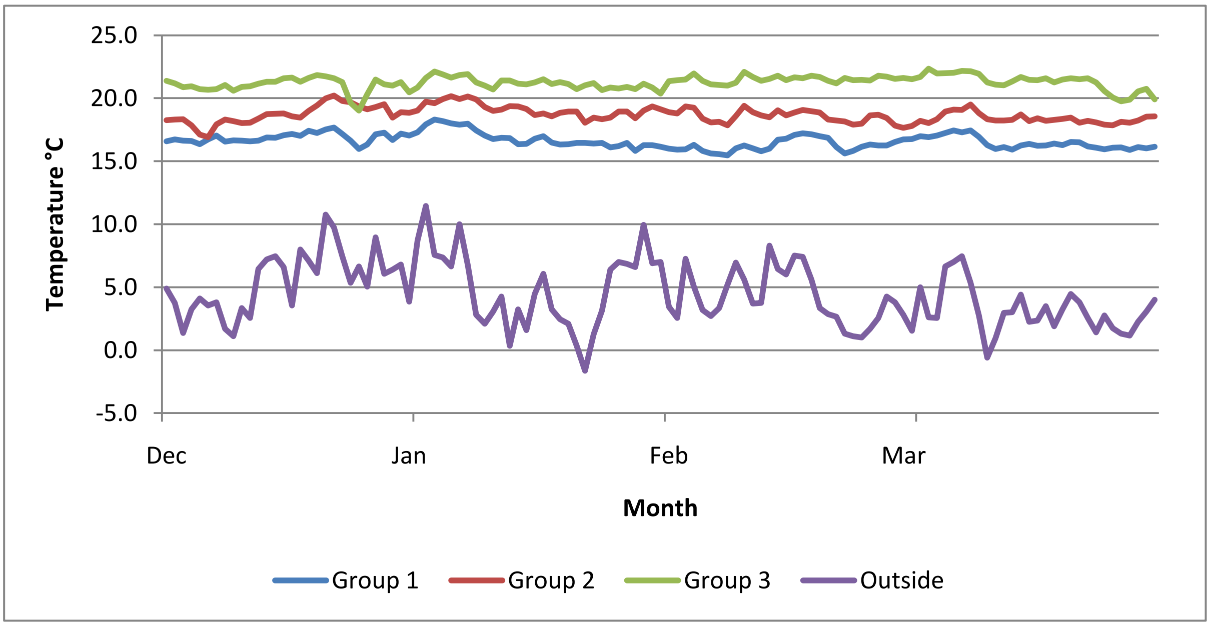
[3]Energy consumption data for site 3 during period 1 not included as no temperature data recorded

Figure 7.1: Average daily temperatures by dwelling group and average daily outside temperatures for period 1



It is evident that there is a slightly greater fluctuation in temperatures for all dwelling groups during period 2. This is almost definitely due to the lower and greater fluctuation in outdoor temperatures during period 2, compared to period 1. The average daily outdoor temperature during period 2 was 2.3°C lower than the temperature during period 1.This is particularly apparent during March where the dwelling temperatures appear to be rising during period 1 but falling during period 2.

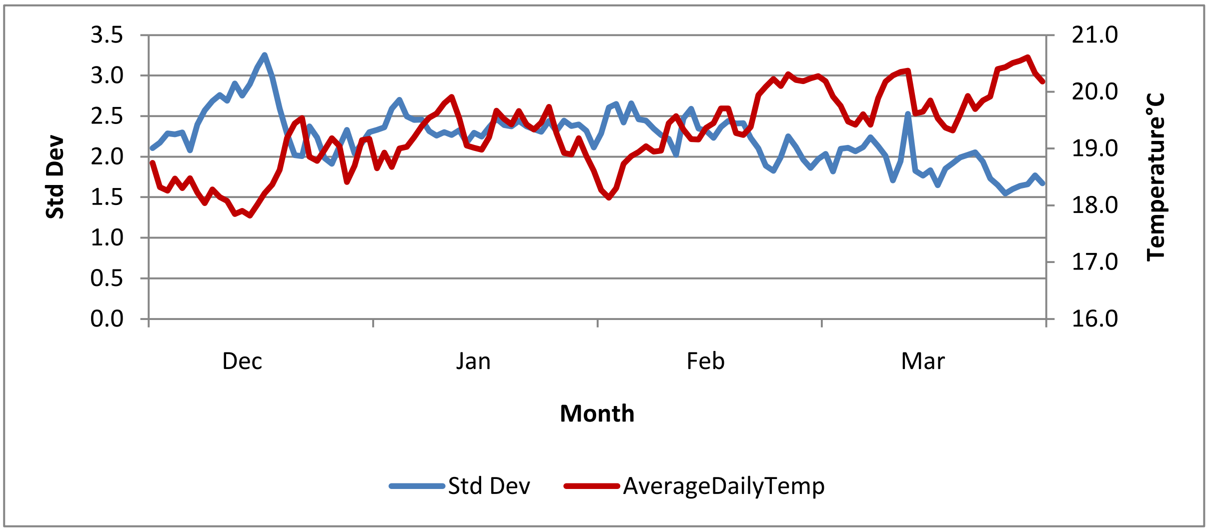
Figure 7.2: Average daily temperatures by dwelling group and average daily outside temperatures for period 2



7.2 Comparing Monitoring Periods

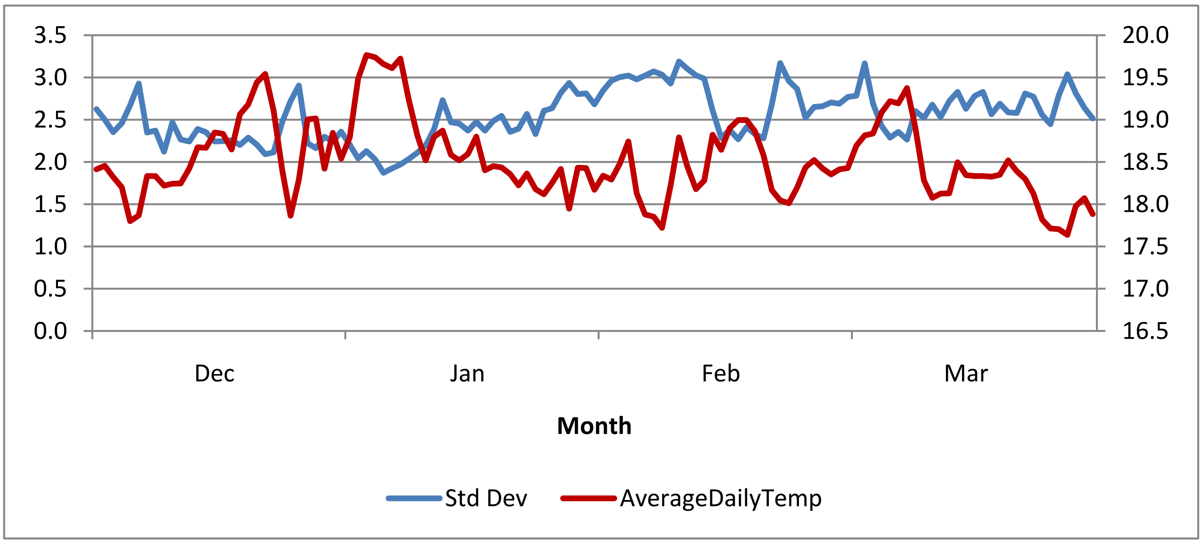
The average daily temperature recorded in all dwellings was 19.3°C during monitoring period 1 and 18.5°C during monitoring period 2. The lower average temperature recorded during period 2 was despite the fact that households used on average 20% more gas (kWh) than period 1.

Figure 7.3: Average daily indoor temperature & standard deviation of average daily indoor temperature for all dwellings during period 1



It can be seen from Figure 7.3 that the standard deviation in temperature was highest in mid December when the inside temperature was at its lowest. The standard deviation of the average daily indoor temperature remains relatively steady until mid February when the values begin to fall until the end of March. This corresponds to a rise in indoor temperature during the same period i.e. mid February to the end of March.

Figure 7.4: Average daily indoor temperature & standard deviation of average daily indoor temperature for all dwellings during period 2



In contrast to period 1, the standard deviation of the average daily inside temperature was greatest during February and March of period 2 and this corresponded to the lowest indoor dwelling temperatures during period 2 also. This drop in indoor temperature was particularly noticable during March. The results demonstrate that the standard deviation of the average daily indoor temperature was at its highest when the temperature was at its lowest.

It is likely that the findings above have been influenced by the outisde ambient temperature. The average daily outside ambient temperature was 6.6^{0}C during period 1 and 4.4^{0}C during period 2. The minimum average daily ambient temperature was -1.1ºC and -1.7ºC during periods 1 and 2 respectively, and the maximum average daily ambient temperature was 12.6^0 during period 1 and 11.5^{0}C during period 2. The average monthly ambient temperatures were similar during December for both periods but there were significant differences in ambient temperatures for the months after this. The average monthly ambient temperatures for period 2 were 1.2ºC, 2.3ºC and 4.9ºC lower during January, February and March respectively, when compared with the same months during period 1. Similar to the ambient temperatures, the average daily inside dwelling temperatures were almost identical during December of periods 1 and 2. The average daily temperatures inside the dwellings during period 2 were 0.5ºC, 1ºC and 1.5ºC lower during January, February and March respectively, when compared with period 1.

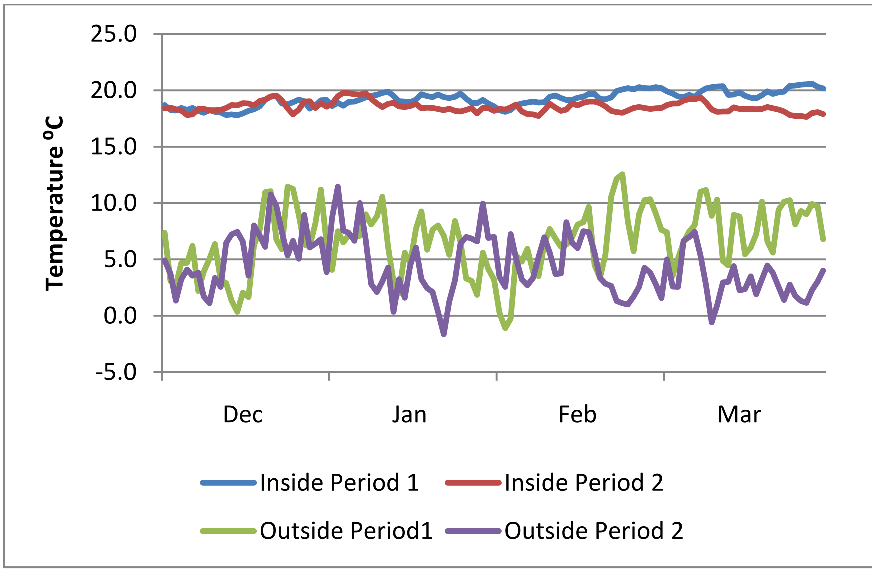
Table 7.3: Average monthly inside dwelling and outside ambient temperatures for periods 1 & 2

	Temperature (°C)			
	December	January	February	March
Period 1-Inside	18.5	19.2	19.4	19.9
Period 2-Inside	18.6	18.7	18.4	18.4
Period 1-Outside	5.9	6.1	6.5	8.0
Period 2-Outside	5.5	4.9	4.2	3.1

Figure 7.5 shows the average daily inside dwelling and outside ambient temperatures for both monitoring periods. It is clear that the inside dwelling temperatures remain relatively steady over both monitoring periods but they are also being influenced by the fluctuation in the outside ambient temperature during both periods. This is particularly evident between mid February and the end of March for both monitoring periods. It is during this time, with the exception of a short period during the beginning of March that the greatest difference in dwelling temperatures exists between monitoring periods.

The outside ambient temperatures also show the most significant diferences between monitoring periods during mid February to the end of March. The ouside ambient temperatures for both periods are very similiar for a number of days at the beginning of March which corresponds to the temperature patterns recorded in the dwellings.

Figure 7.5: Average daily inside dwelling and outside ambient temperatures for periods 1 & 2



Correlation	
Inside Period 1 V Outside Period 1	0.65
Inside Period 2 V Outside Period 2	0.55

The average monthly dwelling temperature during March of period 2 was 1.5°C lower than during March of period 1. The average monthly ambient temperature during March of period 2 was 4.9°C lower than that during March of period 1. As stated earlier in this Chapter, Healy & Clinch (2002) reported that for households with an occupant ≥65 years old, 16% had living room temperatures below 18°C and 50% had living room temperatures below 20°C during the month of March. These figures are very similar to those recorded during March of period 1 of our study, with 17.9% (n=5) of dwellings with average temperatures below 18°C and 50% (n=14) of dwellings with temperatures below 20°C. However, the temperatures recorded during March of period 2 of our study compare far less favourably with those reported by Healy and Clinch. During March of period 2 of our study, 55.5% (n=15) of dwellings had average temperatures below 18°C and 70.4% (n=19) of dwellings had average temperatures below 20°C.These results show that the significantly lower ambient temperatures have resulted in lower dwelling temperatures during March of period 2 when compared with period 1. These lower outside ambient and inside dwelling temperatures during period 2 are significant from a health perspective. A temperature related mortality study in Dublin found that each 1°C decrease in temperature was associated with a 2.6% increase in total mortality over the subsequent 40 days (Goodman et al, 2004). Keatinge & Donaldson (2000) estimate that half of excess winter deaths are attributable to indoor cold and half to outdoor cold.

The results above show some correlation between inside and outside temperatures but maybe not as much as would be expected. Whilst there were significant differences between monitoring periods in the outside ambient temperature, the average daily dwelling temperature during period 2 was only 0.8°C lower than period 1. It is likely that the less than expected drop in average dwelling temperatures during period 2 has been caused by the use of additional space heating during this period. Heating degree days are indicators of household energy consumption for space heating. Met Eireann reported 8.6% less heating degree days than the 30 year average between December 2011 and March 2012 but reported 13% more heating degree days than average during December to March 2012/13. The number of heating degree days in March 2013 was particularly striking with 40.1% more heating degree days than the 30 year average. This compares to 13.9% less heating degree days for March 2012 when compared with the 30 year average. This data is displayed in Figure 2.4.

"Get out from 11:30 to 5pm. During March put heat on all time once in house-high bills" Site 20 (Period 2)

Households on average used an additional 4kWh of gas per day during period 2 when compared with period 1. The average daily electric usage during both period 1 and period 2 remained steady at 5 kWh per day. Overall the average daily energy usage for all dwellings increased by 16%, and household gas usage increased by 20% during period 2 when compared with period 1. The average daily inside dwelling temperature during February and March of period 2 was 18.4°C. This average daily temperature was achieved during March despite the fact that the average daily ambient temperature was 1.1°C lower during March when compared with February. This would indicate that there was a significant amount of heating used by households during March of period 2. It should be noted that 37.9% (n=11) of dwellings used gas cookers. However, it is likely that the majority of household gas usage was for space heating.

Table 7.4: Average daily gas, electric and total energy usage for all dwellings during period 1 & 2

	Energy Usage (kWh)		
	Gas	Electric	Total Energy
Period 1	19.8	5	24.8 (n=29)
Period 2	23.8	5	28.8 (n=29)

Energy Costs

Using the Eurostat figures which provide tax-inclusive gas and electricity prices to households, it was possible to calculate the average household spend on gas, electricity and total energy during both monitoring periods. The gas prices used were for consumption band D1 and the electricity prices were for consumption band DB. The gas and electricity prices used were for the first semester of 2012 and 2013 as displayed in Tables 2.4, 2.5, 2.6 and 2.7.

Households spent on average €161 on gas during period 1 and €203 during period 2. This was an additional cost of €42. This means that when adjusted for price increases, households spent on average €33 more on gas during period 2 or an additional €17.50 on a bi-monthly bill when compared with period 1. However, despite this additional spend on gas during period 2, households maintained an average daily temperature 0.8°C lower than that of period 1. The average household spend for electricity was €149 and €169 during periods 1 and 2 respectively. However, this additional cost of €20 during period 2 was accounted for in full by a price increase. The average household total spend on energy was €310 during period 1 and €372 during period 2. This was total increases in energy spend during period 2 of €62 and when adjusted for price increases this figure was €33. These figures are for the four month period from December to March.

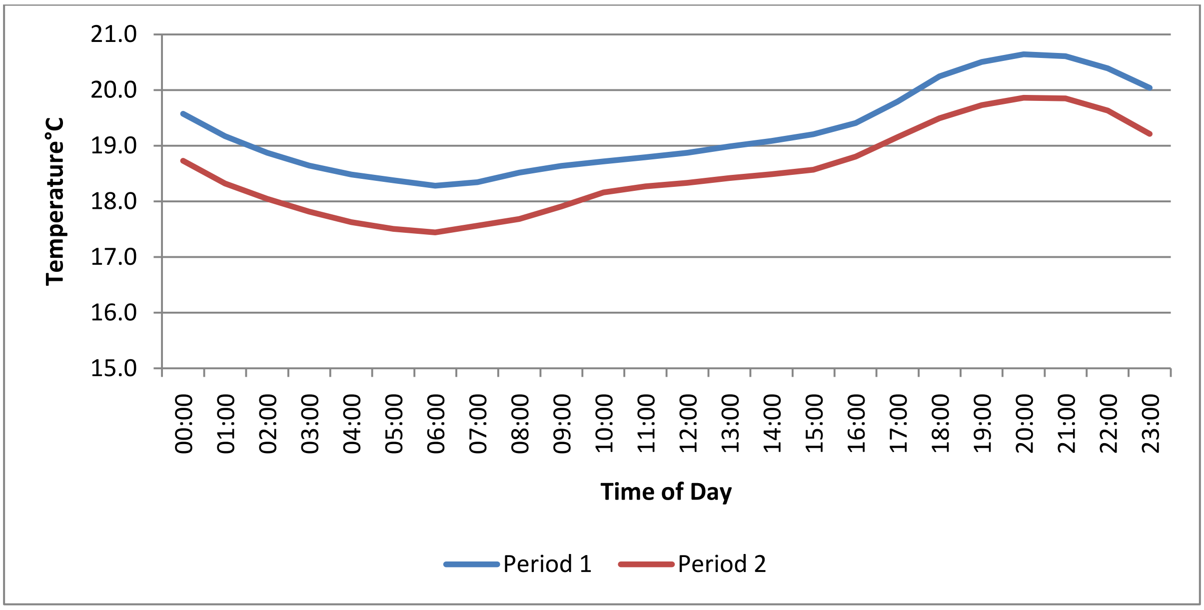
It should be noted that the consumption bands used to calculate the average spend on gas and electricity were based on average gas and electricity usage for the whole sample. The Eurostat prices for the various consumption bands are based on annual household gas and electricity usage. As energy usage data for a 12 month period was not available, it was estimated that the majority of the sample were in the consumption bands D1 (Gas) and DB (Electricity) based on the gas and electricity consumption over the 4 month monitoring periods. It is likely that there were households in consumption bands both above and below Band DB (Electricity) and above Band D1 (Gas). In the lower consumption bands the average price per kWh is higher because the standing charges and network charges form a larger proportion of the annual costs (SEAI, 2013). This would also mean that those households consuming large amounts of energy would at least be paying less per kWh.

In conclusion, the figures for household energy spend are an estimate of the average gas and electricity spend for the whole sample. There may be households who are spending less or more depending on which gas and electricity consumption band they fall into. It must also be taken into account that all of these households are entitled to free units on either their gas or electricity and therefore this would be discounted from their bill. The fact that we only have energy consumption data for a 4 month period has restricted scope for analyses of household energy spend. Energy usage data for a 12 month period would be of great benefit in allowing a more accurate estimate of the energy spend for each individual household. It would obviously be of even greater benefit to be able to access household utility bills.

7.3 Heating Periods and Occupancy

Figure 7.6 shows the average daily temperatures by time of day for all dwellings during periods 1 and 2. During both monitoring periods there were modest temperature rises of less than 1°C during the morning and early afternoon i.e. between 7am and 3pm. The dwelling temperature steadily rises from 3pm until approximately 8pm during both periods with the peak temperatures reached between 8pm and 9pm. The highest dwelling temperatures were in the evening period between 5pm and 11pm. The dwelling temperature gradually declines by 1.7°C during the night i.e. 11pm to 7am for monitoring period 1. Similarly during monitoring period 2, there was a gradual decline in dwelling temperature of 1.6°C between 11pm and 7am. Overall the results for both monitoring periods would suggest that the evening time between 5pm and 11pm is the most occupied and most heated time of the day.

Figure 7.6: Average daily temperatures by time of day for all dwellings during period 1 & 2



This gradual decline in dwelling temperature during the night for both monitoring periods may indicate that some dwellings were using their heating during this time. This argument was supported by a number of comments in the dwelling occupant questionnaire. In addition the average night temperature (11pm-7am) was only 0.5°C and 0.6°C lower than the rest of the day (7am-11pm) for all dwellings during monitoring periods 1 and 2 respectively. As outside ambient temperatures by time of day were not available this theory could not be further investigated.

“During cold weather use heat all day & sometimes at night (thermostat turned down at night)” Site 27

“Usually go out between 10am-2pm. Stayed inside because had surgery. Heat on 24/7 during cold weather + used electric heater. In hospital for 5 days around new year” Site 9

It is evident from Table 7.5 that the highest average temperatures were in the evening for both monitoring periods. The average evening temperature for all dwellings was 20.4°C during monitoring period 1 and 19.6°C during period 2. These temperatures are similiar to those recorded by Kane et al (2011) who monitored living room temperatures in a sample of 300 dewllings of varying types in the UK during the month of February. Kane et al reported average evening living room temperatures of 19.6°C for all dwellings and 20.2°C for the 34 flats in the sample.

Table 7.5: Average dwelling temperatures by time of day for periods 1 & 2

	Temperature (°C)			
	Morning (7am-9am)	Day (9am-5pm)	Evening (5pm-11pm)	Night (11pm-7am)
Period 1	18.4	19	20.4	18.9
Period 2	17.6	18.4	19.6	18.1

Overall the results in our study for the evening time are encouraging considering that this is an occupied period. It would appear that occupants are using their heating during the evening period at a time when they are in the house. However, results for average evening temperatures for the whole sample must be interpreted with caution. Further analysis reveals that only 54% (n=15) of dwellings during period 1 and 41% (n=12) of dwellings during period 2 achieved average evening temperatures of 20°C or greater. The average evening temperature for each dwelling surveyed varied from 16.8°C at site 18 to 27.1°C at site 17 during period 1 and from 15°C at site 3 to 25.6°C at site 17 during period 2. This represents a variance of over 10°C in average evening temperatures between dwellings, indicating dwelling occupants have very different demand temperatures. This may also mean that those dwellings with high temperatures are raising the average temperatures for the whole sample and masking the issue with dwellings having low temperatures. This is confirmed in the findings that 14% (n=4) of dwellings had average evening temperatures below 18°C during period 1 and 21% (n=6) during period 2. Even more alarming is that 10% (n=3) of dwellings had average evening temperatures below 16°C during period 2.

It is clear that some occupants are heating their homes adequately in the evening and achieving thermal comfort. The findings from the dwelling occupant questionnaire support this argument with almost 60% of occupants stating they used their heating for 6 hours or more per day. The quotes from the comments section of the questionnaire also indicate that some households are using adequate heating during occupied periods.

“Heat on whenever in house during cold days”-site13

“Leave heat on all day, turn off when going to bed”-site28

However, it also appears that a significant number of households are not heating their homes adequately in the evening and to a lesser extent there are occupants who are excessively heating their homes during the evening period. We know from the temperature data and the dwelling occupant questionnaire that the evening is the most occupied time of the day. The dwelling occupant questionnaire revealed that over two thirds of occupants spent all or most of the day in the home. It is positive that the majority of dwellings are heating their homes in the evening period, albeit not always achieving thermal comfort. It is likely that the primary reason for this is that the occupant is not using enough heating. However, both the efficiency of the heating system and the energy efficiency of the building may be contributing factors. It must also be remembered that whilst the thermal comfort level set for this study is 20°C to 24°C, the lower limit of 20°C is intended for bedrooms and not living rooms. The WHO recommends a living room temperature of 21°C, with increases of 2-3°C for those more vulnerable to the effects of cold strain, such as the sedentary elderly (Collins, 1986).

7.4 Dwelling Type and Size

Surprisingly the lowest recorded temperatures were in mid-terrace dwellings and the highest in end-terrace dwellings. The average daily temperatures in ground floor and first floor mid-terrace dwellings were 19.1°C and 18.4°C respectively during period 1. This compared with average daily temperatures of 19.4°C and 20.6°C in ground floor and first floor end-terrace dwellings during the same period. Similar patterns emerged during period 2 with average daily temperatures of 18.6°C and 17.5°C in ground floor and first floor mid-terrace dwellings, and 19.1°C and 19.3°C in ground floor and first floor end-terrace dwellings.

Yohanis & Mondol (2010) using a similar sample size to this study reported that for all house types, the lowest average winter temperatures were recorded in terraced dwellings. The average whole house winter temperature in the terraced dwellings was 17.7°C compared to 18.8°C in detached dwellings. It is suggested by Yohanis & Mondol that the lower temperatures in terraced houses may be due to lower occupancy.

Kane et al (2011) also found that indoor temperatures measured during the month of February were lower in terraced houses than semi-detached houses. Kane et al recorded average living-room temperatures of 17.9°C and 18.2°C for mid-terrace and end-terrace dwellings respectively. This compares with an average living-room temperature of 18.5°C in semi-detached dwellings.

The suggestion that lower occupancy may influence lower temperatures is not plausible in our study as all but one of the sample dwellings were single occupancy. It would appear that there is not as significant a correlation between house type and the indoor temperature as would be expected, and that the occupant behaviour including heating practices and duration is the single biggest determinant of dwelling temperature. This argument is supported by the energy usage data recorded for each dwelling type which is presented in Table 7.6.

Table 7.6: Average daily gas and total energy usage by dwelling type for period 1 & 2

	Energy Usage (kWh)			
	Daily Gas Usage Period1	Daily Energy Usage Period 1	Daily Gas Usage Period 2	Daily Energy Usage Period 2
Ground Floor Mid Terrace (n=7)	19.7	23.0	23.4	26.9
Ground Floor End Terrace (n=10)	20.8	26.0	24.9	30.5
First Floor Mid Terrace (n=8)	11.8	18.2	15.5	21.6
First Floor End Terrace (n=4)	33.3	38.2	38.2	42.2
Total Sample (n=29)	19.8	24.8	23.8	28.8

The end-terrace dwellings used more energy than the mid-terrace dwellings during both monitoring periods. The difference in energy consumption is particularly evident when comparing the first floor end-terrace dwellings with the first floor mid-terrace dwellings. The first floor end-terrace dwellings used double the energy and 2 to 3 times more gas than the first floor mid-terrace dwellings during both monitoring periods. The gas usage data in particular confirms that the end-terrace dwelling occupants were using more heating than their mid-terrace dwelling counterparts.

As there were only four dwellings in the first floor end terrace category, we cannot draw any definite conclusions but this again highlights the significance of the effect of occupant heating practices on the dwelling temperature.

Any findings and/or conclusions from analysis by house type in this study must be interpreted with caution. The sample size is small and there are a myriad of other factors outside the scope of this study to explain the variance in temperature and energy usage in different house types. One such factor would be the location of the living room within one and two bed end-terrace dwellings i.e. number of exposed walls. The living room in some cases would have had only one external wall but in other cases there would have been two or three external walls. The location of the living room may therefore have influenced the temperature recorded. It would be recommended to further investigate the relationship between house type, temperature and energy usage by using a larger sample size and also taking into account a number of other factors including dwelling orientation, wind chill and transfer of heat from adjoining dwellings.

Further to analysis of average daily temperatures by house size, it was found that studio dwellings (n=17) had lower average temperatures than both one bed and two bed dwellings (n=12). Studio dwellings had average daily temperatures of 18.9°C and 18.2°C during periods 1 and 2 respectively. This compares with average daily temperatures of 19.7°C and 18.9°C in one and two bed dwellings during periods 1 and 2. This is surprising considering that both the living and sleeping facilities are provided within one room in the studio dwellings. This room is therefore the most occupied room and the one in which the temperature was being monitored. The energy usage data reveals that studio flats had lower average daily gas and total energy consumption than the one and two bed dwellings. Similar to the analysis of house type and temperature, these results would indicate that occupant heating practices and varying demand temperatures are the most significant determinants of dwelling temperature. However, as with analysis by house type, analysis by house size is restricted due to the small sample size and a number of factors not accounted for in this study.

7.5 Dwelling Space Heating Type

There were seventeen dwellings using gas fired central heating, two using electric heating and ten using both gas fired central heating and electric heating. In all cases electric heating consisted of stand-alone mobile electric heaters i.e. not central heating or storage heaters. The dwellings using a combination of gas and electric heating had the highest average daily temperatures. In most of these dwellings gas was the primary heat source and this was supplemented by electric heating, particularly during colder periods. Daily average temperatures in dwellings using only gas fired central heating, were slightly lower than those using both gas and electric but they also consumed less energy.

Although there were only two dwellings using electric heating as their sole form of space heating, the average daily temperatures were significantly lower than those recorded in gas fired centrally heated homes. The average daily temperature for dwellings using only electric space heating was 16.5°C during period 1 and 14.9°C during period 2. It should be noted that the average daily temperature for period 1 is for site 18 only, as the data logger failed to record any temperatures at site 3 for this period. However, similar energy usage recorded at site 3 for both monitoring periods would indicate that the temperature for period 1 would have been one of the lowest in the sample.

Table 7.7 shows the average daily temperatures and energy usage by dwelling space heating type. The energy usage for all the individual sample dwellings is detailed in Table 6.20 in the Data Summary chapter. In relation to energy usage, dwellings using only electric heating consumed a fraction of energy compared to those dwellings using gas fired central heating e.g.; dwellings using gas and electric heating used nearly four times as much energy as dwellings using electric heating only, during monitoring period 2. It would be expected that dwellings using central heating would have higher indoor temperatures than non-centrally heated homes. The Building Research Establishment have estimated that homes heated by central heating tend to be 2.5°C warmer than those heated by stand alone room heating systems (DECC, 2013). However this argument can only partially explain the difference in temperature between centrally heated and non-centrally heated dwellings in this sample. Due to the small number of dwellings using electric heating only, any comparisons with other heating types must be interpreted with caution but these individual dwellings are interesting from an energy consumption and thermal comfort perspective.

Table 7.7: Average daily temperatures and energy usage by dwelling space heating type for period 1 & 2

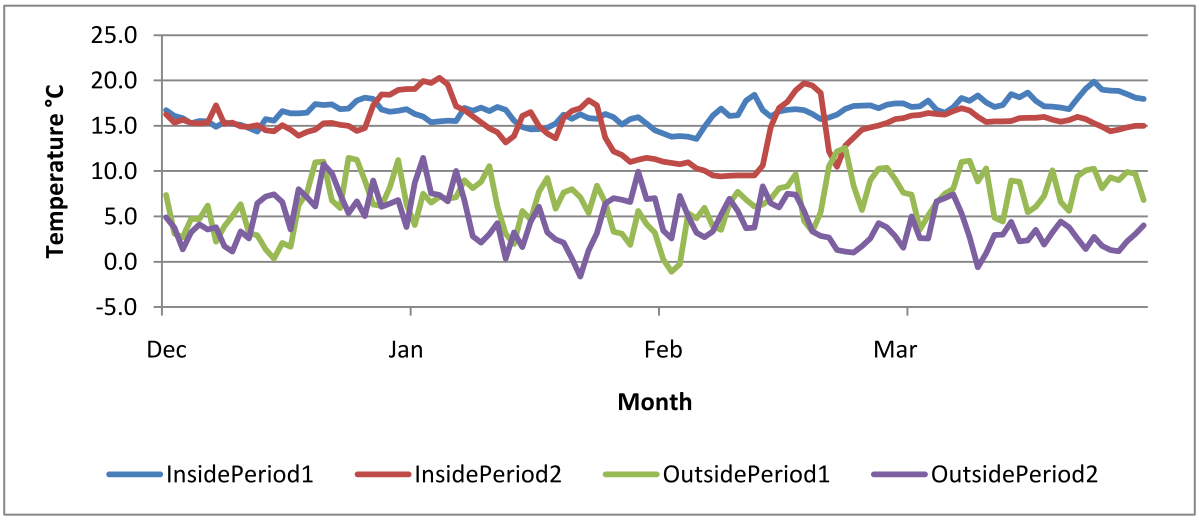
	Period 1		**Period 2**	
Space Heating Type	**Temperature (°C)**	**Energy Usage (kWh)**	**Temperature (°C)**	**Energy Usage (kWh)**
GFCH	19.2	24.3	18.6	27.1
Electric	16.5	11.6 (14.6-site 18 only)	14.9	9.7
GFCH & Electric	19.5	28.4	19.2	35.6
Total Sample	19.3	24.8	18.5	28.8

The dwelling occupant at site 18 used electric space heating only. This occupant was using one stand-alone mobile electric heater to heat their studio dwelling. In the questionnaire the dwelling occupant stated the following:

"Had gas removed as do not trust. Keep heat on day and night and house is adequately warm" Site 18

The average daily temperatures at site 18 were 16.5°C and 15°C during periods 1 and 2 respectively, which were the lowest and second lowest recorded temperatures in the sample. It can be seen from Figure 7.7 that the dwelling temperature during period 1 remained relatively steady but fluctuated a bit more during period 2. There is a considerable time between late January and early to mid February during period 2 when the average dwelling temperature does not get above 12°C. It is likely that this was an unoccupied period as the occupant stated in the questionnaire that during the last six months, they had been hospitalised for approximately two weeks.

Figure 7.7: Average daily inside temperatures at site 18 and average daily outside temperatures for period 1 & 2



Site 18 had an average daily energy consumption of 14.6kWh during period 1 and 10.1kWh during period 2. The greater fluctuation in temperature during period 2 is therefore likely to be caused by unoccupied periods, reduced energy usage and the lower outside temperatures during this period. The average minimum and maximum dwelling temperatures were 16°C and 17.2°C for period 1 and 14.1°C and 15.7°C for period 2. This means that there was a relatively small variance in dwelling temperatures over both periods, and this may be due to a small but continuous heating load throughout the monitoring periods. Although this household was using small amounts of energy, it was consuming almost three times more electricity than the average sample dwelling during period 1 and more than twice the sample average in period 2. These results highlight the inefficiency of electric space heating.

The findings for site 18 are particularly significant as the temperatures recorded are likely to have a negative effect on the health of the occupant. Site 18 had temperatures below 16°C for 27% of the half hourly readings recorded during period 1 and 61% of half hourly readings during period 2. As previously stated indoor temperature below 16°C are known to impair respiratory function. Site 18 had temperatures below 12°C for 16% of the half hourly readings recorded during period 2. At temperatures below 12°C there is an increased risk of cardiovascular strain (Collins, 1986). Although there may have been one or more unoccupied periods during period 2 these results are most alarming. The dwelling occupant would be particularly vulnerable to the effects of low temperatures given that they have mobility problems, use a walking aid and spend all day in their home. They also have a number of long term health problems and are visited by their GP on a weekly basis. It must also be remembered that these temperatures were recorded in the living/sleeping area where the occupant spent almost all of their time. Goodman et al (2004) have shown the relationship between cold weather and increased mortality from respiratory and cardiovascular disease for people living in Dublin. Interestingly this occupant was satisfied with the temperature in their home. This raises concerns in relation to self rating thermal comfort which is discussed later in this chapter.

Despite having gas fired central heating, the other dwelling which used only electric space heating was site 3. There were no temperatures recorded at site 3 during period 1 due to a data logger failure but the average daily temperature for period 2 was 14.8°C. Although this dwelling had the lowest recorded average temperature during period 2, unlike site 18, the occupant was not in the home for the majority of the daytime. Site 3 is looked at in greater detail in the BER section of this chapter.

There were only two other dwellings that used more kilowatt hours of electricity than gas over both monitoring periods. Site 14 was a studio dwelling and had average daily temperatures of 16.5°C and 17.2°C during periods 1 and 2 respectively. Site 14 was one of the few dwellings which had a higher average temperature during period 2. This dwelling had an average daily gas consumption of 0.4kWh and 0.7kWh during periods 1 and 2, with an average daily electricity consumption of 5.8kWh and 11.1kWh during periods 1 and 2. These figures show that this occupant was using very small amounts of gas heating. However, considering that the household electricity consumption almost doubled for period 2, this may explain the higher average temperature during period 2 despite the lower average outside temperature. In the questionnaire the occupant stated that the gas central heating was not working properly and this is why they were using two stand-alone mobile electric heaters. Wilkinson et al (2001) found strong but not conclusive links between winter mortality, cold related mortality and suboptimal home heating. This lack of usage of the gas fired central heating may have significant impacts on the occupant's health. Further analysis of the temperature data for site 14 reveals that 32% and 29% of the half hourly readings recorded during periods 1 and 2 respectively were below 16°C.

The occupant at site 14 stated in the questionnaire that they spent most of the day in their home and listed mental health and circulation issues as their long-term health problems. There is a body of evidence suggestive of significant independent associations between living in a cold home and mental ill-health (Liddell & Morris, 2010).

Site 22 also used more kilowatt hours of electricity than gas over both monitoring periods. Site 22 had average daily temperatures of 16.6°C and 15.7°C but was also the lowest consumer of energy in the sample with average daily energy consumption of 5.7kWh and 6.1kWh during periods 1 and 2 respectively. Site 22 had temperatures below 16°C for 25% and 48% of the half hourly readings during periods 1 and 2 respectively. Although these temperatures are extremely low, the occupant did state in the questionnaire that they were not normally at home during the day. The occupant also self-rated their health as “very good” and they were one of only two households not to list a long-term health problem.

These households are being exposed to health hazards associated with cold strain including impaired respiratory function and increased risk of cardiovascular strain. It is perhaps surprising that despite the fact that of all of the four households above have the option of using their gas fired central heating, they have all opted to use electricity as their primary source of space heating. There may be various reasons for this as outlined above but the one common factor is that all of the above dwelling occupants stated they had “free units” for their electricity. It would be likely that switching the “free unit’s” allocation to their gas would be far more beneficial to these households and allow them to heat their home better and more efficiently.

7.6 Building Energy Rating (BER)

The sample dwellings were built between 1969 and 1988 which is prior to the introduction of minimum energy performance for buildings. It is not surprising that the sample dwellings have poor energy efficiency ratings with over two thirds of the sample having a BER of E or F. Clinch & Healy (2000) estimated that 40% of excess winter mortality in Ireland attributable to cardiovascular and respiratory diseases may be associated with poor housing energy efficiency.

As would be expected, dwellings with a BER C maintained the highest average daily temperatures at 21.3°C during period 1 and 19.2°C during period 2. It should be noted that the number of dwellings with a BER of C increased from one to four between monitoring periods. This was due to a data logger failure at site 3 during period 1 and energy efficiency upgrades at sites 2 and 17 between monitoring periods. As there was only one dwelling with a BER of C during period 1, our analysis focuses mainly on period 2. Surprisingly these dwellings had the second highest energy usage for all energy bands during both monitoring periods. As all but one of the dwellings in this band was one and two bed, the larger sized units may partially explain the higher energy consumption.

Figure 7.8: Average daily temperatures for BER C dwellings for period 2

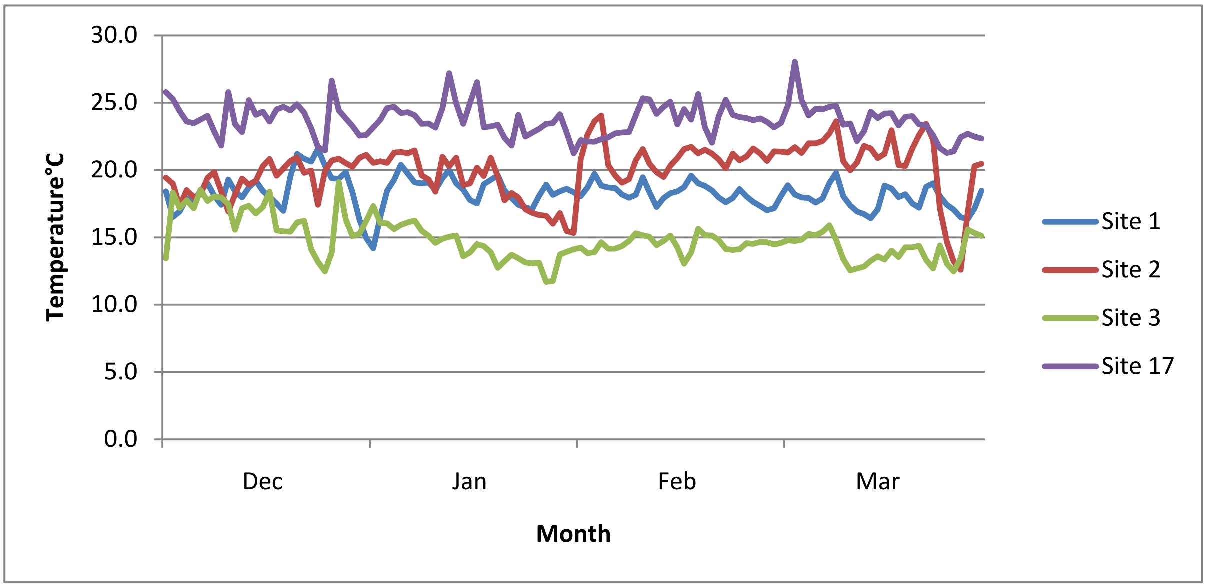


Figure 7.8 shows the average daily temperatures during period 2 for the four dwellings with a BER C. It is clear that all of the dwellings show varying temperature patterns over the period. The highest average temperature was at site 17 which would possibly be expected considering this dwelling had a BER of C1, whilst the other three had a BER of C3. Site 17 underwent energy efficiency upgrades between monitoring periods and is looked at in more detail below. Sites 1, 2 and 3 were all within the same complex and had all been recently upgraded to a BER C3. Site 2 had energy efficiency retrofit works completed between the monitoring periods and is discussed in more detail below. Sites 1 and 3 are the main reason why we have a lower average temperature than would be expected for dwellings in this energy band. Site 1 had an average daily temperature of 18.3°C during period 2 compared with 21.3°C during period 1. This lower temperature is hard to explain considering the occupant used nearly 25% more gas (kWh) during period 2. The lower outdoor temperature can partially account for the lower dwelling temperature, but it may be that this person was occupying their bedroom more during period 2 and was therefore not heating their living room as much. There seems to have been one significant fall in temperature at the end of December so this may represent an unoccupied period.

Site 3 had the lowest average temperature for the whole sample at 14.8°C during period 2. As discussed earlier in this chapter this low temperature may be partly explained by the fact that this occupant used electric heating only, even though they had gas fired central heating available. Site 3 had the fifth and third lowest energy consumption for the sample during periods 1 and 2 respectively. Site 3 had temperatures below 16°C for 72% of the half hourly readings during period 2. Although the occupant stated that they were only in the house for two to four hours during the daytime, they were being continuously exposed to extremely cold temperatures during occupied times including the early morning, evening and night.

We know that the evening time between 5pm and 11pm is the most occupied period and the average evening temperature was 15°C during period 2 in this dwelling. These findings show that this dwelling maintains a low indoor temperature despite the fact that it has undergone energy efficiency upgrades. It can therefore not be assumed that improving the thermal efficiency of a building will improve the thermal comfort of its occupants; this relies on occupants using their heating adequately.

Table 7.8: Average daily temperature and energy usage by dwelling BER

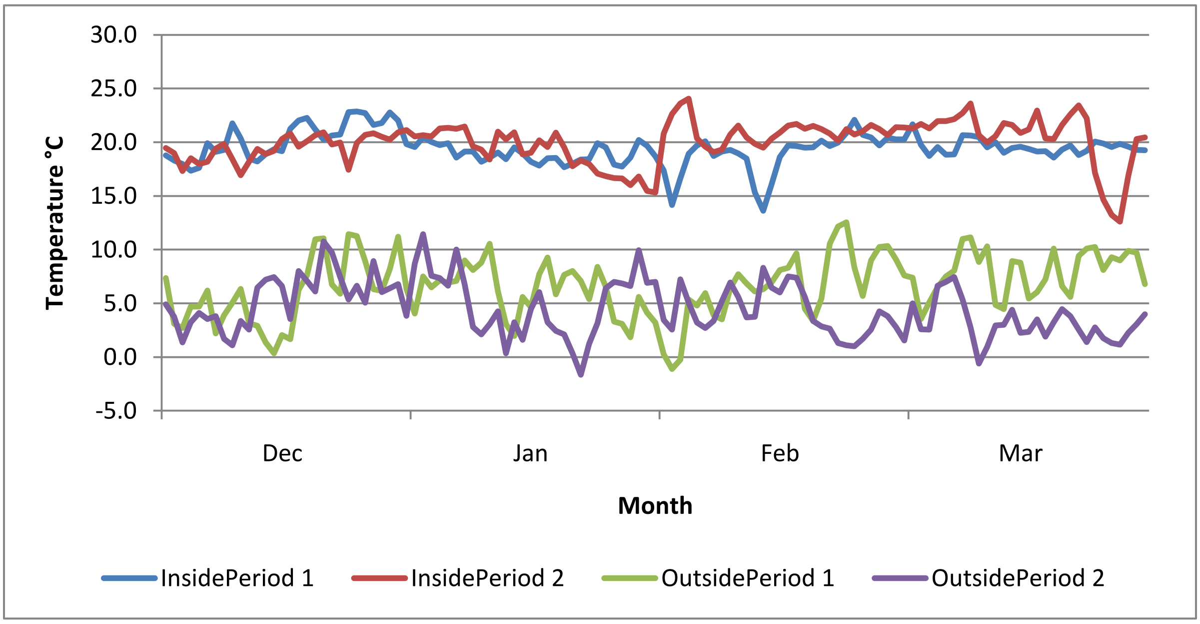
	Period 1			Period 2			
BER	Temp (°C)	Total Energy (kWh)	Gas Usage (kWh)	BER	Temp (°C)	Total Energy (kWh)	Gas Usage (kWh)
BER C(n=1)	21.3	26.4	23.3	BER C(n=4)	19.2	31.4	24.2
BER D(n=5)	19.8	22.8	19.4	BER D(n=4)	18	22.3	16.1
BER E(n=11)	18.7	19.2	15.2	BER E(n=10)	18.2	20.9	16.3
BER F(n=11)	19.4	31.4	26	BER F(n=11)	18.7	37.4	32.7

In terms of energy consumption dwellings with a BER of D or E were more efficient than both the C and F bands as can be seen in Table 7.8. Dwellings with a BER D had an average daily temperature of 19.8°C during period 1 and 18.2°C during period 2. This drop in temperature during period 2 may be partially due to site 17, which had the highest average temperature during period 1 but moved into the band C category during period 2. The dwellings with a BER E showed a fall of 0.5°C in the average temperature between monitoring periods. This was the smallest fall in temperature for any BER band and was achieved with only a small increase in energy consumption during period 2. It is interesting that during period 2, the dwellings with a BER of E managed to achieve a slightly higher average temperature than their band D counterparts whilst using a similar amount of energy. Those dwellings with a BER of D and E also used similar amounts of gas during period 2. Dwellings with a BER of F had an average daily temperature greater than band E during period 1 and greater than bands D and E during period 2. However, band F dwellings had the highest energy usage over both monitoring periods. They consumed on average 51% more energy than band D dwellings and 71% more energy than band E dwellings when averaged over both periods. Despite this, it is worth noting that the most inefficient dwellings i.e. band F, managed to achieve an average temperature during period 2 that was only 0.5°C lower than the most efficient dwellings i.e. band C. The band F dwellings however, had to use almost 20% more total energy and nearly one third more gas energy than the band C dwellings to achieve this temperature.

Energy Efficiency Upgrades

Site 2 underwent thermal efficiency upgrade works including cavity wall and attic insulation, installation of a hot water cylinder lagging jacket and draught proofing. Site 2 had a BER of E1 during period 1 and a BER of C3 during period 2.

Figure 7.9: Average daily dwelling temperatures at site 2 & average daily outside temperatures during period 1 & 2

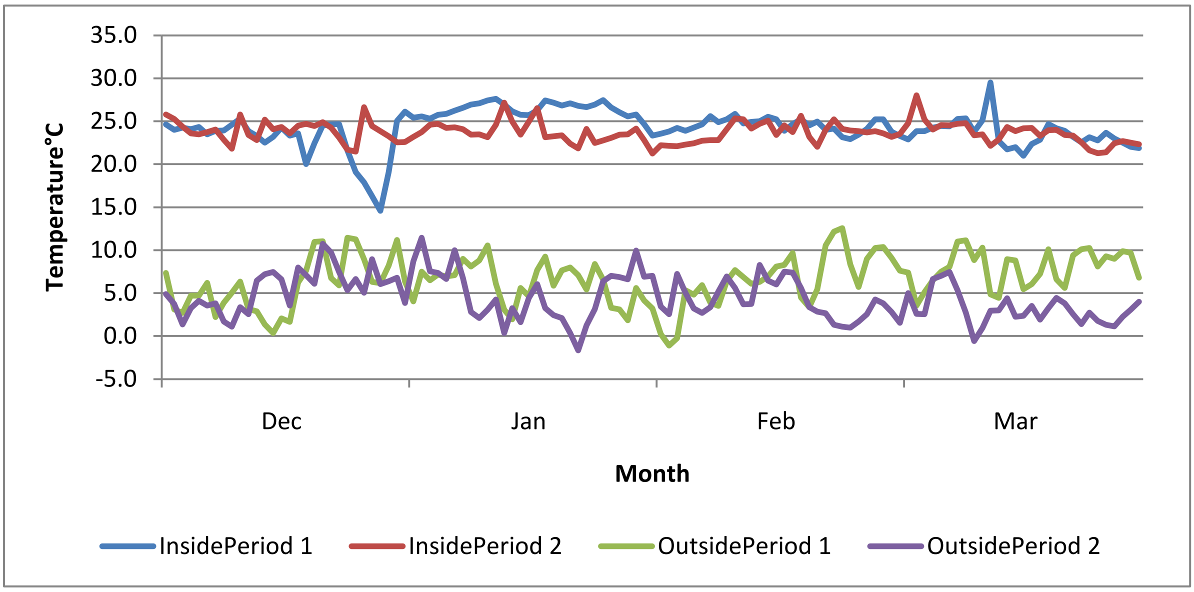


Site 2 had average daily temperatures of 19.6°C and 20.0°C during periods 1 and 2 respectively. Although the dwelling temperatures at site 2 for both periods are quite similar, the outside temperature during period 2 was 2.2°C lower than that of period 1. In addition, this household managed to achieve a higher indoor temperature during period 2 using a similar amount of energy during both periods. Site 2 had an average daily energy consumption of 32.9 kWh during period 1 and 32.5 kWh during period 2. The household average daily gas usage was almost identical too, with 23.9kWh and 23.5kWh consumed during periods 1 and 2. Although there has been only a slight reduction in energy consumption post intervention, there is increased thermal comfort. It is likely that given similar outdoor temperatures to period 1, there would have been more significant gains in thermal comfort and possible energy savings during period 2.

Site 17 had a BER of D2 during period 1 and a BER of C1 during period 2. The thermal efficiency upgrade works included insulation and heating. Site 2 had average daily temperatures of 24.3°C and 23.7°C during periods 1 and 2 respectively. Similar to site 2, this dwelling had almost identical energy usage during both periods. Site 2 had an average daily energy consumption of 52.3 kWh and 51.8 kWh and an average daily gas usage of 49.4kWh and 49.3kWh during periods 1 and 2. Considering there was an increase of 0.6°C in temperature at site 2 post interventions, a similar increase in temperature would have been expected at site 17.

This lower than expected temperature may be due to occupant behaviour and greater usage of heating in unmonitored parts of the house during period 2 i.e. the bedroom. It is likely that if the outdoor temperature during period 2 was similar to that of period 1, there would have been increased thermal comfort for this household. This argument is supported by the fact that for the whole sample, there was a decrease of 0.8°C in the average temperature during period 2 despite an increase of 16% in energy usage and 20% in gas usage when compared with period 1.

Figure 7.10: Average daily dwelling temperatures at site 17 & average daily outside temperatures during period 1 & 2



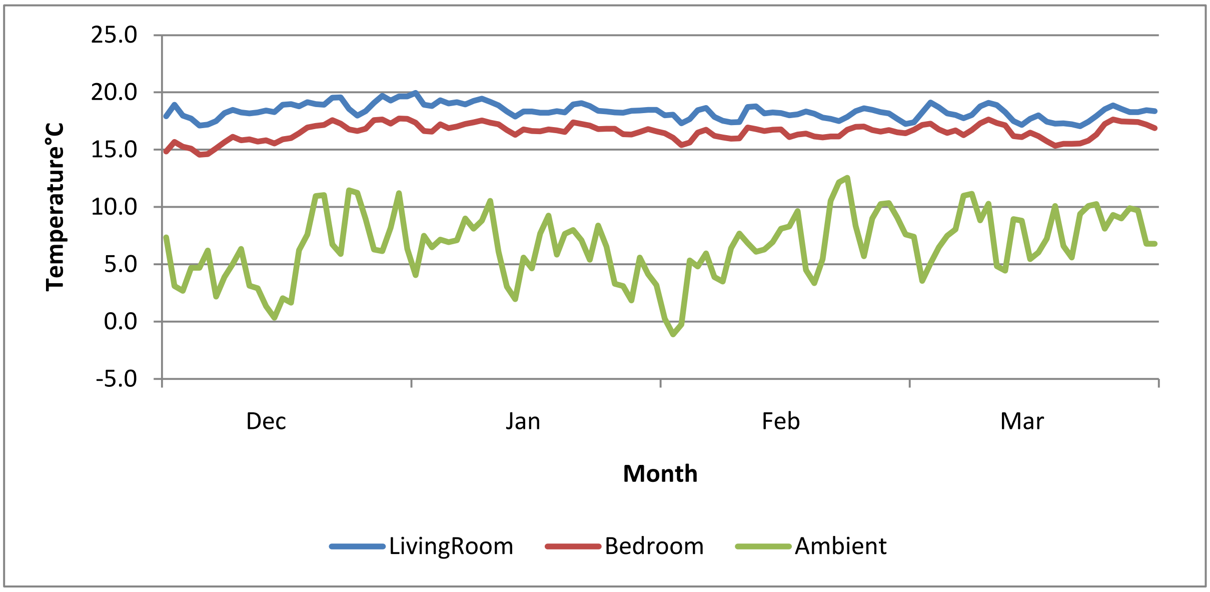
Oreszczyn et al. (2006) reported that dwellings which received both heating and insulation measures through the Warm Front scheme resulted in daytime living room temperatures 1.6°C higher than pre-intervention dwellings. The findings from our study do not compare favourably with Oresczyn et al but the findings for sites 2 and 17 with regard energy usage are similar to those reported by Hong et al (2009), who investigated the effect of the Warm Front scheme in the UK on space heating fuel consumption. Hong et al reported that for dwellings that had insulation and gas central heating installed, there was no reduction in fuel consumption despite increased post-intervention temperatures. In the above example, as in this study, there has been little or no reduction in energy usage post intervention as would be expected. This lack of reduction in energy usage for sites 2 and 17 can be attributed to the "take back" factor i.e. occupant desire for increased temperature to achieve thermal comfort. There may be a number of reasons for the lack of increased temperature at site 17 as discussed above but it may be that it is more difficult to achieve improved thermal comfort for a household with a desire for high temperatures.

"Don't have heat on timer, just switch on when I need, do not economise" Site 17

7.7 Living Room and Bedroom Temperature

Site 13 was the only dwelling where more than one data logger was used. There was a data logger placed in the living room during monitoring periods 1 and 2. During period 1 only, there was also a data logger placed in the bedroom. However, it was the average daily living room temperatures that were used for site 13 in order to be consistent with all other monitored sites.

Figure 7.11: Average daily living room and bedroom temperatures for site 13 and average daily ambient temperatures during period 1



The average daily temperature in the living room was 18.3°C and the average daily temperature in the bedroom was 16.6°C. Despite the lower temperatures in the bedroom, it can be seen from Figure 7.11 that the temperatures in both rooms follow very similar patterns. In the questionnaire, the dwelling occupant stated that they used only a small amount of heating in the bedroom. It may be that that the heating being used in the living room was somewhat influencing the bedroom temperature. As the bedroom only has one external wall and the living room has external walls on three sides, it would be expected to find higher temperatures in the bedroom if a similar amount of heating was being used in both rooms. As would be expected it is clearly evident that significantly more space heating is being used in the living room.

Table 7.9 also shows that the bedroom temperature when analysed by time of day shows similar fluctuations to the temperature in the living room. It is evident that the evening was the most heated period in the living room and this also corresponds to the warmest period in the bedroom, although the rise in bedroom temperature is not as pronounced as the living room in the evening time. The average bedroom temperature at night was 16.6°C which is very worrying given that is an occupied period. The bedroom had temperatures below 20°C for 99.9% of the half hourly readings and temperatures of ≤16°C for 36% of the half hourly readings.

This clearly demonstrates that although the bedroom may be only occupied at night, the dwelling occupant was being exposed to temperatures that can cause cold strain resulting in adverse health impacts, particularly for the elderly (Collins & Exton-Smith, 1983).

Table 7.9: Average daily living room and bedroom temperatures by time of day at site 13 during period 1

	Temperature (°C)	
	Living Room	Bedroom
Morning (7-9hrs)	17.9	16.3
Day (9-17hrs)	17.8	16.2
Evening (17-23hrs)	19.3	17.1
Night (23-7hrs)	18.3	16.6

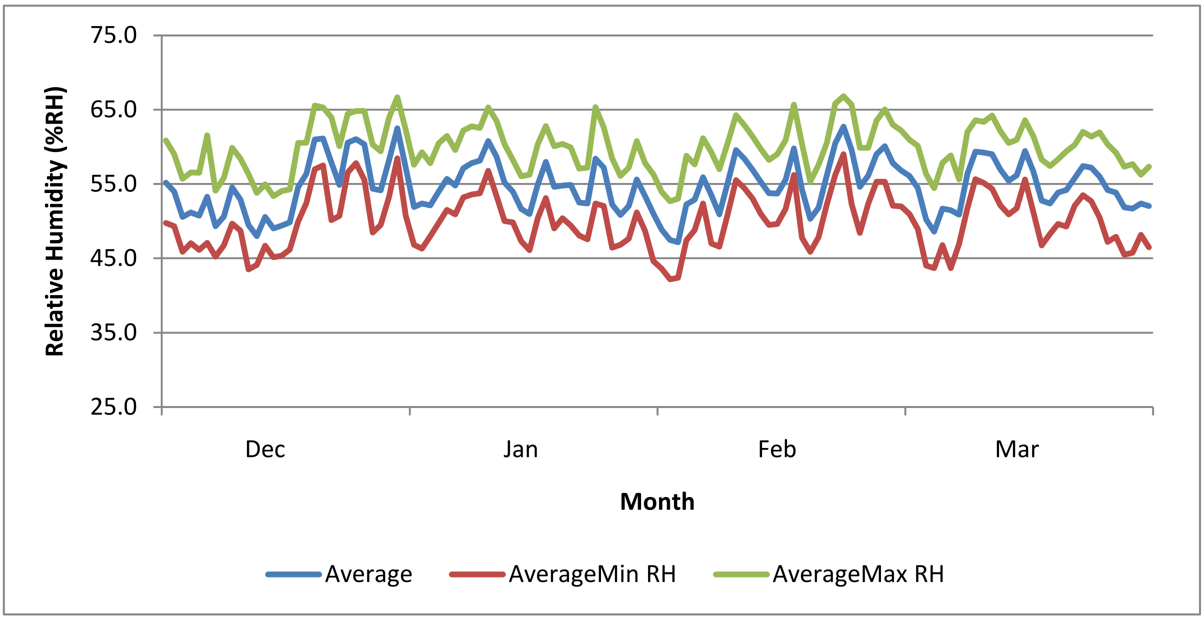
Low bedroom temperatures may have been an issue for other dwellings in the sample and this raises the question of the suitability of using living room temperature as a measure of thermal comfort. It has been reported in the UK that living room temperature is often not a good indication of whole house temperature (Milne & Boardman, 2000). However, almost 60% (n=17) of our sample were studio dwellings with living and sleeping facilities within the monitored room. In the dwelling occupant questionnaire all households stated that the living room or studio was the room they occupied most and this was the room in which the temperature was monitored.

It would have been preferable to also monitor bedroom temperatures in the one and two bed dwellings but this was a limitation of this study due to limited availability of data loggers. Temperature data for the bedrooms may in particular have allowed better understanding of the relationship between energy consumption and temperature. However, our study managed to monitor temperature over a long period of time in the most occupied parts of the sample dwellings and therefore it is believed provided a reasonable metric of thermal comfort.

7.8 Relative Humidity and Thermal Comfort

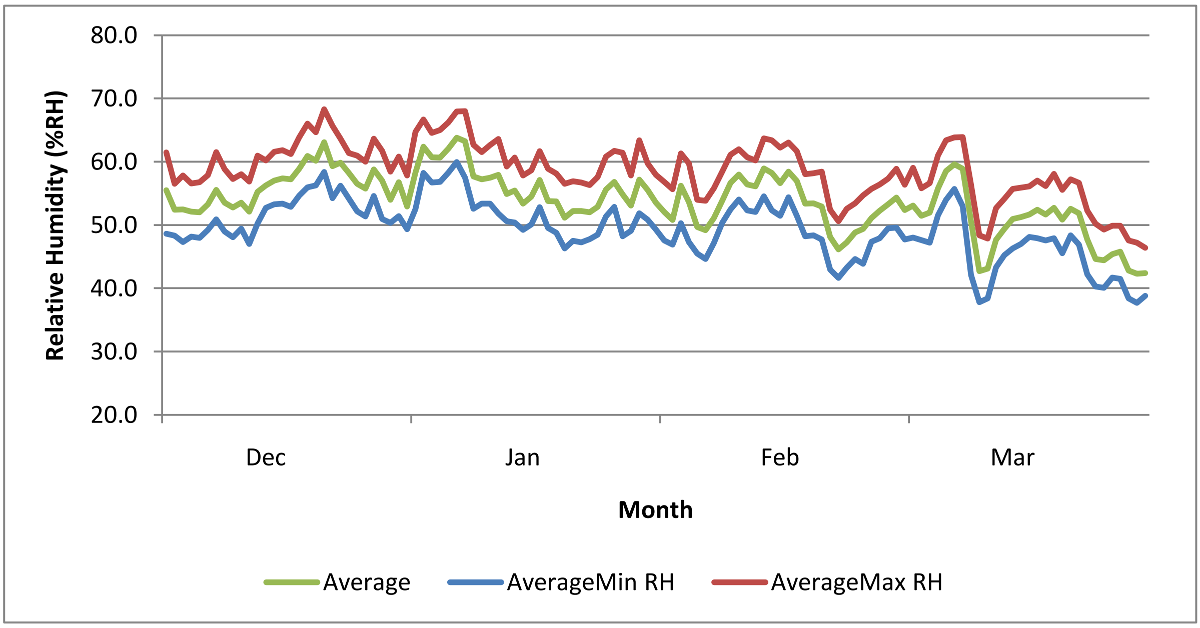
Relative humidity (% RH) is a measure of the moisture in the air, compared to the potential saturation level and is an important determinant of thermal comfort. The American Society of Heating, Refrigerating, and Air Conditioning Engineers recommends a relative humidity range of 25%RH to 60%RH for normally clothed building occupants (ASHRAE, 2001). Figure 7.12 and 7.13 show the daily average, average maximum and average minimum relative humidity for all dwellings during periods 1 and 2.

Figure 7.12: Average, average maximum & average minimum daily relative humidity recorded in all dwellings during period 1



The average daily relative humidity for all dwellings was 55%RH during monitoring period 1 and 54%RH during monitoring period 2. The average daily relative humidity measured in each dwelling varied from 35%RH to 74%RH during period 1 and from 33%RH to 72%RH during period 2. The average minimum daily relative humidity recorded in all dwellings was 50%RH during period 1 and 49%RH during period 2. The average maximum daily relative humidity recorded in all dwellings was 60%RH and 59%RH during period 1 and 2 respectively.

Figure 7.13: Average, average maximum & average minimum daily relative humidity recorded in all dwellings during period 2



These results show that overall the sample households were experiencing high levels of relative humidity. There were no dwellings with average daily relative humidity levels below the lower bound threshold of 25%RH during either periods but 32% (n=9) and 21% (n=6) of dwellings during periods 1 and 2 respectively had average daily relative humidity levels above the higher bound threshold of 60%RH. These dwellings had relative humidity levels above 60%RH for 68% and 76% of the half hourly readings during periods 1 and 2 respectively. The whole sample had on average, relative humidity levels above 60%RH for 28% of the half hourly readings during periods 1 and 2 respectively. Physical discomfort can arise as a result of both high and low relative humidity as the relative humidity has a direct impact on comfort perception (Meyer, 1983). However, at moderate temperatures (<26°C) and moderate activity levels, the influence of relative humidity has only a modest impact on thermal sensation. If humidity limits are based on the maintenance of acceptable thermal conditions based solely on comfort considerations, including thermal sensation, skin wetness, skin dryness, and eye irritation, a wide range of humidity is acceptable (ISO, 2005).

The ASHRAE guidance focuses on thermal comfort but relative humidity also has important implications for health. Low relative humidity (<20%) can cause eye irritation (McIntyre, 1978). Low relative humidity has also been shown to improve survival of certain viruses including influenza (Buckland & Tyrrell, 1962). If using the lower bound threshold of 25%RH the results from our study have raised no concern in relation to low relative humidity. Site 17 was the only dwelling with low relative humidity levels for considerable periods. Site 17 had relative humidity readings below 25%RH for 6% of the half hourly readings during period 1 and 5% of the half hourly readings during period 2. However, site 17 had relative humidity readings below 40%RH for 72% and 91% of half hourly readings during periods 1 and 2 respectively. Some health studies have advocated a relative humidity range of 40 to 60 percent to minimize adverse health effects (Almso & Almso, 2014). Schaffer et al (1976) found that influenza infection was highest in environments with relative humidity below 40%. In our study the sample dwellings had on average, relative humidity levels below 40%RH for 7% of the half hourly readings during period 1 and 10% of half hourly readings during period 2.

The results from our study have raised more significant health concerns regarding high relative humidity (>60%). Higher relative humidity levels can encourage the growth of mould and mildew. In addition, dust mites, bacteria and fungi all thrive under moist, humid conditions. Most species of fungi cannot grow unless the relative humidity exceeds 60%RH (Alsmo & Almso, 2014). As stated above there were a significant number of dwellings with average daily relative humidity levels above 60%RH but exposure to high relative humidity levels was not just confined to these households.

There were 19 dwellings (68%) and 23 dwellings (79%) during periods 1 and 2 respectively that maintained average daily relative humidity levels below 60%RH.

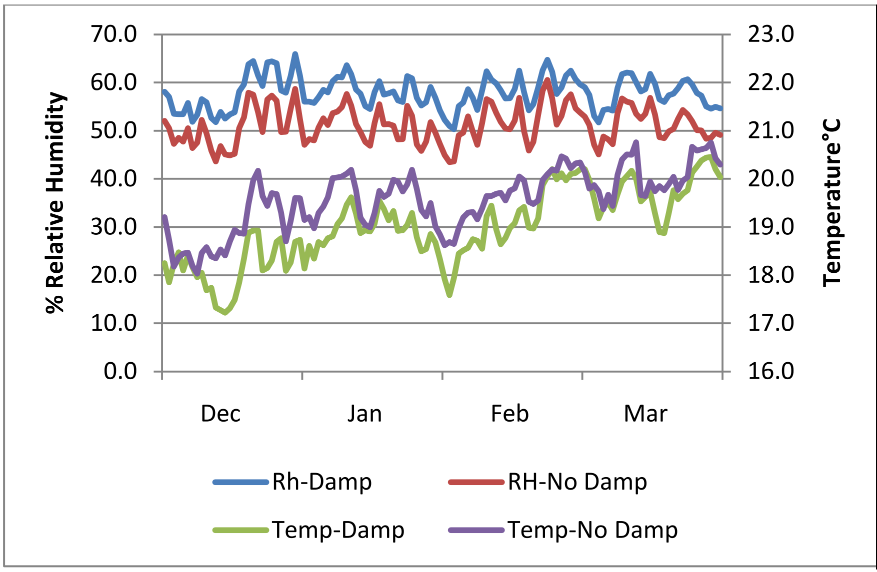
Although these dwellings had average relative humidity levels within the recommended range, the results revealed that they also had relative humidity levels above 60%RH for 9% and 15% of the half hourly readings during periods 1 and 2 respectively. Some fungi and viruses require relative humidity levels above 70 percent in order to thrive. Schaffer et al (1976) found that influenza infection was highest in environments with relative humidity below 40%RH, fell to a minimum between 40%RH and 60%RH and increased again at exposure between 70%RH and 80%RH. In our study the sample dwellings had on average, relative humidity levels above 70%RH for 7% of the half hourly readings during period 1 and 6% of half hourly readings during period 2. Exposure to long periods of high relative humidity was an issue for a number of dwellings e.g. site 14 had relative humidity readings above 60%RH for 99% of the half hourly readings during both periods and site 23 had relative humidity readings above 60%RH for 96% and 80% of the half hourly readings during periods 1 and 2 respectively.

Excessive moisture in the air (i.e., high relative humidity) that is not properly controlled can lead to excessive dampness (National Institute for Occupational Safety & Health, 2014). A general indicator for dampness includes observations of high relative humidity, condensation on surfaces, moisture/water damage, signs of leaks and stained/discoloured surface materials (WHO, 2011). In the dwelling occupant questionnaire respondents were asked if they had damp, mould or black stains on walls, windows or ceilings. Almost half of the households (48.3%) reported having dampness or mould in their home. The findings from our study are high compared with other studies. The WHO LARES study, reported there was evidence of mould growth in at least one room for 25% of all dwellings surveyed (WHO, 2007). Zock et al (2000) and Baker & Henderson (1999) also reported similar levels of damp and/or mould for their self reported samples. However, the LARES study used data gathered during dwelling surveys by trained assessors. In our study the dwelling surveys conducted by the researcher found that 7 dwellings (24.1%) had evidence of dampness and/or mould growth. Since the 1990's dampness, moisture and mould in indoor environments have been associated with adverse health effects in population studies in Europe and North America (WHO, 2011, Fisk et al (2007). The most commonly reported health effects are airways symptoms, such as cough and wheeze, but other respiratory effects, and skin and general symptoms have also been reported. In addition associations between buildings with excess moisture and asthma in both children and adults have been documented.

Figure 7.14 and 7.15 show the average daily relative humidity and average daily temperatures for both the damp and non-damp reported dwellings during periods 1 and 2. It is clearly evident over both periods that the dwelling occupants who reported dampness and/or mould growth had higher relative humidity levels in their homes. The households which reported dampness and/or mould growth had average daily relative humidity of 58%RH and 57%RH during periods 1 and 2.

This compares with 51%RH and 50%RH for households who did not report dampness and/or mould growth.

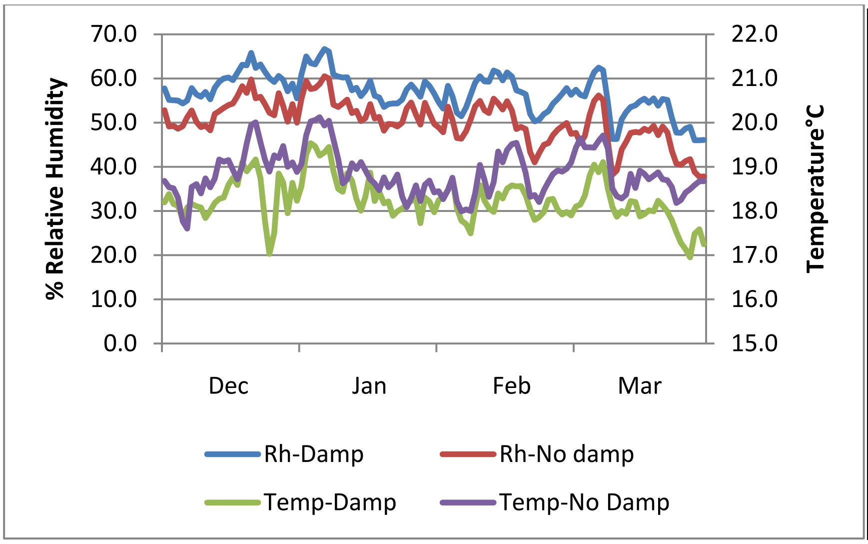
Figure 7.14: Average daily relative humidity & temperature for damp & non-damp dwellings for period 1



Correlation	
RH Damp V Temp Damp	0.41
RH Non-damp V Temp Non-damp	0.54

The damp reported dwellings also appear to have lower average daily temperatures than the non-damp reported sample. The damp reported dwellings had average daily temperatures of 18.3°C and 19°C during periods 1 and 2 respectively. This compares with 18.9°C and 19.6°C for households that did not report dampness. Relative humidity is strongly related to temperature. As the air warms up the relative humidity declines (Alsmo & Alsmo, 2014). This relationship between the dwelling temperature and relative humidity is clearly evident in Table 7.10 also.

Figure 7.15: Average daily relative humidity & temperature for damp & non-damp dwellings for period 2



Correlation	
RH Damp V Temp Damp	0.75
RH Non-damp V Temp Non-damp	0.55

As temperature drops, relative humidity increases because the air can hold less moisture at lower temperatures, so that what it was and now is holding represents a greater percentage of what it is capable of holding. It is evident from Figure 7.14 and 7.15 that there is a close correlation between the temperature and relative humidity recorded. Table 7.10 clearly shows that the average daily relative humidity is highest for the group 1 dwellings i.e. the dwellings with the lowest average daily temperature. The average daily relative humidity is lowest for the group 3 dwellings i.e. the dwellings with the highest average daily temperature. These findings are significant from both a thermal comfort and health aspect. The results show that households in the sample experiencing the lowest average daily temperatures are also experiencing the highest average daily relative humidity. These dwelling are therefore likely being exposed to conditions that are not conducive to thermal comfort and potentially detrimental to health.

Table 7.10: Average daily relative humidity by dwelling temperature group for period 1 & 2

Dwelling group	Period 1 % RH	Period 2 %RH
Group 1 (<18°C)	61 (n=8)	60 (n=12)
Group 2 (18-19.9°C)	56 (n=12)	52 (n=9)
Group 3 (≥20°C)	46 (n=8)	46 (n=8)

7.9 Fuel Poverty and Thermal Comfort

Fuel poverty or energy poverty refers to a situation when someone is unable to afford to heat their home to a level that is healthy and safe. A government definition of energy poverty has been set out in Warmer Homes – A Strategy for Affordable Energy Poverty in Ireland (Department of Communications, Energy and Natural Resources), 2011. This definition states that a household is considered to be energy poor if it is unable to attain an acceptable standard of warmth and energy services in the home at an affordable cost.

There are objective and subjective methods of measuring fuel poverty. The ‘subjective method’ of measuring fuel poverty is based on self-reporting of difficulties with keeping the home adequately warm. In the Republic of Ireland this is measured annually through the European Survey of Income and Living Conditions (EU-SILC) by asking respondents whether they are able to keep the house adequately warm or whether they have had to go without heating in the last year because they could not afford it.

The dwelling occupant questionnaire used in our study asked respondents whether they were able to keep their home adequately warm and whether they had to go without heating in the last year because they could not afford it. These questions were asked after both monitoring periods.

There were 17.9% (n=5) and 25% (n=7) of households during periods 1 and 2 respectively who stated they were unable to keep their home adequately warm. In total 14.3% (n=4) of households during periods 1 and 2 respectively reported having to go without heating during the last year because they could not afford it.

"House very cold and heat goes straight out of house when heat on, am always cold. Do not know about all my entitlements. Put heat on for few hrs in morning & evening. During cold weather heat on all time." Site 15

"Don't turn heat on until 3pm because cost. Heat for 2hrs, house warms up & adequately warm once heat kept on." Site 7

The 2012 EU-SILC survey reported that 8.5% of households in Ireland were unable to keep their house adequately warm and 12.9% of households went without heating at some stage in the last year (CSO, 2014). Healy & Clinch (2002) using data from a national household survey of the Republic of Ireland, reported that 17.4% of the sample declared an inability to adequately heat the home to a comfortable temperature. Healy & Clinch found higher levels of fuel poverty for lone pensioners, with 34.8% of females and 26.1% of males declaring being unable to adequately heat their home. Whilst the findings in our study regarding having to go without heating were slightly higher than the EU-SILC reported figure, the number of households in our study stating they were unable to keep their home adequately warm was significantly higher than the EU-SILC number. However, the results of our study were similar to those reported by Healy & Clinch. In our study, the higher than normal reporting of being unable to adequately heat the home may still represent an under-declaration if the dwelling temperatures are considered. Table 7.11 shows the average daily dwelling temperatures by the EU-SILC fuel poverty indicators.

Table 7.11: Average daily dwelling temperatures by fuel poverty indicators

	Temperature (°C)			
	Keep home warm-Yes	Keep home warm-No	Go without heat-Yes	Go without heat-No
[4]Period 1	19.4°C (n=23)	18.5°C (n=5)	18.6°C (n=4)	19.4°C (n=24)
[4]Period 2	18.7°C (n=21)	17.9°C (n=7)	19.3°C (n=4)	18.4°C (n=24)

[4]Site 3 not included in period 1 as no temperature data & site 25 not included in period 2 as no questionnaire

Households, who stated they could not keep their home adequately warm, maintained average daily temperatures that were 0.9°C and 0.8°C lower than households who stated they could keep their home adequately warm, during periods 1 and 2 respectively. All but one of the dwellings that stated they could not keep their home adequately warm maintained average daily temperatures below 20°C. Healy & Clinch (2002) reported lower living room temperatures for fuel poor households with 68.6% of fuel poor households having living room temperatures below 20°C. However, in our study only 7 of the 23 households who stated they could keep their home adequately warm maintained average daily temperatures of 20°C or more during period 1. The results for period 2 were similar with 7 of the 21 households who declared being able to keep their homes adequately warm achieving average daily temperatures at or above the WHO lower bound thermal comfort threshold of 20°C. This shows that low indoor temperatures were not just confined to fuel poor households. This may be explained by individual variance in sensitivity to cold. As we get older some people become more sensitive to cold whilst other have reduced sensitivity meaning they are more vulnerable to thermal shock (Ormandy & Ezratty, 2011).

In relation to households who stated they had to go without heating in the last year, they maintained an average daily temperature that was 0.9°C lower than households who did not have to go without heating during period 2. Surprisingly during period 1, these dwellings maintained an average daily temperature that was 0.8°C higher than the households which did not have to go without heating. Equally surprisingly, of the households who stated they had to go without heating at some stage in the last year, two of the four during both period 1 and 2 declared that they were able to keep their home adequately warm. These findings may indicate that some households declaring having to go without heating are suffering from intermittent fuel poverty or occasional difficulties in achieving affordable warmth.

"Would like to use more heat but must be careful due to price. Would like to be more active & outside but cant because of health" Site 26

There are limitations to the use of subjective measures of fuel poverty among older people. In Northern Ireland as across the UK, it is observed in the house condition surveys that older people tend to report their housing condition and comfort of their home very favourably with limited agreement with objective measures (Northern Ireland Housing Executive, 2009). It may be that this was not a problem in this study due to the reporting of higher than average fuel poverty indicators. However, the dwelling occupant questionnaire also revealed that only half of the households were content with the temperature of their home.

Respondents were asked to rate thermal comfort in their home. During period 1, 53.6% (n=15) of households stated the temperature in their home was just right and 46.4% (n=13) stated the temperature was too cold. For period 2, 46.4% (n=13) of households stated the temperature in their hone was just right, 50% (n=14) stated their home was too cold and 3.6% (n=1) stated their home was too warm.

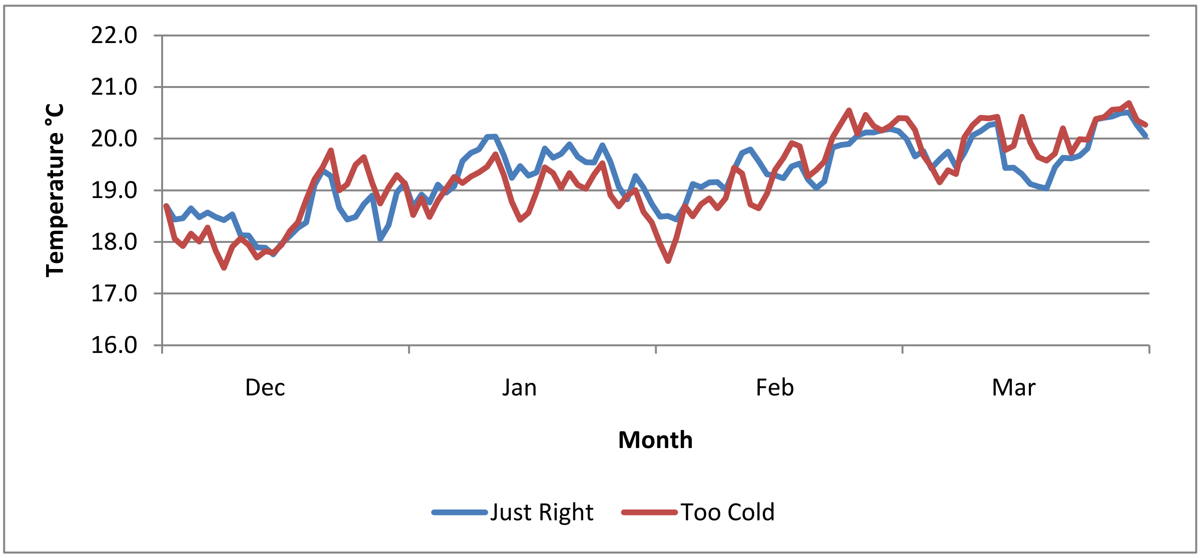
For the "too cold" sample, the most common responses when asked why they could not adequately heat their home were; dampness, draughts and cost of heating. As there were more than twice as many households rating their home as "too cold" compared to those stating they were unable to adequately heat their home, it is possible that the level of fuel poverty amongst this sample is greater than reported. It may also be possible that some households felt they were able to adequately heat their homes but if they did not use sufficient heating their house would be too cold. This argument is supported by a number of the comments in the dwelling occupant questionnaires.

"Can keep house warm once heat turned on" Site 6

"House too cold because end-terrace. Can keep home warm but only if heat on. Heat broke for 5 days in March-used electric. Normally try to get out for couple of hrs each day-turn off heat when out. Concerned about bills because of state cutbacks" Site 27

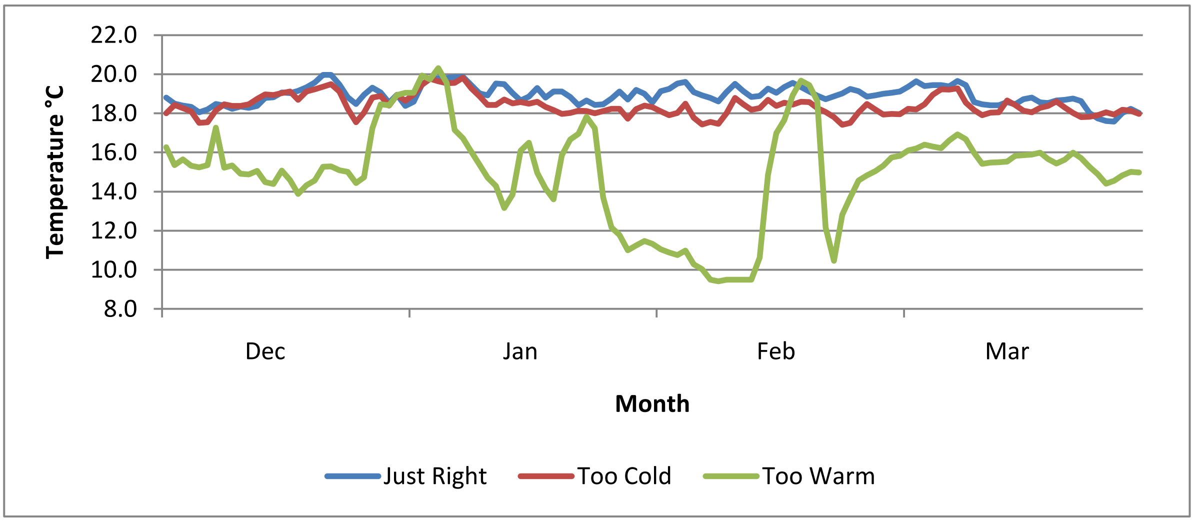
It is clear from Figure 7.16 and 7.17 that the "just right" and "too cold" samples had very similar average daily temperature patterns during period 1. The "just right" sample dwellings had an average daily temperature of 19.3°C and the "too cold" sample had an average temperature of 19.2°C.

Figure 7.16: Average daily dwelling temperatures by occupant thermal comfort perception for period 1



During period 2, the “just right” sample had an average daily tempertaure of 18.9°C and the “too cold” had an average temperature just 0.5°C lower at 18.4°C. There was just one household during period 2 who stated the temperature in their house was “too warm” and amazingly the average daily temperature in this house was just 15°C. It is difficult to comprehend this households perception of thermal comfort in their home but this ocupant at site 14 has been discussed earlier in this chapter and was identified as particularly vulnerable due to low indoor temperatures and poor health. This again raises questions in relation to the subjective measure of thermal comfort. Although most thermal comfort surveys use the WHO thermal comfort range of 18°C to 24°C (20-24°C for the elderly), Hong et al (2009) concluded that perceptions of thermal comfort generally have a greater range with a lower limit closer to 16°C.

Figure 7.17: Average daily dwelling temperatures by occupant thermal comfort perception for period 2



As the tempertaures in the “too cold” and “just right” sub-samples were quite similiar it is not surprising that several households who reported a “just right” temperature in their home still spoke about their home being cold in the comments section of the questionnaire.

“Put heat on timer when out so warm when come back, if I don’t house is cold. Bad problems with dampness & mould. Put heat on at lower temp for afternoon & boost at night” Site 5

“Leave heat on when go out as too cold when come back. 1hr in morning, 4hrs in afternoon/evening, top up by 1-2 hrs per day during Winter. During March heating on all day as would get cold if not left on” Site 2

The WHO LARES study used the perception method to measure thermal comfort, for representative samples of dwellings in eight European cities. This study found that 47% of all households reported "too cold" temperatures in the winter and/or transient season. This figure is very similar to the findings in our study. Although approximately half of the sample in our study reported the temperature in their home to be "too cold", this is still some way short of the 70% of households who had average daily temperatures below the lower bound threshold for thermal comfort. This indicates that thermal discomfort in our study had been under-declared as is often the case with self-reported data (Watts, 1971). Healy & Clinch (2002) found significant variances between self-reported and objective measures of thermal comfort for certain population groups, most notably the over 65's group. Up until 1996, the English House Conditions Survey utilised both self-reported and objective measures of thermal comfort. The 1996 EHCS found that there were significant variances between the actual indoor dwelling temperatures recorded and the perceived thermal comfort of the dwelling occupants (DETR 2000).

Fuel Poverty, Thermal Comfort and Health

Fuel poor households (those declaring an inability to adequately heat their home to a comfortable temperature) reported poorer health than non-fuel poor households. All fuel poor households reported having breathing disorders, problems with circulation and/or arthritis, and all but one fuel poor household stated they had a disability which included mobility, eyesight, hearing or mental health. All but one fuel poor household also revealed that these health problems were affected by cold weather. A reduction of 1°C in the living-room temperature of an elderly person is associated with rise of 1.3mmHg blood pressure, due to cold extremities and lowered core body temperature (Woodhouse et al, 1993). Fuel poor households were also more likely to report dampness and or draughts in the home with only one fuel poor household not reporting these problems.

"Health very poor & bad circulation, on 20 tablets a day. In winter heating on all day to warm house, freezing if heat not on. Health gets worse during cold weather & have to stay in house" Site 4

"Arthritis bad during winter. House difficult to heat during winter. Only keep house warm if heat on all time" Site 8

In relation to the household thermal comfort perception there was slightly greater reporting of health problems and issues with dampness for those living in perceived cold dwellings. During period 1 twelve of the fourteen households in the "too cold" sample reported problems with arthritis and/or circulation and eleven of the fourteen households reported the same health problems during period 2.

For the “too cold” sample, there were thirteen of the fourteen households during period 1 and twelve of the fourteen households during period 2 who declared having damp and/or draughts in their home.

“Very difficult to heat house because damp” Site 14

Fuel Poverty-Other Indicators

An important aspect of fuel poverty among older people is the requirement that people go without other essentials in order to keep warm (Goodman et al, 2011). Fuel poor households simply do not have enough income to afford to heat and their home adequately. The consequences are multiple debts, the forgoing of other essential needs, ill health and mental stress due to the difficulty of paying bills (Energy Saving Trust, 2005).

We have already looked at the EU-SILC indicator regarding having to go without heating but there are other essentials which people can go without which can give an insight into potential fuel poverty. Households were asked after each monitoring period if the cost of keeping your house warm over the previous 4 months meant that there was less money available to spend on other necessities, for example food or clothing. There were 44.8% (n=13) of households during period 1 and 60.7% (n=17) of households during period 2 who declared having less to spend on other necessities due to the cost of keeping their home warm.

“Had less money to spend on foodstuffs due to heating cost. Can’t use electric as too expensive and gas not working properly” Site 24

With regard to costs, households were asked if the price of heating their homes worried them, and also if they worried about being cut off. Over half of the sample stated they were somewhat to very worried about the price of heating their homes during both periods. However, only one sixth of the sample households declared that they were somewhat worried to very worried about being cut off. This discrepancy between these responses demonstrated that although worried, respondents were not concerned about being cut off, possibly because they will go without other expenditures to ensure being cut off is never a possibility. Anderson et al (2009) concluded that older people tend to perceive energy costs as a discretionary household expenditure that they have some control over. People adjust their energy consumption according to what they feel they can afford and to balance their budget.

“Must pay rent & bills-can eat on the street but not sleep on street” Site 29

“Gas & electric must be paid-willing to sacrifice other necessities such as food, heat most important. Temperature ok once use enough heat.” Site 21

Households were asked how they kept warm during the winter periods. Almost the entire sample stated they used their heating system more than normal in order to keep warm. Of the households who stated they used their heating more than normal, twelve households also stated that they were worried about energy bills during periods 1 and 2 because of this.

As discussed earlier in this chapter households had to spend 20% more on energy bills during period 2 when compared with period 1. This increased expenditure was a combination of additional energy usage due to the lower ambient temperatures during period 2 and energy price increases. Whilst it is encouraging that households were willing to spend more on heating during period 2, research has shown that residential consumption of energy does not tend to be sensitive to energy prices. Di Cosmo & Hyland (2013) found that a 10% increase in energy prices was only associated with a 0.7% decrease in consumption. We know that as a proportion of total household expenditure, households in the lowest income decile (≤€238) spend more on fuel and light than households in the highest income decile i.e. 7% compared with 2.5% (CSO, 2012). As the majority of households (n=24) had an income at state pension level this additional household energy cost during period 2 could have an impact on prevalence of fuel poverty in the sample.

Fuel Poverty Summary

Although the findings in our study must be interpreted with caution due to the small numbers, there are some interesting observations in relation to fuel poverty and thermal comfort. The findings in our study are similar to estimates in the Warmer Homes-A strategy for Affordable Energy Poverty in Ireland, 2011, which suggests that one-fifth of households in Ireland are likely to experience some form of energy (fuel) poverty (DCENR, 2011). Using the dwelling temperature data it was found that fuel poor households (those declaring an inability to adequately heat their home to a comfortable temperature) experienced lower temperatures than other households.
In fact, all but one of these fuel poor households had average daily temperatures below 20°C and were therefore being exposed to increased risks of impaired health. Cold homes have been associated with worsening arthritis and an increased risk of falls with many health effects evident even when other factors such as income poverty are accounted for (Marmot Review Team, 2011).

The subjective thermal comfort findings also revealed that all but one of the fuel poor households was living in thermal discomfort. There were a small number of households who declared having to go without heating in the last year because they could not afford it, but also maintained average daily temperatures above the WHO lower bound thermal comfort threshold of 20°C. There were also households who stated they went without heating, but also declared that they were able to adequately heat their home.

These findings may indicate that some households are suffering from intermittent fuel poverty or occasional difficulties in achieving affordable warmth. There was evidence of households having to go without other necessities in order to heat their home with approximately half of the sample stating the cost of keeping their home warm meant there was less money for other necessities including food and clothing. Approximately half of the households were worried about the cost of heating their homes but a much smaller number were worried about having their gas or electric cut off. This demonstrates that the sample were debt adverse as they will pay their bills but may forgo other necessities.

There was slightly greater reporting of being unable to adequately heat the home to a comfortable temperature, having to go without other necessities in order to heat the home, and concerns in relation to the cost of heating during period 2. It is likely that this is due to the lower ambient temperatures during period 2. It might have been expected to see more households report fuel poverty indicators during period 2 due to the lower ambient temperatures and also the additional energy spend. However, as stated above there are limitations to the use of subjective measures of fuel poverty amongst the elderly. A cross European analysis of housing and social conditions has shown that Irish households persistently “under declare” their levels of hardship and housing deprivation (Healy, 2002). It would possibly be of benefit to assess the level of fuel poverty in the sample using the expenditure method i.e. when a household is spending more than 10% of its income on energy, including heating and lighting. Overall, both the objective and subjective thermal comfort findings in our study may indicate that the levels of fuel poverty reported using the subjective method are possibly an under-declaration. However, it may also be that some households can afford to heat their homes to higher temperatures but choose not to because they are satisfied with their level of thermal comfort. This would probably be even more alarming as these households are not achieving minimum indoor temperatures required to avoid cold strain and ill-health (Collins, 1986).

CHAPTER 8

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary

The most important finding in this study was that over two thirds of the sample households were living in homes with temperatures that are known to be uncomfortable and potentially a health risk. On average, the sample dwellings only maintained temperatures greater than or equal to 20°C for 41.2% of the temperature readings during period 1 and 33.3% of the temperature readings during period 2. The majority of dwellings recorded temperatures of less than 16°C, some for considerable periods of time. Temperatures below 16°C are known to reduce resistance to respiratory infection (Marmot Review Team, 2011). There were also a small number of dwellings that recorded indoor temperatures below 12°C which are known to cause increased strain on the cardiovascular system (Collins, 1986). These findings are even more alarming considering that two thirds of the sample households stated they spent "most to all day" inside their home. Although the majority of households described their health status as fair to very-good, all but two stated they had long term health problems and half of the households stated that their health problems were affected by cold weather. The effect of cold homes is most acute for those with existing cardiovascular disease and/or respiratory conditions (Goodman et al, 2011).

Approximately half of the sample households stated the temperature in their home was "too cold" and the other half stated the temperature was "just right". These results confirm that older people tend to report their housing condition and comfort of their home somewhat favourably with limited agreement with objective measures. The highest average daily dwelling temperatures were in the evening between 5pm and 11pm. It would appear that occupants were using their heating during the evening period at a time when they were in the house. It is positive that the majority of dwellings were heating their homes in the evening period, albeit not always achieving thermal comfort. It is likely that the primary reason for this is that the occupant was not using enough heating. The amount of heating used is an occupant choice but it may have been influenced by the costs of heating the home. However, both the efficiency of the heating system and the energy efficiency of the building may be contributing factors.

As would be expected, the lower outside ambient temperature during period 2 coincided with lower inside dwelling temperature during period 2 when compared with period 1. Despite the increased energy usage during period 2, the average daily inside temperature was lower than period 1. The additional household energy spend during period 2, due to increased energy consumption and higher fuel prices than period 1, may have been significant for this sample. As households were spending a greater percentage of their disposable income on heating during period 2, this had the potential to push more people into fuel poverty.

It is encouraging that despite the additional energy costs during period 2, the majority of households were willing to consume additional energy to heat their home. This was also despite over half the sample stating they were worried about the cost of heating their home. However, in reality the sample households would have had to spend significantly more on heating during both monitoring periods in order to achieve thermal comfort.

The theoretically most efficient dwellings in the sample i.e. with a BER of C had the highest average temperatures but were not the most efficient in terms of energy consumption. As would be expected the dwellings with a BER of F were the least efficient in terms of energy consumption but did not have the lowest average temperatures.

There were two dwellings that underwent energy efficiency upgrades between monitoring periods. Only one of these households experienced increased thermal comfort during period 2. In both dwellings there was no reduction in energy consumption during period 2. This lack of reduction in energy usage can be attributed to the "take back" factor i.e. occupant desire for increased temperature to achieve thermal comfort. It is likely that if the outdoor temperature during period 2 was similar to that of period 1, there would have been increased thermal comfort and possibly a reduction in energy consumption for both households during period 2.

Approximately one third of the sample dwellings during period 1 and one fifth of the dwellings during period 2 had relative humidity levels above the level recommended by ASHRAE for thermal comfort i.e. 60%RH. High relative humidity levels can encourage the growth of mould and mildew. In addition, dust mites, bacteria and fungi all thrive under moist, humid conditions. Excessive moisture in the air (i.e., high relative humidity) that is not properly controlled can lead to excessive dampness. Households who reported dampness and/or mould growth had higher relative humidity levels in their homes than those who did not report dampness.

There was a strong relationship between indoor dwelling temperature and relative humidity. The dwellings that had the lowest average daily temperatures also had the highest average daily relative humidity levels. This meant that some households were exposed to extremes of both temperature and relative humidity which was significant from both a thermal comfort and health perspective.

The subjective method of measuring fuel poverty using the EU-SILC indicators found that 17.9% and 25% of households declared an inability to adequately heat their home to a comfortable temperature during periods 1 and 2 respectively. The objective and subjective thermal comfort findings in our study may indicate that the levels of fuel poverty reported using the subjective method are an under-declaration, as is often the case with older people.

Fuel poor households (those declaring an inability to adequately heat their home to a comfortable temperature) experienced lower temperatures than other households. In fact, all but one of the fuel poor households had average daily temperatures below 20°C.

An important aspect of fuel poverty among older people is the requirement that people go without other essentials in order to keep warm. In total 14.3% of households during periods 1 and 2 respectively reported having to go without heating during the last year because they could not afford it. There was evidence of households having to go without other necessities in order to heat their home with approximately half of the sample stating the cost of keeping their home warm meant there was less money for other necessities including food and clothing. This was evidence of the "heat or eat" phenomenon.

Overall this study has raised significant concerns in relation to the thermal comfort of the sample households and impacts on their health. It would appear that the majority of households are using their heating for significant periods of the day but they are not always achieving thermal comfort. This may be partially due to the inefficiency of the sample dwellings but the results would indicate that occupant heating practices and varying demand temperatures are the most significant determinants of dwelling temperature. Households experiencing both low temperatures and high relative humidity are most vulnerable to negative health impacts.

This sample focuses on low income older people living alone which are recognised as a particularly vulnerable group. However, all of the dwellings in this sample are sheltered housing units and households are provided with a range of supports. In addition the dwellings including heating systems are maintained by the local authority. They are also small housing units and therefore do not have the issue of spatial shrinkage i.e. only being able to heat part of the house. As the majority of older people in Ireland are owner occupiers, the burden of home maintenance must be absorbed into their household budget. We know from the literature review chapter that older people in Ireland are more likely to occupy older housing that lacks energy efficiency measures and is more difficult to heat. Older people in Ireland are also most likely to occupy detached and semi-detached dwellings which are more difficult to heat than flats and apartments. It can therefore be concluded that the problems with low dwelling temperatures in this sample may not just be an issue for the social housing sector.

8.2 Conclusions

- In over 70% of the dwellings during both monitoring periods, the average daily indoor temperature was below 20°C, which is the lower limit recommended by the WHO for thermal comfort. Less than 30% of dwellings maintained average daily temperatures within the WHO thermal comfort guidelines for the elderly. On average, the sample dwellings maintained temperatures greater than or equal to 20°C for 41.2% of the temperature readings during period 1 and 33.3% of the temperature readings during period 2.

- The highest average temperatures were in the evening between 5pm and 11pm. The average evening temperature for all dwellings was 20.4°C and 19.6°C during periods 1 and 2 respectively. This was encouraging considering the evening time was the most occupied period of the day.

- In relation to occupant perception of thermal comfort, approximately half of the households stated the temperature in their home was "too cold" and the other half stated the temperature was "just right" during both monitoring periods.

- There was an occupant need for very different demand temperatures. The average daily temperature measured in each dwelling varied from 16.5°C to 24.3°C during period 1 and from 14.8°C to 23.7°C during period 2. Occupant behaviours including heating practices was the single biggest factor influencing dwelling temperature.

- The average daily outside temperature was 6.6°C during period 1 and 4.4°C during period 2. The lower outside temperature during period 2 was reflected in the inside dwelling temperature which was 0.8°C lower during period 2.

- Households consumed on average 20% more gas during period 2 when compared with period 1. This was an additional household spend of €62 on energy during period 2. However, despite this additional energy usage the sample dwellings maintained lower average temperatures during period 2.

- There were 32% and 21% of dwellings during periods 1 and 2 respectively which had average daily relative humidity levels above the ASHRAE recommended higher bound threshold for thermal comfort of 60%RH. The households who experienced the highest average daily relative humidity also experienced the lowest average daily temperatures.

- The subjective method of measuring fuel poverty using the EU-SILC indicators revealed that 17.9% and 25% of households during periods 1 and 2 respectively were experiencing fuel poverty. Fuel poor households (those declaring an inability to adequately heat their home) maintained lower average daily temperatures than other households.

- There was 45% and 62% of the sample during periods 1 and 2 respectively who stated the cost of keeping their home warm meant there was less money for other necessities including food and clothing. There was also slightly greater reporting of being worried about the price of heating the home and being worried about gas or electricity being cut off during period 2.

8.3 Recommendations

- Local Authorities, Housing Associations and the private sector must develop best practice in the design of housing, particularly for vulnerable groups including older people. This is particularly relevant given the current housing crisis and the Government's commitment to a significant building programme in the coming years. This should incorporate smart home technology. Many older people's homes already have assistive technologies including pendant alarms and the majority of homes have a phone line and/or broadband connection. An integrated communications system incorporating security, motion sensors, fall detectors and temperature sensors for detection of extreme temperatures, both high and low should be considered. This is a proactive, preventative approach and these technologies can provide unobstructive supervision of vulnerable people who want to continue to be independent in their own home.

- There needs to be a co-ordinated approach between local authorities, health services and social services to protect the health and well being of older people and in particular those identified as vulnerable e.g. an older person at risk from a cold home environment. This could include a system to allow health services to refer patients for housing advice where they present with conditions that may be attributable to their housing condition. This is a preventative strategy that provides alternatives to hospitalisation.

- Older people living in energy inefficient homes are consuming considerable amounts of energy for heating. Improving the energy efficiency of older persons housing will facilitate a healthier home environment, reduce fuel poverty and help meet climate change targets.

- Funding to Local Authorities for improving the thermal efficiency of their housing stock must continue. There has been some evidence of this funding leading to improved thermal comfort for households in this study. Local Authorities should prioritise their senior citizen housing units as part of these programmes.

- There is a need for data to demonstrate the health and cost benefits of housing interventions and in particular retrofitting. Small scale studies measuring dwelling temperature and energy usage pre and post retrofit would demonstrate the outcomes of improved thermal efficiency in the housing stock

- An additional fuel allowance payment is needed during particularly cold winters. The additional household energy spend during period 2 in this study was due to the lower than average ambient temperatures and increased fuel prices. Fuel prices should also be more closely linked to state subvention. An additional fuel allowance payment could be aligned to both the energy efficiency and income of the home in order to target the most vulnerable.

- There is a need to educate older people on the health effects of cold homes. This has been included in previous publications by the SEAI but it needs to be reinforced, particularly given that older people tend to report favourably their thermal comfort. Also, full explanations of heating costs and how to use timers and get the most out of energy sources should be a priority for service providers.

- A separate and confidential report on the study findings will be prepared for Dublin City Council senior management, housing maintenance section and the older person's unit.

The following is recommended if completing a similar survey to our study:

- A larger sample size would be recommended in order to facilitate greater analysis of sub-samples including house type, house size and heating type. Greater sample numbers would also allow analysis of the relationship between cold homes and occupant health and wellbeing. Additional factors including dwelling orientation and heat transfer from adjoining properties should also be considered.

- Although the energy usage data available in this study was useful, real-time energy usage would allow greater scope for analysing household energy usage behaviours.

- Outside ambient temperature data by time of day would allow a greater understanding of the inside dwelling temperatures and in particular heating periods.

- The EU-SILC indicators of fuel poverty may under-represent the scale of fuel poverty amongst older people in particular and should be interpreted with caution. It would be recommended that where possible the expenditure method of measuring fuel poverty be utilised.

The following is recommended if completing a nationally representative study:

- Data on the living conditions of older people in Ireland is limited. As with previous research our study found that older people tend to report the condition and thermal comfort of their home favourably with limited agreement with objective measures. For policy to be evidence based, up to date data on older peoples house condition and thermal comfort is urgently needed.

- The most recently available nationally representative data on housing condition in Ireland is the Irish National Survey of Housing Quality conducted in 2001-2002 but this was based on self reporting. It would be recommended that a survey similar to the Northern Ireland House Condition Survey using trained assessors be conducted in the Republic of Ireland to provide a current picture of the housing stock.

- A national house conditions survey could also incorporate temperature monitoring within a nationally representative sample of dwelling houses. It would be recommended that any such survey would include information on occupant behaviours including heating practices.
- Energy usage data as part of a house conditions survey would also be of great benefit. Access to utility bills would allow greater scope for interpretation of temperature results and investigating prevalence of fuel poverty.

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APPENDIX 1

TEMPERATURE AND RELATIVE HUMIDITY DATA LOGGER

OM-EL-USB-2

TEMPERATURE AND RELATIVE HUMIDITY DATA LOGGER
(DEW POINT INDICATION VIA WINDOWS SOFTWARE)

TEMPERATURE
Range: -35 to 80°C (-31 to 176°F)
Resolution: 0.5°C(1°F)
Accuracy: OM-EL-USB-2: ±0.5°C (±1.0°F);
HUMIDITY
Range: 0 to 100% RH
Resolution: 0.5% RH
Accuracy 20 to 80% RH;
DEW POINT
Accuracy (overall error in the calculated dew point for RH measurements from 40 to 100% RH @ 25°C): ±2°C (±4°F)

GENERAL
Memory: 16,000 temperature and 16,000 relative humidity readings
Logging Interval: 10 seconds to 12 hours
Operating Temperature Range: -35 to 80°C (-31 to 176°F)
Alarm Thresholds: High/low alarm thresholds for % RH and temperature, selectable in software
Start Date/Time: Selectable in software
Status Indicators (LEDs): Red and green
Software: Windows 98/2000/XP/VISTA
Power: 12 AA 3.6 V lithium battery (included)
Battery Life: 1 year typical (depends on sample rate, ambient temperaure and use of alarm LEDs)
Weight: 57 g (2 oz)
Dimensions: See dimensional drawing above

APPENDIX 2

RESEARCHER DWELLING SURVEY

Researcher checklist

Washing machine	☐	Tumble dryer	☐	Washer/dryer	☐
Cooker	☐				
Microwave	☐				
Fridge	☐	Freezer	☐	Fridge/freezer	☐
Electric kettle	☐				
Toaster	☐				
TV	☐				
Electric heater	☐	Quantity	☐		
Energy saving light bulbs	☐	Quantity	☐		
Door draft excluders	☐				
Hot water cylinder lagged	☐				
Dampness/mould/discolouration	☐				
Vents closed/blocked	☐				

APPENDIX 3

QUESTIONNAIRE-MONITORING PERIOD 1

The questionnaire outlined below is not the format received by respondents but it is a complete list of all the questions.

SOME INFORMATION ABOUT YOU AND YOUR HOUSEHOLD

1. **Please complete the following:**

Age	Sex	Marital Status	Occupation or previous occupation

2. Please tick, if you receive:

- ☐ contributory pension
- ☐ non contributory pension
- ☐ transition pension
- ☐ private pension
- ☐ both private & state pensions
- ☐ invalidity pension
- ☐ widow/widower's pension
- ☐ blind pension

3. **Please tick if you receive:**

- ☐ disability allowance
- ☐ Household Benefit Allowance
  (gas/electricity allowance, free TV licence, telephone allowance)
- ☐ fuel allowance
- ☐ smokeless fuel allowance
- ☐ living alone allowance
- ☐ rent allowance
- ☐ carers allowance
- ☐ free travel pass
- ☐ home help service

4. **How much money comes into your home after tax, including money from benefits and allowances?**
Please remember, this information is confidential and will only be used for research purposes.

Please answer either per week OR per month – whichever is easiest for you

Per week		**Per month**	
under €150	☐	under €650	☐
€151 - €200	☐	€651 - €867	☐
€201 - €220	☐	€868 - €954	☐
€221 - €250	☐	€955 - €1,084	☐
€251 - €350	☐	€1,085 - €1,517	☐
€351- €450	☐	€1,518 - €1,950	☐
€451 - €600	☐	€1,951 - €2,600	☐
€601- €800	☐	€2,601 - €3,467	☐
Over €800	☐	Over €3,468	☐

5. **How many times every fortnight would you:**

	Never	1-2 times	3-4 times	Over 4 times
Have visitors in your home (friends, family, neighbours)	☐	☐	☐	☐
Go out to visit friends	☐	☐	☐	☐
Go out to visit family	☐	☐	☐	☐
Go out for hobbies/social activities	☐	☐	☐	☐
Go out for meals/eat out	☐	☐	☐	☐
Go to a day centre	☐	☐	☐	☐

SOME INFORMATION ABOUT YOUR HOME

6. **When was your home built?**

- ☐ after 2006
- ☐ 2001-2006
- ☐ 1997-2000
- ☐ 1991-1996
- ☐ 1981-1990
- ☐ 1971-1980
- ☐ 1961-1970
- ☐ 1941-1960
- ☐ 1900-1940
- ☐ before 1899
- ☐ I don't know

7. **In winter, which room is the warmest in your home?**

____

8. **In winter, which room do you occupy most during the day?**

____

9. **Which of the following features do you have in your home?**

- ☐ single glazed windows
- ☐ at least half my windows are double glazed windows
- ☐ at least half my windows are triple glazed windows
- ☐ water cylinder lagging jacket
- ☐ door draft excluders
- ☐ window draft excluders
- ☐ floor insulation
- ☐ pipe insulation
- ☐ attic insulation
- ☐ cavity wall insulation
- ☐ internal wall insulation
- ☐ external wall insulation

- ☐ none of these
- ☐ I don't know

10. **Which of these items do you have in your home?**

- ☐ mobile phone
- ☐ smoke alarm
- ☐ colour television
- ☐ pendant alarm/remote monitoring system
- ☐ internet access
- ☐ carbon monoxide monitor
- ☐ radio

11. **Please tick if your home has:**

☐ had the electricity/gas cut off for delayed payment of bills in the last 5 years
☐ been put on the vulnerable persons register for electricity/gas
☐ a prepaid meter for gas or electricity
☐ a smart meter
☐ a coin operated or debit card electricity meter
☐ damp, mould or black stains on walls, windows, doors or ceilings
☐ damp table salt
☐ energy saving light bulbs in most rooms
☐ draughts

12. **Does your home have a building energy rating (BER) certificate?**

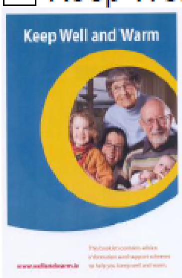
☐ yes ☐ no ☐ I don't know

13. **If yes, what is the building energy rating (BER)?**

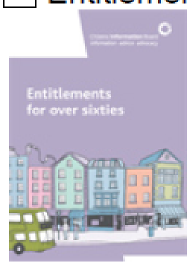
☐ A1	☐ A2	☐ A3	☐ B1	☐ B2	☐ B3
☐ C1	☐ C2	☐ C3	☐ D1	☐ D2	
☐ E1	☐ E2	☐ F	☐ G	☐ I don't know	

14. **Please tick if you have received any of the following publications in the past year:**

☐ Keep Well & Warm booklet



☐ Entitlements for Over Sixties booklet



☐ booklets on energy efficiency from the ESB, Bord Gais, Airtricity or any other provider

15. **Has your home had major improvements to make it warmer in the last 5 years (for example, new windows, attic insulation installed)?**

☐ yes ☐ no ☐ I don't know

SOME INFORMATION ON THE FUELS YOU USE IN YOUR HOME

16. **Do you use any of these to help heat your home?**

☐ bottled gas
☐ electric storage heaters
☐ electric plug-in heater
☐ solid fuels (wood, coal, turf)
☐ other. Please specify__________
☐ none of these

17. **Please select all the ways you heat water for bathing?**

☐ mains gas
☐ oil
☐ electricity (kettle)
☐ other. Please specify ____________
☐ I don't know
☐ solid fuel
☐ LPG/bottled gas/gas tank

18. **Are you able to control the temperature of your central heating system?**

☐ yes ☐ no

19. **If you receive a gas bill and/or an electricity bill, approximately how much do each of these bills cost you every 2 months during coldweather?**

Gas Bill

☐ €0 - €50
☐ €51 - €100
☐ €101 - €150
☐ €151 - €200
☐ €201 - €249
☐ over €250
☐ I don't know

Electricity Bill

☐ €0 - €50
☐ €51 - €100
☐ €101 - €150
☐ €151 - €200
☐ €201 - €249
☐ over €250
☐ I don't know

20. **Do you save up to pay for electricity and/or gas?**

☐ yes ☐ no ☐ I cannot afford to save

21. **Are you in arrears with your gas bill?** ☐ yes ☐ no

22. **Are you in arrears with your electricity bill?** ☐ yes ☐ no

23. **Would you be interested in having a pre-pay electricity or gas meter installed in your home?**

- ☐ yes
- ☐ no
- ☐ I have a pre-pay electricity meter
- ☐ I have a pre-pay gas meter

24. **Please select how you pay for electricity and gas?**

	Electricity	Gas
It is part of my rent	☐	☐
Cash	☐	☐
Cheque	☐	☐
Laser Card	☐	☐
Credit Card	☐	☐
Direct Debit	☐	☐
One lump sum	☐	☐
Instalments	☐	☐
Other payment	☐	☐
A relative pays it	☐	☐
I have free units	☐	☐
Pre-pay meter	☐	☐
Not applicable	☐	☐

25. **Have you switched your electricity account from one supplier to another to save money (Airtricity, Bord Gais, ESB)?**

☐ yes ☐ no

SOME INFORMATION ON THE IMPACT OF COLD WEATHER ON YOU AND YOUR HOUSEHOLD

26. **During the winter, do you think your home is:**

☐ too warm
☐ just right. Neither too warm nor too cold.
☐ too cold. If your home is too cold, why is this? ____________________

27. **During the winter, how many day time hours do you have your heating on for?**

☐ less than 1 hour
☐ 1 – 2 hours
☐ 2 – 4 hours
☐ 4 – 6 hours
☐ 6 – 10 hours
☐ more than 10 hours

28. **During the winter, how much time do you spend indoors at home on a typical day?**

☐ 1 - 2 hours
☐ 2 - 4 hours
☐ most of the day
☐ all day
☐ other. Please specify: ______________________________________

29. **What do you think about the price of heating your home?**

☐ I am very worried about the price
☐ I am somewhat worried about the price
☐ It is not something I think about
☐ I am not very worried
☐ I am not at all worried

30. **Are you worried about your electricity or gas being cut off due to you not being able to pay your bill?**

☐ I am very worried
☐ I am somewhat worried
☐ It is not something I think about
☐ I am not very worried
☐ I am not at all worried

31. **Thinking of the <u>December to March period just gone(2011-2012)</u> , did the cost of keeping your house warm mean that there was less money available to spend on other necessities, for example food or clothing?**

☐ yes ☐ no

32. **During the severe cold weather of last winter(2010-2011), did the cost of keeping your house warm mean that there was less money available to spend on other necessities, for example food or clothing?**

☐ yes ☐ no

33. **During the <u>December to March period just gone(2011-2012)</u>, how did you keep warm?**

☐ I used my heating system/fire more than usual.
Are you concerned about your bills because of this? ☐ yes ☐ no
☐ I stayed inside my home
☐ I used a hot water bottle/electric blanket(s)
☐ I wore a coat or used a blanket indoors
☐ I blocked vents*
☐ I went to bed earlier to keep warm
☐ I used the oven for additional heat
☐ I heated only one/two rooms in the home
☐ I slept in the living room because the bedroom was too cold
☐ I used extra covers on my bed
☐ I had at least one hot meal everyday
☐ I drank hot drinks throughout the day
☐ I drank alcohol to keep warm (for example, whiskey)
☐ I went somewhere else to keep warm and save on heating costs (for example, library, pub, shopping centre)
☐ I kept active indoors
☐ other. Please specify ______________________________

34. **During the severe cold weather of last winter (2010-2011) did you take any additional measures from those which you have outlined in Q33 above in order to keep warm?**

☐ yes ☐ no
If yes, please give details:____

* This is not recommended

35. **Thinking of the December to March period just gone (2011-2012) did you spend less time inside the house and more time going out for social activities etc, compared to the previous winter (2010-2011) due to the milder weather conditions?**

☐ yes ☐ no

36. **Yes No**

☐ ☐ I have two pairs of strong shoes
☐ ☐ I have a warm waterproof overcoat
☐ ☐ I can replace any worn out furniture
☐ ☐ I can buy new, not second-hand, clothes
☐ ☐ I can have a roast joint or its equivalent once a week
☐ ☐ I can keep my home adequately warm
☐ ☐ I can buy presents for family or friends at least once a year
☐ ☐ I can have family or friends for a drink or meal once a month
☐ ☐ I eat meals with meat/fish/vegetarian equivalent every second day
☐ ☐ I had a morning/afternoon/evening out in the last fortnight for entertainment
☐ ☐ I had to go without heating during the last year through lack of money
☐ ☐ I use meals on wheels

37. **Have you avoided cooking to save on electricity or gas in the last 12 months?**

☐ yes ☐ no

38. **If you have received help to pay your bills in the last 12 months, please tick who you received assistance from:**

☐ friends/family
☐ charitable organisations such as Saint Vincent de Paul, ALONE
☐ your Community Welfare Officer (Exceptional Needs Payment)
☐ a moneylender
☐ a credit union or bank
☐ other. Please specify ____________________

39. **If you receive the fuel allowance, how much of it would you generally spend on fuel?**

☐ all
☐ more than half
☐ less than half
☐ none
☐ I don't know
☐ I do not receive the fuel allowance

40. **An additional once-off fuel allowance payment of €40 was to be paid with some welfare payments between 22 December 2010 and 7 January 2011. Did you get this?**

☐ yes ☐ no ☐ I don't know

41. **Do you generally watch or listen to the weather forecast every day?**

☐ yes ☐ no

42. **How do you respond to cold weather warnings?**

☐ I do not do anything different
☐ I use my heating system more than usual
☐ I make sure I have adequate fuel in my home
☐ I make sure I have adequate fresh and tinned food supplies
☐ I stay indoors at home
☐ I call a relative
☐ other. Please specify ______________________________

43. **Who would you contact if your heating system broke down?**

____

☐ I do not know who to contact

SOME INFORMATION ON YOUR HEALTH AND WELLBEING

44. **Would you say your health is:**

- ☐ very good
- ☐ good
- ☐ fair
- ☐ bad
- ☐ very bad

45. **Please tick if you:**

- ☐ have a full GMS medical card
- ☐ have a GP only medical card
- ☐ have health insurance e.g. VHI, Quinn, Aviva etc.
- ☐ receive visits from the public health nurse/district nurse
- ☐ have Home Help visits – receive home help or formal carers who call in
- ☐ received the H1N1 (swine flu) vaccination in the last year
- ☐ get a yearly flu vaccine
- ☐ other services. Please specify ______________________________

46. **If you do not receive the flu vaccine why not?** ____________________

47. **In the last 6 months have you:**

- ☐ had pneumonia
- ☐ had a stroke
- ☐ had a heart attack
- ☐ had a mental health problem
- ☐ had a blood pressure problem
- ☐ had a fall outside your home
- ☐ had a fall inside your home
- ☐ been admitted to hospital

48. **How often do you visit a GP?**

- ☐ I never visit a GP
- ☐ less than once a year
- ☐ at least once a year
- ☐ more than once a year

49. **Are you lonely:**

- ☐ never
- ☐ occasionally
- ☐ frequently
- ☐ almost all the time

50. **Do you use:**

☐ a walking aid ☐ a stair lift ☐ a wheelchair

51. **If you smoke, how many cigarettes do you smoke a day?**

____

52. **If you have long-term health problems please indicate what type you have:**

☐ breathing disorders (such as asthma, chronic bronchitis or emphysema)
☐ heart disease (such as angina, heart failure or have had a heart attack)
☐ problems with circulation (such as peripheral vascular disease (PVD), ulcers or chilblains on your legs)
☐ stroke (or mini-strokes (TIA's))
☐ allergies
☐ arthritis
☐ diabetes
☐ mental health difficulties (such as diagnosed depression or schizophrenia)
☐ chronic pain
☐ cancer
☐ other. Please specify ________________

53. **Are any of these health problems affected by cold weather?**

☐ yes ☐ no

54. **If you have a disability, please state if your disability is related to:**

☐ eyesight
☐ hearing
☐ mobility
☐ mental health
☐ a learning disability
☐ other. Please specify ______________________________________

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY

In the space below, please provide us with any other information that you feel is relevant:

____

____

____

APPENDIX 4

QUESTIONNAIRE-MONITORING PERIOD 2

The questionnaire outlined below is not the format received by respondents but it is a complete list of all the questions.

SOME INFORMATION ON THE FUELS YOU USE IN YOUR HOME

1. **Do you use an immersion to heat your water during the winter?**

   ☐ yes ☐ no

2. **Are you in arrears with your gas bill?** ☐ yes ☐ no

3. **Are you in arrears with your electricity bill?** ☐ yes ☐ no

SOME INFORMATION ON THE IMPACT OF COLD WEATHER ON YOU AND YOUR HOUSEHOLD

4. **During the winter, do you think your home is:**

   ☐ too warm
   ☐ just right. Neither too warm nor too cold.
   ☐ too cold. If your home is too cold, why is this? ____________________

5. **During the winter, how many day time hours do you have your heating on for?**

   ☐ less than 1 hour
   ☐ 1 – 2 hours
   ☐ 2 – 4 hours
   ☐ 4 – 6 hours
   ☐ 6 – 10 hours
   ☐ more than 10 hours

6. **During the winter, how much time do you spend indoors at home on a typical day?**

   ☐ 1 - 2 hours
   ☐ 2 - 4 hours
   ☐ most of the day
   ☐ all day
   ☐ other. Please specify: ______________________________________

7. **What do you think about the price of heating your home?**

- ☐ I am very worried about the price
- ☐ I am somewhat worried about the price
- ☐ It is not something I think about
- ☐ I am not very worried
- ☐ I am not at all worried

8. **Are you worried about your electricity or gas being cut off due to you not being able to pay your bill?**

- ☐ I am very worried
- ☐ I am somewhat worried
- ☐ It is not something I think about
- ☐ I am not very worried
- ☐ I am not at all worried

9. **Thinking of the <u>December to March period just gone(2012-2013)</u> , did the cost of keeping your house warm mean that there was less money available to spend on other necessities, for example food or clothing?**

☐ yes ☐ no

10. **During the <u>December to March period just gone(2012-2013)</u>, how did you keep warm?**

- ☐ I used my heating system/fire more than usual.
  Are you concerned about your bills because of this? ☐ yes ☐ no
- ☐ I stayed inside my home
- ☐ I used a hot water bottle/electric blanket(s)
- ☐ I wore a coat or used a blanket indoors
- ☐ I blocked vents*
- ☐ I went to bed earlier to keep warm
- ☐ I used the oven for additional heat
- ☐ I heated only one/two rooms in the home
- ☐ I slept in the living room because the bedroom was too cold
- ☐ I used extra covers on my bed
- ☐ I had at least one hot meal everyday
- ☐ I drank hot drinks throughout the day
- ☐ I drank alcohol to keep warm (for example, whiskey)
- ☐ I went somewhere else to keep warm and save on heating costs (for example, library, pub, shopping centre)
- ☐ I kept active indoors
- ☐ other. Please specify ______________________________

11. **During the severe cold weather in March just gone did you take any additional measures from those which you have outlined in Q10 above in order to keep warm?**

☐ yes ☐ no

If yes, please give details:____________________________________

12. **Thinking of the month of March just gone did you spend more time inside the house and less time going out for social activities etc, compared to the previous three months (2012-2013) due to the colder weather conditions?**

☐ yes ☐ no

13. **Yes No**

☐ ☐ I can keep my home adequately warm

☐ ☐ I had to go without heating during the last year through lack of money

14. **Have you avoided cooking to save on electricity or gas in the last 12 months?**

☐ yes ☐ no

15. **If you have received help to pay your bills in the last 12 months, please tick who you received assistance from:**

☐ friends/family

☐ charitable organisations such as Saint Vincent de Paul, ALONE

☐ your Community Welfare Officer (Exceptional Needs Payment)

☐ a moneylender

☐ a credit union or bank

☐ other. Please specify ____________________

16. **How do you respond to cold weather warnings?**

☐ I do not do anything different

☐ I use my heating system more than usual

☐ I make sure I have adequate fuel in my home

☐ I make sure I have adequate fresh and tinned food supplies

☐ I stay indoors at home

☐ I call a relative

☐ other. Please specify ______________________________

SOME INFORMATION ON YOUR HEALTH AND WELLBEING

17. **Would you say your health is:**

- ☐ very good
- ☐ good
- ☐ fair
- ☐ bad
- ☐ very bad

18. **Please tick if you:**

- ☐ have a full GMS medical card
- ☐ have a GP only medical card
- ☐ have health insurance e.g. VHI, Quinn, Aviva etc.
- ☐ receive visits from the public health nurse/district nurse
- ☐ have Home Help visits – receive home help or formal carers who call in
- ☐ other services. Please specify ________________________________

19. **In the last 6 months have you:**

- ☐ had pneumonia
- ☐ had a stroke
- ☐ had a heart attack
- ☐ had a mental health problem
- ☐ had a blood pressure problem
- ☐ had a fall outside your home
- ☐ had a fall inside your home
- ☐ been admitted to hospital

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY

In the space below, please provide us with any other information that you feel is relevant:

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