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C.Ahern

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SCHOOL OF THE BUILT ENVIRONMENT

May 2010

MSc Thesis

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An Investigation into the Retrofitting of Air Source Heat Pumps into Fabric Improved, Detached, Oil Centrally Heated Dwellings in Rural Ireland

Supervisor: Dr. Philip Griffiths

Submitted May 2010

This thesis is submitted for the degree of Master of Science (MSc)

Abstract

The Irish residential sector's share of total energy usage was 25% in 2006 and was second only to the transport sector.

Ireland's housing stock has been identified as being the least energy efficient in Northern Europe, therefore energy consumption in the domestic sector is greater than necessary, as people live in inefficient dwellings and must consume more energy to heat their homes. Consequently, environmental emissions are also greater than necessary. Examining CO_2 emissions per dwelling; the average Irish Dwelling in 2005 emitted 47% more CO_2 emissions that the average dwelling in the UK. Emissions were 92% higher than the average for the EU-15 and 104% more than the EU-27.

Enhancement of energy efficiency and introduction of newer and more efficient space and water heating technologies in the domestic sector are essential if Ireland's is to achieve the target set out under The European Services Directive of 20% energy efficiency savings by 2020 .

Irelands recently published National Energy Efficiency Action Plan (NEAPP) identifies the following major energy efficiency challenges in the Irish Residential Sector:

A. To create a generation of buildings that meet expectation of comfort and functionality while significantly reducting energy usage and CO_2 emissions; and
B. To address the legacy of older housing with poor energy and CO_2 performance

The Irish government has introduced policies such as The National Insulation Scheme and The Greener Homes Scheme. These schemes are designed to encourage home owner's to increase the efficiency of the existing housing stock and to accelerate the uptake of renewable heating technologies by the domestic renovation sector.

The Irish domestic sector currently relies heavily on conventional boilers for space and water heating even though electric or gas engine driven vapour compression heat pumps can provide heating and cooling with more than three times the efficiency of conventional boilers. To date, despite their excellent performance heat pumps are not the primary choice of the general Irish domestic consumer. This is at odds with trends in other European countries where heat pumps have already taken a significant proportion of the market for heating appliances.

It is not sensible to integrate renewable heating technologies into thermally inefficient homes as the typically long paybacks associated, might never be realised within the lifetime of the technology if the home does not have the ability to hold onto the heat.

As a result, the purpose of this dissertation is to explore the economic and carbon case for retrofitting heat pump systems into existing dwellings which has been thermally upgraded under national retrofit programmes.

In Ireland the predominant house type is detached housing which constitutes 43 % of entire stock. 72% of the detached housing stock is rurally located and 68% is heated by fuel oil. 82% of houses in Ireland have a radiator heating system. Detached housing, due to larger size and high surface area to volume ratio, has a greater heat loss per m^2 than all other house types of the same construction period. It follows that, if a heat pump can be successfully deployed in a house of this type it can be successfully deployed in almost all other house types and thus detached dwellings becomes the case study of this investigation.

The investigation found the economic and carbon case for fabric improvement measures to be categorical; fabric improvement measures can reduce cost and CO_2 emissions from their current levels by up to 65% for older housing (pre 1979) and by even 40% in newer housing. Fabric improvement measures can realise the greatest potential for carbon emissions savings and shall contribute the greatest share of our European Directives on energy efficiency.

This analysis confirms that the integration of heat pumps into fabric improved dwellings is both viable and desirable from an economic and energy efficiency standpoint. The results prove that heat pumps can be successfully employed in both new and older housing and into heating systems serving radiators without the necessity of replacing the existing radiators and still realise an average saving of 30% in both cost and CO_2 emissions.

In addition to an examination of overall detached residential sector energy usage and CO_2 emissions the report presents the following;

- An updated profile of the housing stock using data from the Census 2006 and the Irish National Survey of Housing Quality (INSHQ) 2001-2002
- Offers and update on data used in the only previous housing study in Ireland which was carried out in 2001;
- Identifies key data gaps, such as the lack of robust, end use data and suggests areas for further study;
- Comments on current government energy policy measures for the promotion of energy efficiency and renewable energy technologies in Ireland.

Acknowledgements

Dr. Eddie Conlon for his help and guidance in using SPSS, Ms. Laura Henderson of Elmhurst Energy in the UK for free issuing their design software. Dr. Ken Beattie of DIT for putting me onto Elmhurst Energy, the study by Southwest Colleges and for help with IES. To Dr. Ben Costelloe for his time and putting me firmly back on the straight and narrow. To my tutor Philip Griffiths. To my friend Robin for the unenviable task of proof reading this and to my husband Cathal, it really was a group effort!

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Symbols and Units

Symbol	Name	Unit
C_{ih}	Effective internal heating capacity of the building elements	Wh/m^{3}K
$COP_{\theta set}$	set coefficient of performance of the heat pump for domestic hot water demand at the set buffer storage temperature θset	-
f_{AS}	design factor for attached systems	-
f_{DHW}	design factor for domestic hot water systems	-
f_{HL}	design factor for the heat load	-
$\Phi_{hp,el,\theta set}$	electrical power of the heat pump for domestic hot water demand at θset	kW
P_{el}	effective electrical power input	kW
Q	energy	kWh
Q_{daily}	total hot water energy demand per day	kWh
Q_{S}	energy stored in the buffer storage	kWh
Q_{DP}	energy demand during the defined period	kWh
$Q_{l,s}$	heat losses of the buffer storage in a defined time period	kWh
$Q_{s,eff}$	effective (useful) amount of energy in the buffer storage	kWh
$q_{l,s}$	specific daily thermal losses of the buffer storage	kWh/(24h·l)
t_{DP}	duration of the defined period	h
$t_{Energy,HP}$	duration of period when energy is available for the heat pump	h
V_{S}	volume of buffer storage	l
V_{DP60}	volume delivered during the defined period at 60 °C	l
$V_{l,s}$	volume amounting to the thermal losses of the buffer storage	l
$V_{\Phi set}$	volume of hot water at θset that has the same enthalpy as QDP	L
Φ_{AS}	heating capacity of attached systems	kW
Φ_{DHW}	heating capacity of the heat pump for domestic hot water use	kW
Φ_{HL}	heat load capacity	kW
$\Phi_{hp,\theta set}$	heating capacity of the heat pump at θset	kW
Φ_{hp}	heating capacity of the heat pump	kW
Φ_{SU}	heating capacity of the heat supply system	kW
λ	thermal conductivity	W/(mK)
θ_{CW}	inlet temperature (cold water)	°C
θ_{DPset}	set point for temperature in the buffer storage	°C
θ_{e}	design external air temperature	°C
$\theta_{m,e}$	local mean external air temperature	°C
θ_{min}	minimum value for domestic hot water draught off	°C
θ_{set}	set temperature	°C
A	area	m2

Symbols and Units (continued)

B´	characteristic parameter	m2
c_p	specific heat capacity at constant pressure	J/(kg.K)
d	thickness	m
e_i	shielding coefficient	-
e_k, e_l	correction factors for the exposure	-
G_w	ground water correction factor	-
h	surface coefficient of heat transfer	$W/(m^2K)$
H	heat loss coefficient, heat transfer coefficient	W/K
l	length	m
n	external air exchange rate	h^{-1}
n_{50}	air exchange rate at 50 Pa pressure difference between the inside and the outside of the building	h^{-1}
P	perimeter of the floor slab	m
Q	quantity of heat, quantity of energy	J
T	thermodynamic temperature on the Kelvin scale	K
U	thermal transmittance	$W/(m^2K)$
v	wind velocity	m/s
V	volume	m^3
V	air flow rate	m^3/s
ε	height correction factor	-
Φ	heat loss, heat power	W
Φ_{HL}	heat load	W
η	efficiency	%
λ	conductivity	W//(m·K)
θ	temperature on the Celsius scale	°C
ρ	density of air at θint,i	kg/m^3
Ψ	linear thermal transmittance	W/(m·K)
t_o	outdoor / ambient temperature	°C
t_f	Heating Water flow temperature	°C
t_r	heating water return temperature	°C
t_m	water temperature	°C
t_c	Indoor comfort temperature	°C
t_b	Balance temperature	°C
		-
		-

Indices and Abbreviations

A,B,C etc	House Type
1SDG	1 storey house double glazed
1SSG	1 storey house single glazed
2SDG	2 storey house double glazed
2SSG	2 storey house single glazed
ASHP	Air Source Heat Pump
GSHP	Ground Source Heat Pump
COP	coefficient of performance
DHW	domestic hot water
SPF	seasonal performance factor
KWh	Kilowatt hours
CO_2	Carbon Dioxide
INSHQ	Irish National Survey of Housing Quality
CSO	Central Statistics Office
ktoe	Kilo tonnes of oil equivalent
CO_2-eq	Carbon dioxide equivalent
Pa	Pascals of Pressure
PAYS	Pay as you Save Scheme
GHGS	Greener Homes Scheme
WES	Warmer Homes Shame
EHPA	European Heat Pump Association
BER	Building Energy Rating
SEAI	Sustainable Energy Authority of Ireland
a	air
h	height
o	original
inf	infiltration
T	transmission
e	external, exterior
l	thermal bridge
env	envelope
V	ventilation
min	minimum
g	ground
e	external / exterior
k	building element
nat	natural
O	outdoor
$\Delta\theta$	Indoor temperature difference

1.0 Introduction

1.0 Introduction

Fossil fuels accounted for 96% of all energy use in Ireland's in 2007 (NEEAP 2009). This reliance on fossil fuel means that Ireland's is very exposed to the threat of increasing oil prices as fuel supplies dwindle. Simply put, Ireland's current trend of increasing energy use derived from fossil fuels is not sustainable. Action needs to be taken now to shift to a sustainable energy future.

By focusing on both the supply and demand sides of the Irish energy balance i.e. the decarbonising of our electricity generation (supply), and increasing the efficiency by which this energy is consumed (demand), the Irish Government's framework for the period 2007 – 2020 aims to steer Ireland's towards a new and sustainable energy future; one that helps increase security of supply, makes energy affordable, protects against international energy price rises whilst improving national competitiveness and reducing GHG emissions.

The Department of Communcations, Energy and Natural Resources (DCENR) published the *National Energy Efficiency Action Plan (NEEAP)* in March 2009. The plan serves a dual purpose by addressing Ireland's's requirements under the Energy Services Directive (ESD) for a national energy efficiency plan, and by setting out Ireland's's proposed actions for meeting the 20% energy efficiency savings target is committed to in the *Energy White Paper in 2007*.

The International Energy Agency (IEA) recognises the importance of energy efficiency stating that while technological progress is needed to achieve some emissions reductions, efficiency gains and deployment of existing low carbon energy accounts for most of the savings (NEEAP 2009). The IEA propose a climate policy scenario which targets a stabilisation of GHG emissions at 450ppm of carbon dioxide equivalent CO2-eq and consists of a broad suite of policy measures designed to steer the world away from the harmful effects of dependence on fossil fuels.

With reference to Figure 1.0.1, it is noticeable that the most significant savings can be realised from energy efficiency followed by renewable energy and bio-fuels.

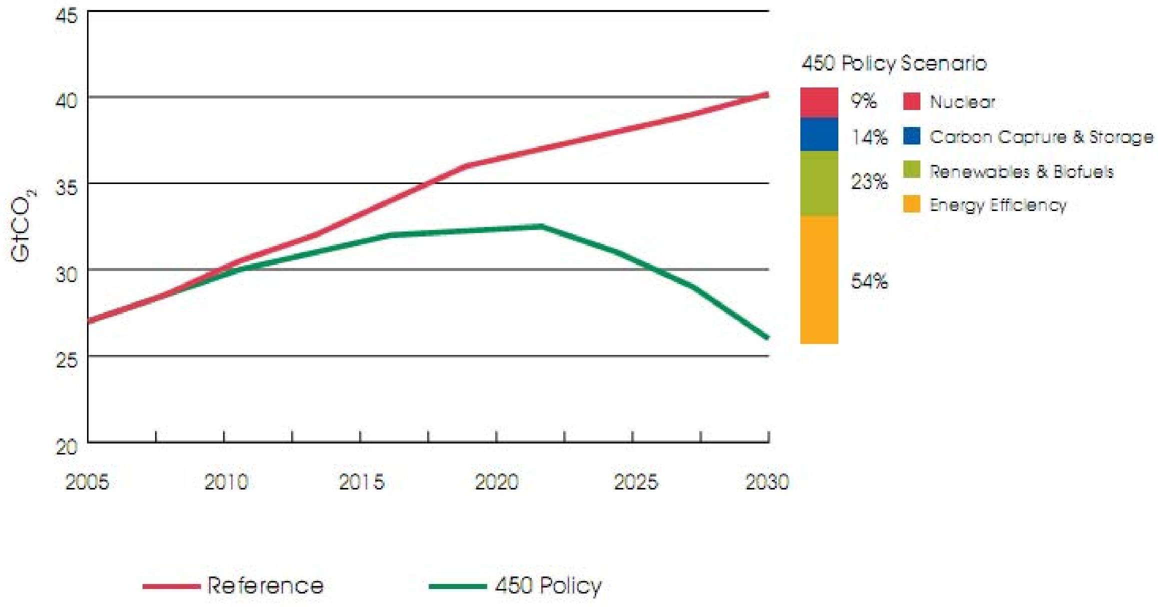

Figure 1.0.1 Reduction in Energy Related CO2 Emissions in the Climate Policy Scenario

Source:IEA/NEEAP

On the supply side, the Irish Government has committed to decarbonising our electricity supply with a set target of 33% of national energy consumption being supplied through renewable energy sources (RES-E) by 2020 (WhitePaper 2007). The main contributor to which shall be wind, as Ireland's, located as it is on the windy west coast of Europe, has considerable potential for the generation of wind energy. The Irish Government is supporting the wind initiative through the wind generation Renewable Energy Feed-in Tariff, or REFIT, the purpose of which is to encourage development of renewable energy resources towards the 2020 goal. It is also hoped that Ireland's, with a target penetration of 500 MW of ocean energy by 2020, shall become a world leader in this area.. (SEAI 2010)

1.1 Extent of the Challenge

Ireland's demand for energy has grown by 84% between 1990 and 2007, with usage increasing in every sector of the economy. In 2008 approximately €6 billion was spent on imported energy, and demand is projected to grow by about 24% over the period 2007-2020 unless action is taken now to reduce demand and usage (NEEAP 2009). This is illustrated in Figure 1.1.1, which shows historical trends in energy consumption and future projections.

The Irish residential sector's share of total energy usage was 25% in 2006 and was second only to the transport sector. In 2006 the sector used 2,990 kilo tonnes CO_2 (ktoe) of final energy, representing 23% of Ireland's Total Final Consumption (TFC) and resulting in 11,896 kt CO2[1]of energy related CO2 emissions. (SEI 2008)

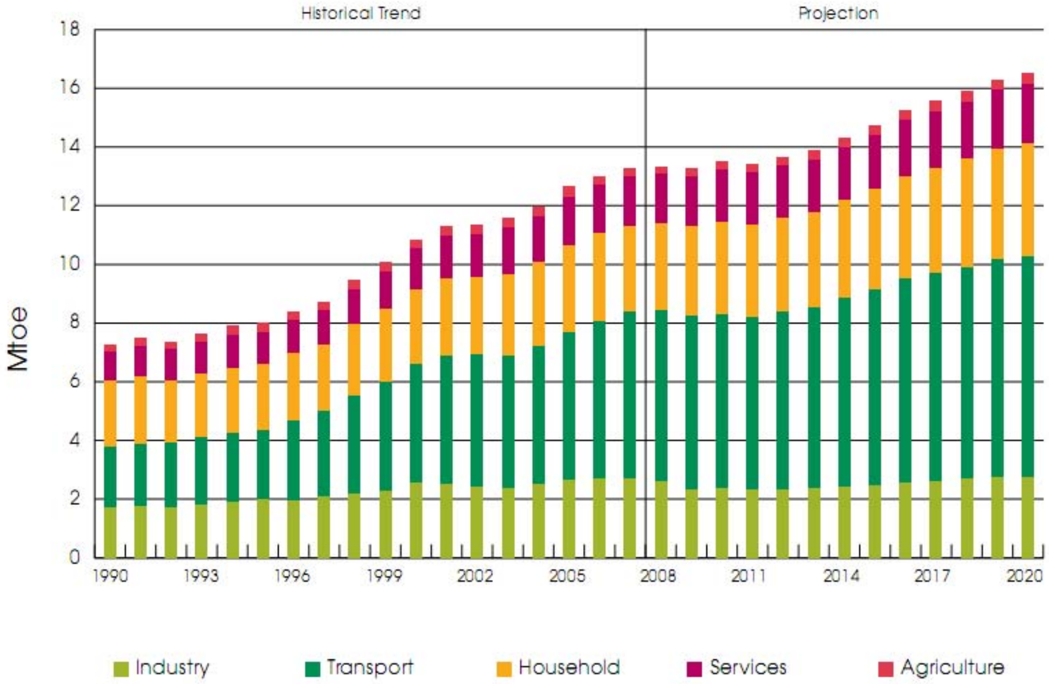

Figure 1.1.1 Total Final Demand of Energy by Sector 1990 -2020 (Final Energy Consumption)

Source: SEAI/NEAPP

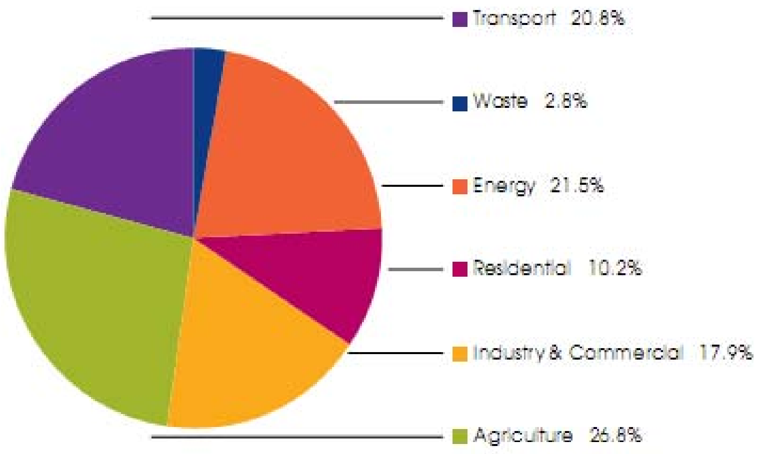

Figure 1.1.2 Ireland's Greenhouse Gas Emissions

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[1] Kilo tonnes carbon dioxide

Source EPA/NEAPP

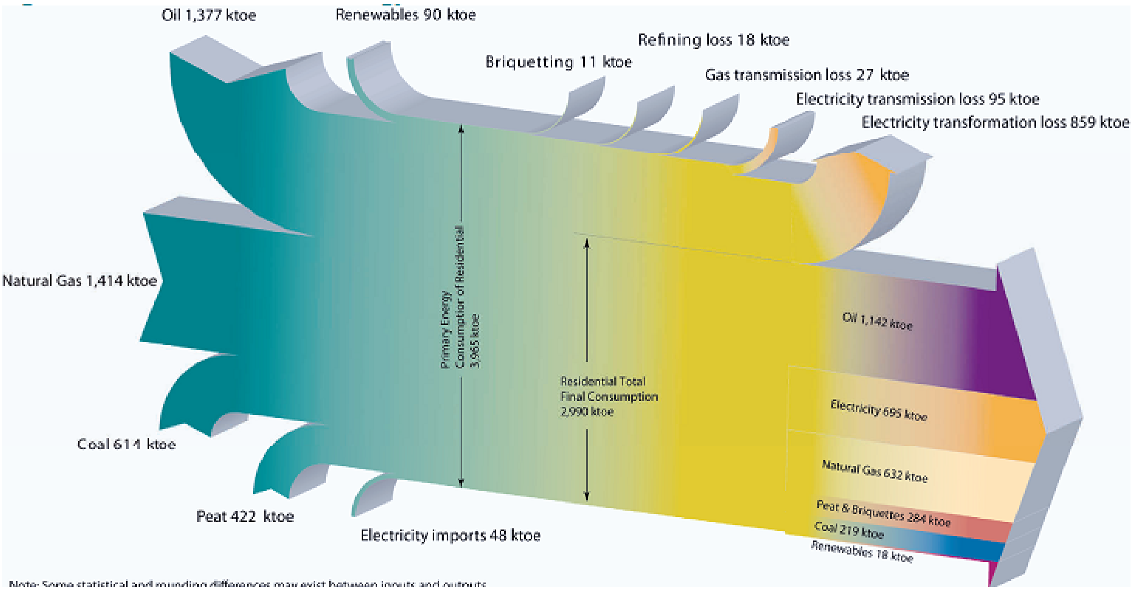

Figure 1.1.3 Residential Sector Energy Balance 2006

Source: SEAI

Referencing Figure 1.1.3; Fuel inputs to the left totalled 3,965 ktoe and include (pro-rata) the fuels used to generate the electricity consumed by the sector. The significant dependence on oil (38% of residential sector TFC) and electricity (23%) is noticeable

Ireland's housing stock has been identified as being the least energy efficient in Northern Europe (Brophy 1999). Energy consumption in the domestic sector is greater than necessary, as people live in inefficient dwellings and must consume more energy to heat their homes. Consequently, environmental emissions are also greater than necessary. Examining CO_2 emissions per dwelling, the average Irish Dwelling in 2005 emitted 47% more CO_2 emissions that the average dwelling in the UK. Emissions were 92% higher than the average for the EU-15 and 104% more than the EU-27. (SEI 2008)

As a result, there is a clear incentive for policy makers to implement programmes and measures that reduce the sector's demand for energy. NEAPP identifies the following major energy efficiency challenges in the Irish Residential Sector:

C. To create a generation of buildings that meet expectation of comfort and functionality while significantly reducting energy usage and CO_2 emissions; and
D. To address the legacy of older housing with poor energy and CO_2 performance

1.2 Policy Measures

Sustainable Energy Authority of Ireland's (SEAI), formerly the Irish Energy Centre was set up by the government in 2002 as Ireland's national energy authority. SEAI, are using legislation and strict guidelines to ensure that homes are as energy efficient as possible.

The key NEEAP actions undertaken by SEAI to date are as follows:

- National Insulation Programme for Economic Recovery to assist homeowners and vulnerable members of society to substantially reduce their energy bills;
- The Home Energy Saving (HES) Scheme, which is administered by SEAI, was launched in March 2009. The scheme provides grant assistance to homeowners for energy efficiency retro-fitting measures including attic and wall insulation, very high-efficiency boilers, heating controls and Building Energy Rating (BER) assessments. The scheme is open to anybody owning a house that was built prior to 2006. Homeowners can expect to save up to €700 per year on their energy bills if they install the full suite of measures available under the scheme. The scheme offers grants of up to 40% of the typical cost of energy efficiency upgrade measures, depending on the measure concerned. The scheme had attracted 40,724 applications by the end of December 2009. In total, 33,434 energy efficient measures were installed in 18,183 homes in 2009;
- The Warmer Homes Scheme (WHS) provides support for low income housing for insulation and other energy efficiency improvement measures. This scheme is also managed by SEAI and implemented by local community groups. Measures include cavity wall insulation, attic insulation, boiler lagging jackets, draught proofing measures and Compact Fluorescent Lamps (CFLs). These measures are provided free or at a nominal cost to the householder. Advice is also provided on minimising energy use. Some €20 million was provided for the scheme in 2009, which included a contribution of €5 million from ESB and Bord Gais Energy (BGE). This enabled energy efficiency improvements to be made in over 19,000 vulnerable homes in 2009, effectively doubling the total number of homes benefitting under the scheme in the previous ten years.
- The Greener Homes Scheme – Grants to householders to install renewable energy technologies;
- Ensuring a move to highly efficient condensing boilers through Regulations setting a minimum efficiency standard (SPF 84%) through Regulations for all new and replacement oil and gas boilers;
- New building regulations delivering a 40% improvement in new housing energy efficiency standards. (Steadily improving since 2002);
- Building Energy Rating (BER) Systems to new houses from 2007 and extended to existing housing from 2009;
- A minimum standard for dwellings occupied by those in receipt of rent supplement is being investigated;
- The National Energy Retrofit Programme, announced in October 2009, which, in broad terms will bring together the Home Energy Saving Scheme and the Warmer Homes Scheme as well as the support programme for business and the public sector.

It will also involve the development and promotion of energy services by the energy companies;

1.3 Heat Supply and Housing

The Government needs to develop new ways of generating renewable energy in all sectors, including heat. Heat generated from renewables sources accounts for only 0.5% of total heat demand and this will have to rise to 13% of thermal energy to come from renewable resources (RES-H) by 2020 to meet the aforementioned Energy Services Directive (WhitePaper 2007).

A significant factor in residential sector energy usage is the system of space heating. Domestic apace and water heating produce over 70% of an average home's CO_2 emissions (NEEAP 2009), therefore reducing these is of paramount importance. It's no surprise that in order to reduce CO_2 emissions, we need to focus our efforts on seeking new, more effective means of heating homes.

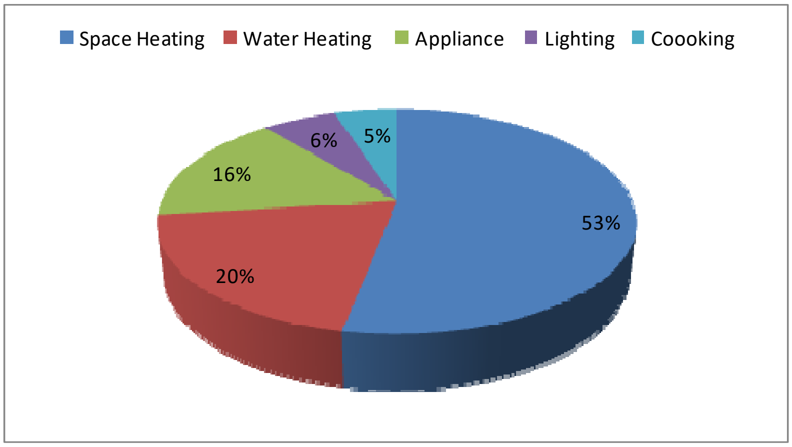

Figure 1.3.1 CO_2 emissions from Average Irish Household

Source:SEAI

The aforementioned Greener Homes Scheme for domestic renewable heat technologies, established in 2006, allows individual householders to obtain grants for the installation of renewable technologies, including wood pellet stoves and boilers, solar panels and heat pumps. The scheme aims to develop a sustainable market for domestic renewable energy technologies by increasing their uptake in the domestic market, thereby reducing greenhouse gas emissions in that sector, encouraging energy efficiency, contributing to security of supply objectives and faciliting greater consumer choice in the heating sector. In developing the market, the scheme paves the way for future regulations in respect of the use of renewable energy in new house building.

Grant aid of €1,100 to €6,500 is provided depending on the individual technology used. See Table 1.3.1. The grant is intended to cover approximately 30 to 40% of the installed cost of the renewable technology. The scheme is being rolled out over a 5 year period and was further resourced in Budget 2007 in light of exponential demand (NEEAP 2009).

Table 1.3.1 Grants available under the Greener Homes Scheme

Technology	**Grant Amount**
Wood Chip of Wood Pellet Boilers	€4,200
Wood Chip of Wood Pellet Stoves	€1,100
Wood Chip of Wood Pellet Stoves with Back Boiler	€1,800
Heat Pump - Horizontal Ground Collector	€4,300
Heat Pump - Vertical Collector	€6,500
Heat Pump - Water (well) to Water	€4,300
Heat Pump - Air Source	€4,000
Solar (per m^2 to a maximum of $12m^2$)	€300

Source: NEEAP 2009

Biomass boilers are proving to be the preferred technology under the Greener Homes Scheme, with applications in this category being 45% of overall demand followed by heat pumps 28% and solar technologies 27% (SEAI).

In order to make a comparision between the different methods of heat provision on the market today, it is first necessary to determine the most commonplace solution that exists today, hereafter referred to as 'The Standard Solution', reference Figure 1.3.2;

> Typically a house in Ireland's derives electricity from the fossil fuel which is combusted in an electricity power station and heat from combustion of oil on site in a boiler.
>
> The highest efficiency domestic condensing oil boiler on the market today (the top-left dot A) is an award winning condensing boiler from Grant Engineering at a quoted seasonal efficiency of 97% (DEAP).
>
> Ireland's power stations (the bottom right dot, B) were 40.6%[2] efficient in 2005 (Department of Communications 2007) at turning chemical energy of fossil fuels into electricity.

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[2] This figure is in part a result of 7.5-8% distribution losses through transformers and overhead and underground cables in the electricity transmission and distribution networks.

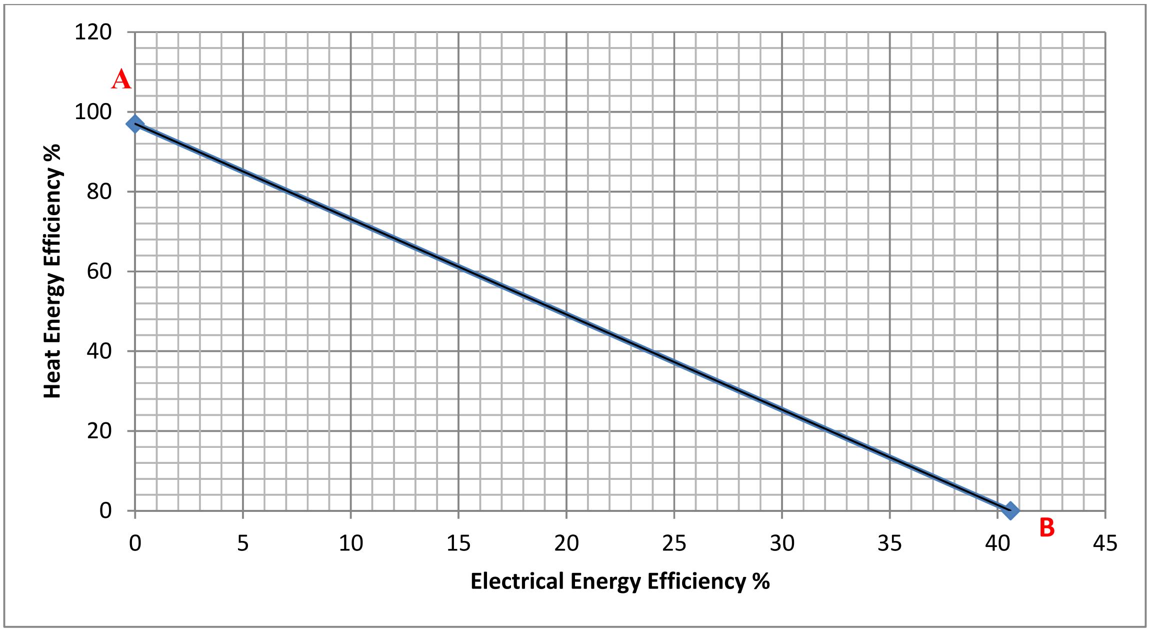


Fig. 1.3.2 Maximum energy efficiency solution for a traditional domestic house in Ireland's (The Standard Solution)

Solar panels are generally *only* employed to provide domestic hot water (DHW) only, therefore 'The Standard Solution' shall now be compared with biomass heating micro-CHP, sterling engines, fuel cells and heat pump technology.

1.3.1 Biomass Heating- Wood Chip or Wood Pellets

The Bio Energy Action Plan published in 2007 identifies one of the issues inhibiting the development of a robust wood energy sector in Ireland's is the slow pace of progress in developing a reliable supply chain from the private sector forest resources. As a result of supply challenges, potential users of wood biomass have traditionally been reluctant to invest in wood boilers (Bioenergy 2007). Consequently, there are no medium or large scale producers of woodchip or wood pellets in the Republic of Ireland's. The Department of Agriculture and Food, and the National Council for Forest Research and Development (COFORD), are actively encouraging the development of an effective and efficient supply chain through a number of support schemes, primarily aimed at the supply chain between forest grower and end user

A number of studies have assessed the potential contribution of wood-biomass. The Environmental Protection Agency (EPA) has identified a potential 0.5 million tonnes of wood residues available each year for energy recovery. This quantity would have an equivalent energy value of approximately 256 million litres of home heating oil (kerosene) or some 200,000 tonnes of oil equivalent (ktoe). *This represents a maximum of one quarter of total kerosene consumption in Ireland's in 2004.* Transportation costs would diminish this displacement potential and this is why proximity of supply and demand is important when assessing the overall potential for wood energy (Bioenergy 2007).

Recent COFORD analysis identified the private sector as the most realistic source for wood-energy and demonstrates that the potential supply from that sector is increasing. Looking forward, if annual afforestation of 10,000 ha per annum or more is achieved over the period 2008 to 2035, then wood fuel becomes a sustainable alternative. Critically, however, if afforestation falls below current levels, then the supply of small dimension material suitable for wood energy will also fall-off in the coming decades, making wood energy unsustainable.

Therefore it would be inadvisable to rely on Biomass as a heat source alone and indeed this notion is supported by SEAI in its action Plan (SEAI 2010) wherein one of its goals is to create comsumer choice in relation to heat energy. This necessitates the development, deployment and adoption of new technologies to exploit renewable energy sources.

> ***'The end-point is carbon free indigenous energy inputs into the system that emphasises electricity as a carrier'***
>
> (SEAI 2010)

1.3.2 Micro-CHP, Fuel Cells, and Sterling Engines

So that we might compare the above listed methods of domestic heat provision with 'The Standard Solution' we next add the efficiencies of micro-CHP studies to Figure 1.3.1. A study of Micro-CHP systems for residential applications was carried out in Belgium in 2005 (Michel De Paepe 2006) . Micro-CHP data was obtained for two commercially available gas engines, two Stirling engines and a fuel cell; the resulting efficiencies found in this study have been plotted on Fig.1.3.2.1

The main thing to notice in this diagram is that the electrical efficiencies of the domestic Micro-CHP system are significantly smaller than the 40.6% efficiency currently delivered by our single-minded 'electricity only' power stations connected to the national grid under 'The Standard Solution'. It is also evident that increasing heat production hinders the electricity production. We may conclude therefore that with respect to micro-CHP that heat is not a 'free- by-product' of electrical production. This is because when CHP plants are constructed they are optimised for either heat or electricity. This scenario could change going forward if more heat is recovered from our electricity power generating station than is currently.

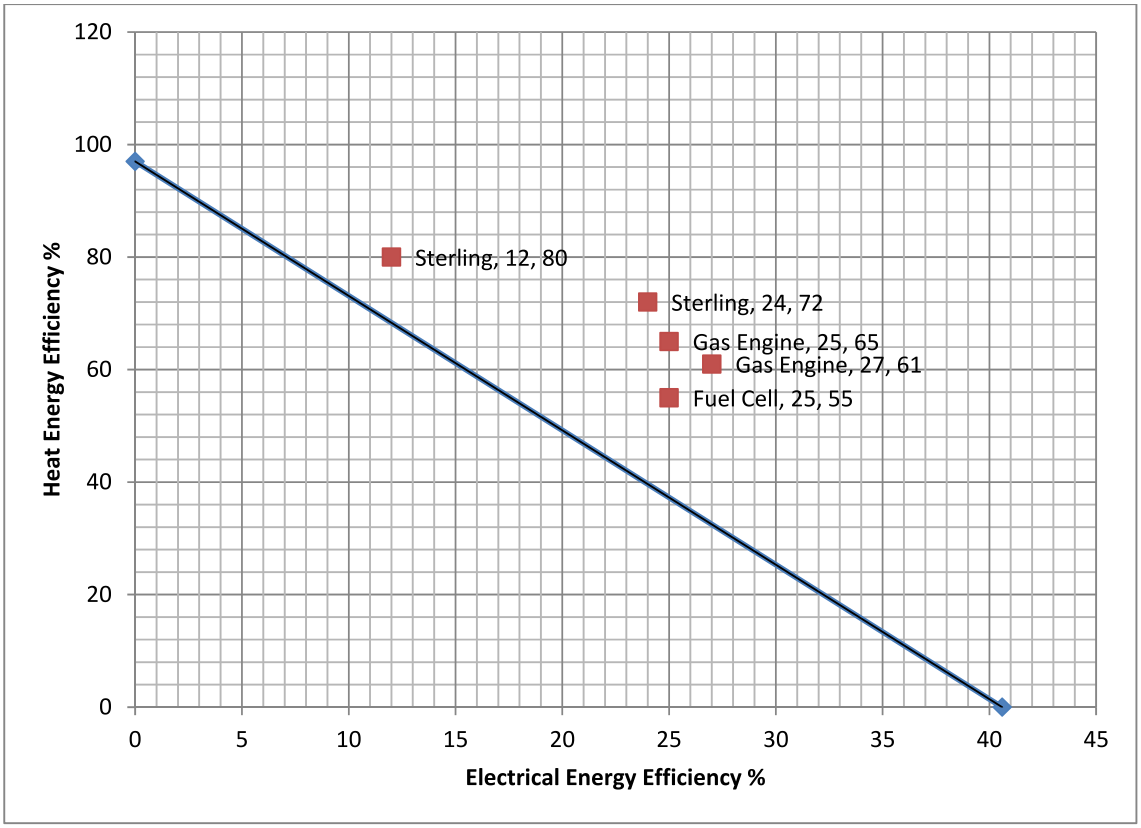


Fig. 1.3.2.1 "Standard Solution" with Micro-CHP

The Micro-CHP study concluded that, from a financial point of view, installing micro-CHP in a household is "not interesting, as investments are high and return is low"

(Michel De Paepe 2006)

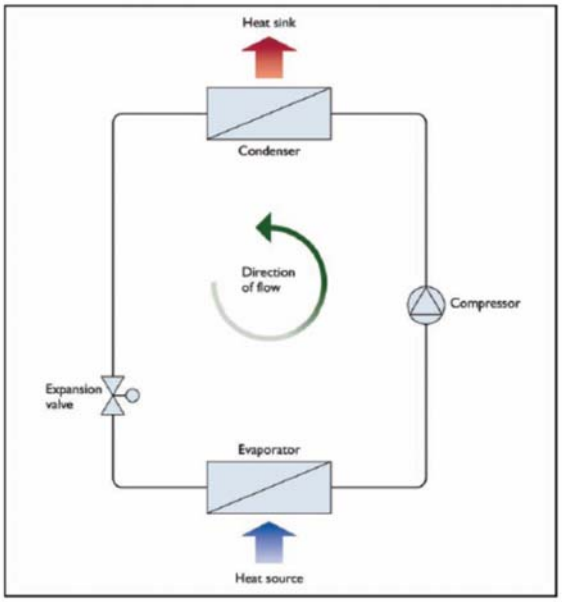
Furthermore

> "90% of electricity production is delivered to the grid with only 10% being used by the household"

(Michel De Paepe 2006)

This is because CHP systems are not flexible in the mix of electricity and heat they deliver; CHP systems will work best only when delivering a particular mix, this inflexibility leads to inefficiencies at times when, for example, excess heat is produced; in a typical house, much of the electricity demand comes in relatively brief spikes, bearing little relation to heating demand. A final problem with some micro-CHP systems is that when they have excess electricity to share, they may do a poor job of delivering power to the network (Michel De Paepe 2006).

1.3.3 Heat Pumps and the Economic Carbon Case



A heat pump is a device which transfers heat from a lower temperature heat source to a higher temperature heat sink. This is opposite to the natural flow[3] of heat from a hot source to a cold sink, but is made possible by the application of an external energy source to drive a thermodynamic refrigeration cycle. The important characteristic of a heat pump is that the amount of heat energy that can be transferred is greater than the energy needed to drive the cycle.

Fig. 1.3.3.1 Vapour-Compression Refrigeration)Heat Pump Cycle

Source: BSRIA 2009 (Reginal 2009)

The ratio between the heat provided to the sink and the energy required is known as the coefficient of performance (COP).

A heat pump with a COP of 3 would output 3kW of Heat Energy for every 1kW of electrical energy giving the unit an efficiency of 300%

The COP is the determinant of whether the heat pumps will be more economic to use than an alternative heating appliance and whether carbon emissions will be less than an alternative heating appliance, For example;

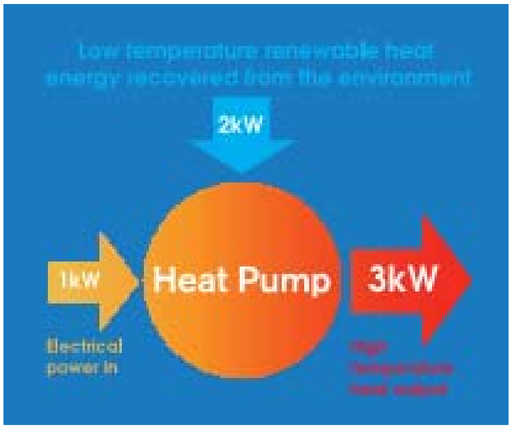


Fig. 1.3.3.2 Heat Pump with COP of 3

Source: Mitsubishi

Electrically driven heat pumps used for space heating application in moderate climates usually have a COP of at least 3.5 at design conditions (Reginal 2009) Therefore if we consider a space heating load of 100kWh per week that can be serviced by a typical electric heat pump operating at an average COP of 3.5 with the oil condensing gas boiler of ‘The Standard Solution’ with a thermal efficiency of 97%:

Heat pump energy consumption $= \frac{Load}{COP} = \frac{100}{3.5} = 28.6\ kWh$

---

[3] The Clausisus Statement of the Second Law of Thermodynamics states that heat will not pass from a cold to a hotter region without an “external agency” being employed.

Boiler energy consumption $= \frac{Load}{Efficiency} = \frac{100}{97\%} = 103.1kWh$

In simple terms, such a heat pump will be cheaper to operate provided that the electricity price is no more than 3.5 times the price of an alternative fuel. There are other factors that come into a more detailed analysis of the benefits, such as maintenance costs and equipment life, and defrost cycles which shall be explored further in subsequent chapter, but the fuel price ratio is the key. This is also the main reason why heat pump markets have not developed in the UK and Ireland's where, historically, electricity has been more than 3.5 times the cost of natural gas and 3 times the cost of oil. However the long-term trend is for gas and oil prices to increase faster than electricity prices thus increasing the cost effectiveness of heat pumps going forward. In addition, was heat pump COP's gradually improve so will the operating cost advantage for heat pumps. (Reginal 2009). Indeed heat pumps are already cheaper to operate that oil and LPG, and much cheaper to operate than direct electric heating (Reginal 2009).

In 2008, the current Irish generator mix emitted carbon dioxide (CO_2) at a rate of 0.5818 $kgCO_2/kWh$ of electricity used (EPA, 2009). The corresponding figures for natural gas, fuel oil and LPG are as follows:

- Natural gas 0.2047 $kgCO_2/kWh$
- Kerosene 0.2570 $kgCO_2/kWh$
- LPG 0.2293 $kgCO_2/kWh$

Using the example given above for an electric heat pump with a COP of 3.5 and condensing boiler operating with an efficiency of 97% (gross calorific fuel basis), the carbon dioxide emissions are:

Heat pump CO_2 emissions = 28.6 x 0.5818= 16.64 kg CO_2

Gas Boiler CO_2 emissions = 100 x 0.2047 = 20.47 kg CO_2

Oil Boiler CO_2 emissions = 100 x 0.2736 = 27.36 kg CO_2

LPG Boiler CO_2 emissions = 100 x 0.2293 = 22.93 kg CO_2

Therefore when the heat pump is operating at a COP of 3.5 it emits 21% less CO_2 than a gas boiler, 30% less than LPG and 41% less than an oil.

The above analysis is supported by (J. Cockroft 2006) who concluded that 'air source heat pumps (ASHP) offer the greatest potential for significant CO_2 emissions reductions compared to a condensing boiler and grid electricity'

Furthermore (J. Cockroft 2006) concluded that 'A reduction in the CO_2 emissions coefficient of grid electricity increases the potential for CO_2 savings from the ASHP, however, reduced heat demands due to improved fabric and air tightness reduce the overall magnitude of the potential savings'

To compare the operation of heat pumps with 'The Standard Solution' we add in heat which uses electricity from the grid to pump ambient heat into buildings. Please see Fig. 1.3.3.3

The lines show combinations of electricity and heat that you can obtain with heat pumps that have a coefficient of performance (COP) of 2, 3, 4, 5 and 6. To better the current day 'Standard Solution' a heat pump with COP greater than 2.5 should be employed. Notably the decarbonising of our energy supply and the ensuing higher efficiencies ensuing can only enhance the performance of the heat pump compared to 'The Standard Solution'. The heat pump performance also compares more favourably to that of the micro-CHP solutions.

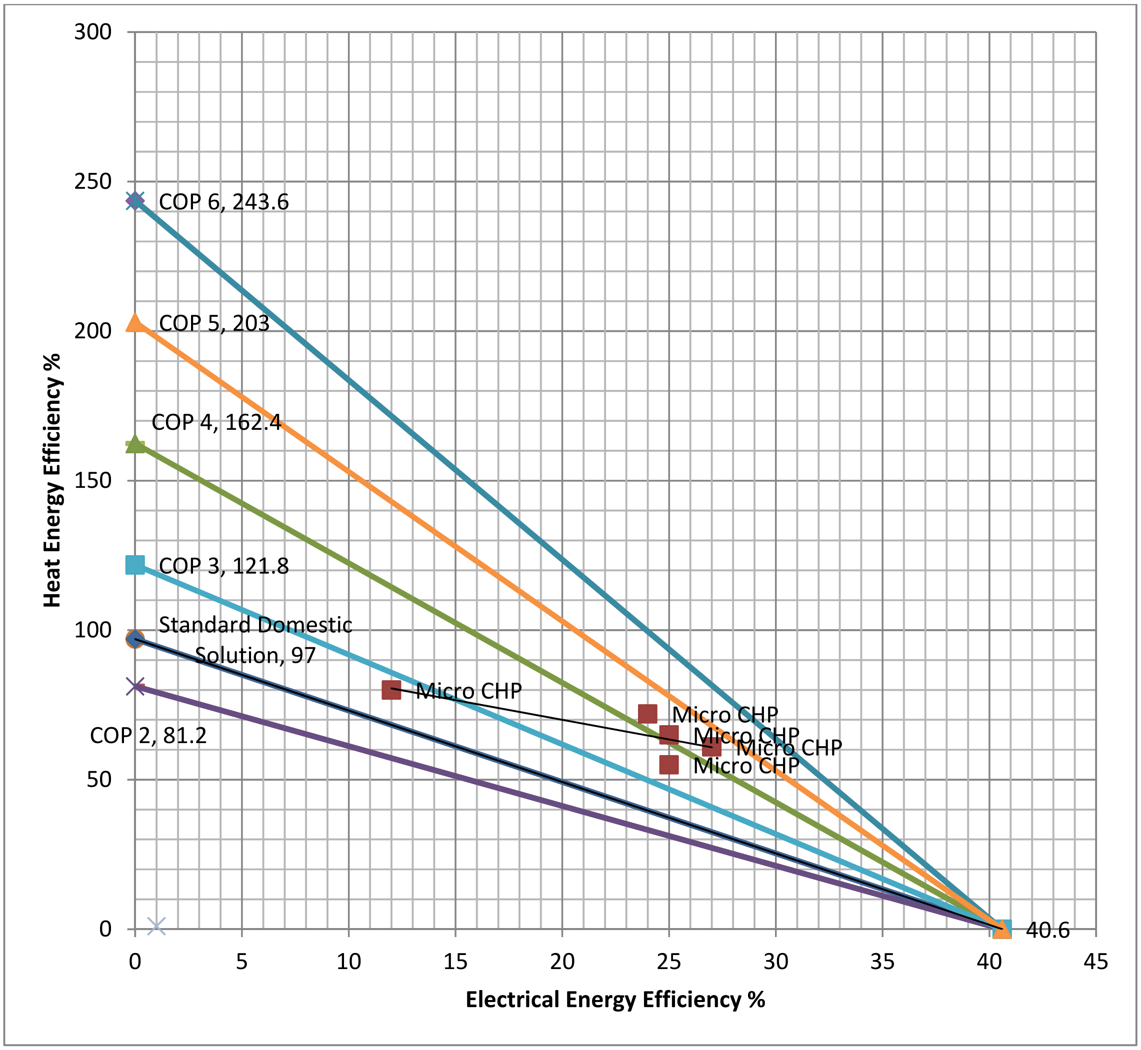


Fig. 1.3.3.3 'The Standard Solution', with Micro-CHP and Heat Pump Solutions

However, despite the promotion of heat pumps via The Greener Homes Scheme and the fact that the Irish mid-temperate climate is so seemingly favourable to their installation, there are only 6061 units installed to date in Ireland's (SEAI 2009). This represents only 0.47% of the

1,288,261 centrally heated homes in 2006 (CSO 2006) and is stark contrast to other European markets which have a residential market share of 20% (EPHA 2009).

Outlined below are a few anecdotal reasons for their small market share to date;

- They are more expensive than ‘conventional’ installations;
- They are a relatively new technology to the residential sector and people are unfamiliar with them;
- Whilst the test standard for establishing the COP of the heat pump at various outdoor temperatures is standard (EN_14511-2 2007), the way the manufacturers express the COP is not, this is misleading to the consumer. The seasonal COP is the important sizing criteria and this changes with location (country) and the prevailing climatic conditions and is not always quoted in the sales literature;
- The COP of a heat pump reduces with outdoor temperature and is also reduced when you increase the flow temperature to your heating system to conventional levels (82^{o}C Flow (t_f) and 70^{o}C return (t_r)), thus it is usual to install additional heating to cope with the load during severe weather conditions thus adding to cost and complexity of the installation;
- As previously stated, fuel price ratio is the key and the cost of electricity has traditionally been much higher than the cost of fossil fuel alternatives, also Ireland, in 2009, had the highest electricity tariff in Europe

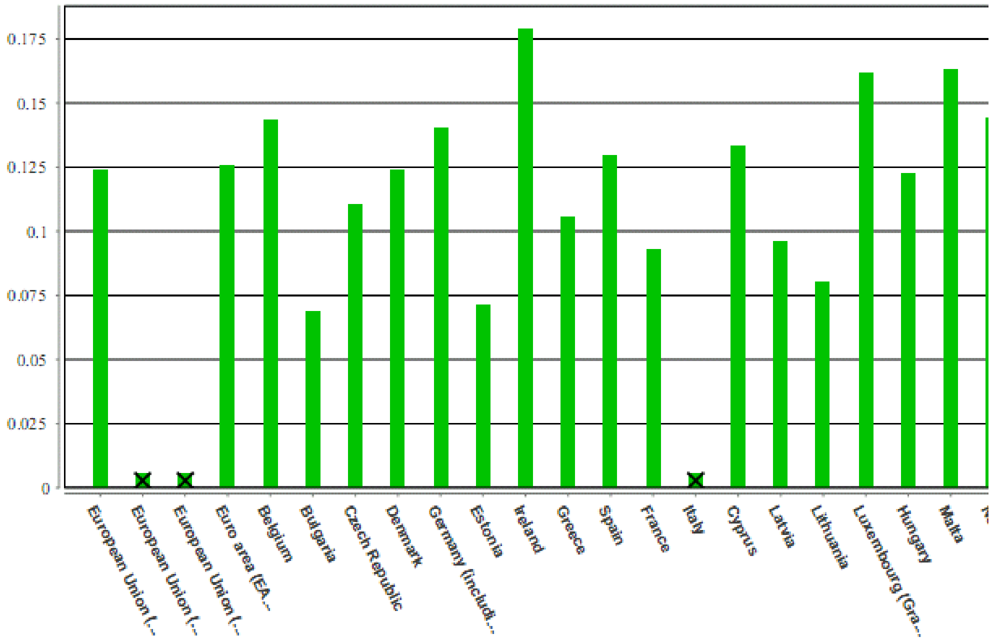


Figure 1.3.3.4 Electricity Prices in Europe

- **Source: Eurostat**

- The existing housing stock typically has a conventional radiator system to replace and replumb the system would require fairly extensive remedial works;

- People are reluctant to have to redecorate their homes to accommodate a new heating system;
- 21% of dwellings in Ireland's are occupied by tenants. Landlords who, by and large, do not pay the energy costs of heating are not motivated to invest in the energy efficiency of the property, while tenants who pay the bill are not motivated to invest in the fabric of a building they do not own.

1.3.4 Types of Heat Pump and Heat Pump Markets

1.3.4.1 European Market

The European Heat Pump Association (EHPA) publishes an outlook report. The 2009 report states that in 2008, heat pumps became an established heating technology in the major European countries. It states that whilst it was necessary in previous years, to explain what a heat pump does, nowadays the technology is accepted, increasingly understood and more often chosen. Total sales in Europe have increased by nearly 50% from 2007 to 2008. The report states that the major markets reported double digit growth rates with the positive exception of France, where sales more than doubled (+127%) due to a beneficial subsidy scheme. See Fig 1.3.4.2

This is particularly remarkable for established markets such as Sweden (+37%) and Switzerland (+27%). It can be explained by a widening application base from new houses to the renovation segment and by an increasing number of installed heat pumps in commercial buildings.

The increasingly strong installation numbers of heat pumps in the renovation segment backs the existing trend towards air-source units. In cases where the building envelope cannot be upgraded to a standard suitable for the efficient operation of heat pumps, the use of domestic hot water pumps is an option to assist rational gas and oil boilers as well as biomass burners. As several countries have agreed minimum shares of renewable sources in the total energy supply to the building, this product segment is seeing exceptional growth.

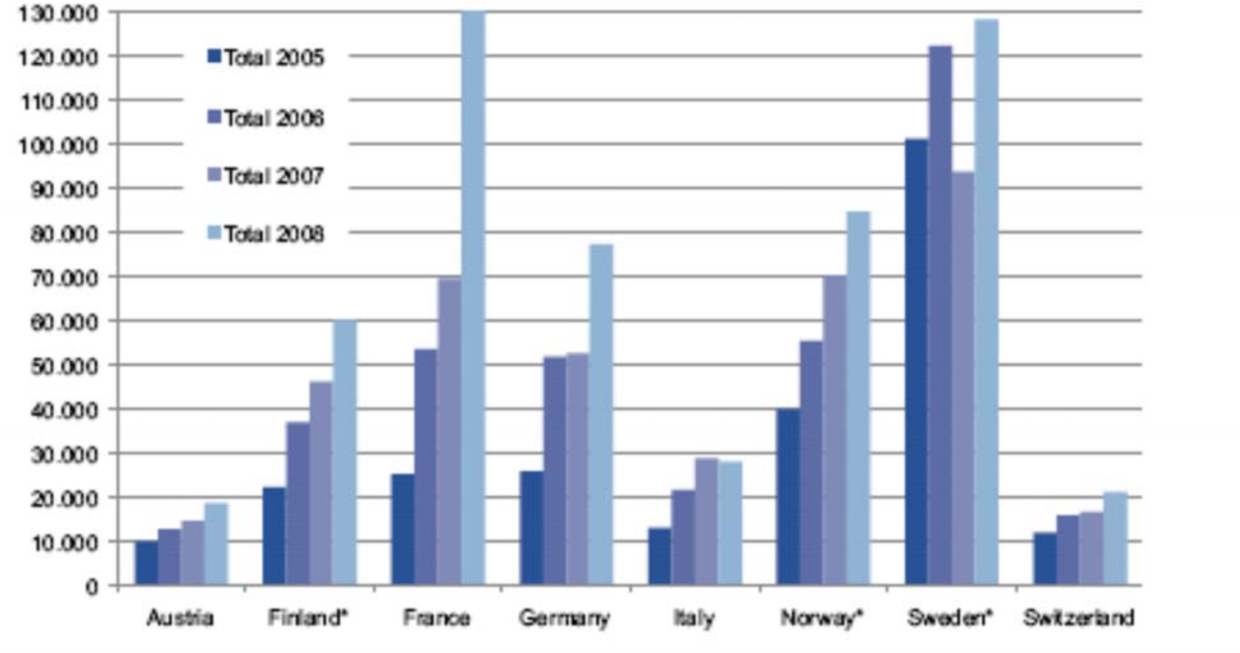


Figure 1.3.4.1.1 Market Growth of total heat pumps sales per country (2005 to 2008)

Source: European Heat Pump Association

A comparison to last year's statistics shows the influence of framework conditions on demand: Germany is up to speed (+46%) after last year's market due to the inclusion of heat pumps into the existing subsidy scheme. As mentioned already, success in the French market is a result of government action.

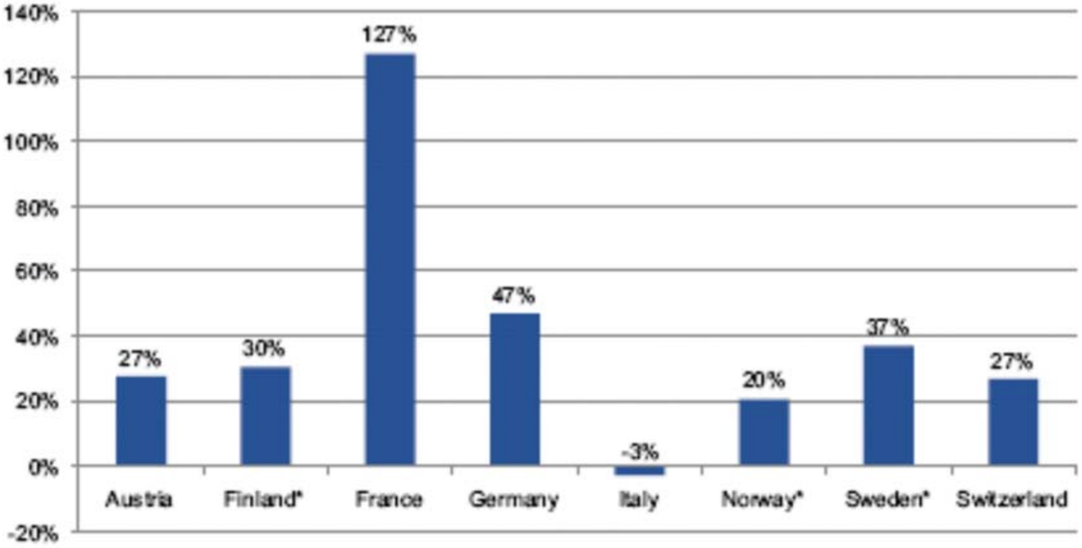


Figure 1.3.4.2 Relative Market Growth per country 2008 Vs 2007

Source: European Heat Pump Association

When looking at the type of energy source used there is a trend towards air-source heat pumps. Generally, more and more heat pump units are reversible and provide heating, cooling and hot water. The majority of these units are again using air as the main energy source. A closer focus to the segment of heating-only heat pumps reveals the strong growth of air-water units. See Fig 1.3.4.3. This development is a strong indicator for the development of the renovation segment, as air-water and – in the Scandinavian countries and southern Europe – reversible air-air are often simpler to employ when refurbishing a building. Sales numbers for tap-water only heat pumps have more than doubled (+122%) from 2007 to 2008. As this type of heat pump is often used to augment a gas/oil fired boiler, increasing numbers do support the trend of using heat pumps in the renovation sector

New European and national legislation, most prominently the Directive on the promotion of the use of energy from renewable sources has considerably improved framework conditions for heat pump markets in all European countries.

The total market size for the 8 countries surveyed has reached 576,392 units in 2008, a 46.8% increase over the least years 392,756 (See Table 1.3.4.1).

Table 1.3.4.1 Total sales in eight EU countries 2005-2008

	2005	2006	2007	2008
units sold	249.394	370.447	392.756	576.392
		+48,5%	+6%	+46,8%

Source: European Heat Pump Association

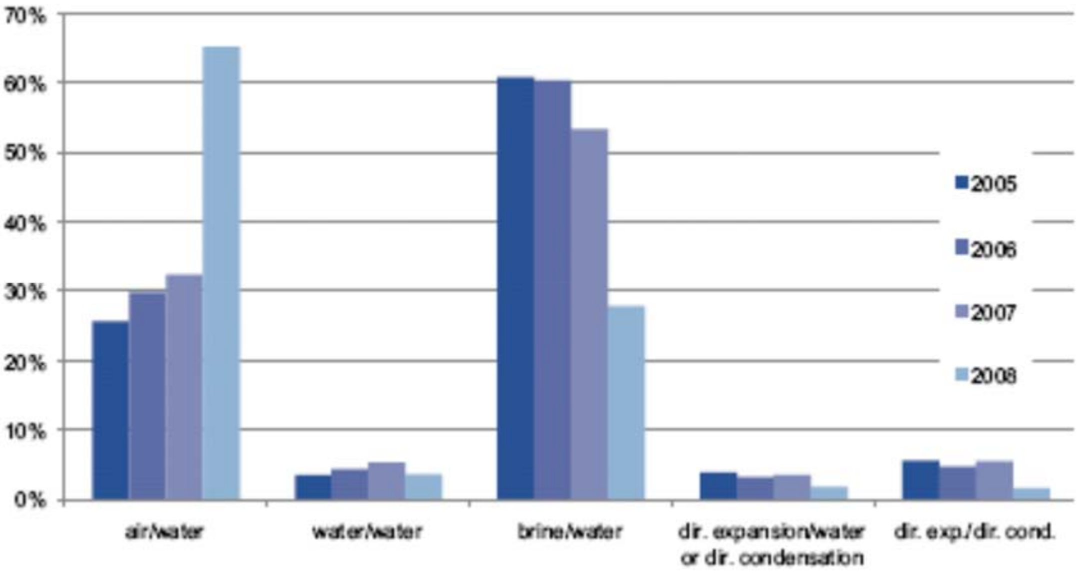


Figure 1.3.4.3 Change of market shares in the heating-only segment

Source: European Heat Pump Association

Table 1.3.4.2 Market Segment for smaller units

	New Building	Renovation
Residential : Single/Double Family House	Mass Market currently developing	Largely undeveloped (besides Sweden, Switzerland)
Residential: Multi-family residency	Small market developing	Initial steps are made
Non-residential (commercial)	Minority share is currently sold heat pumps. Several demonstration projects available, potential for heating and cooling projects by far not exploited	Initial steps, increasingly important with owners that value low operating cost

Source: European Heat Pump Association

The overall market can be distinguished into the segment of new buildings and that of renovation. In turn, both segments can be distinguished in residential and non-residential building classes

These segments show different development states:

1. The segment for new residential one/two family houses is best developed. Markets like Sweden and Switzerland show a market penetration of 95% and 75% respectively. In developing markets like Austria, Germany, Finland, Norway heat pumps have reached a share greater than 20%;
2. The segment for renovation of one/two family houses is currently gaining importance. Still, the efficient use of heat pump in this segment often requires large extra investments in new windows, heat distribution system or insulation;
3. The segment for residential multi-family residences is only slowly developing;
4. The segment for non-residential buildings is characterized by individual projects, Heat pumps are employed where the planner/builder or architect know about the technology and where investors value low-operating costs, thus requesting new technology.

Fig 1.3.4.4 provides a rough estimate for selected EU countries – data for 2007

Fig 1.3.4.4 Change of market shares in the heating-only segment

Source: European Heat Pump Association

1.3.4.2 Irish Heat Pump Market

Ireland's has developed a small but growing market for heat pumps. The main heat pump technologies suitable for Irish dwellings include ground source heat pumps (GSHP's) and air source heat pumps (ASHP's), though currently the former is more favoured by the Irish domestic sector with 81% of heat pumps sold being GSHP units. To date there have been 5663 units installed, of the number installed, 56% were horizontal ground collector heat pumps, 25% were vertical ground collector heat pumps, 17% were ASHP and only 2% were water (well) to water heat pumps. Figure 1.3.4.2.1

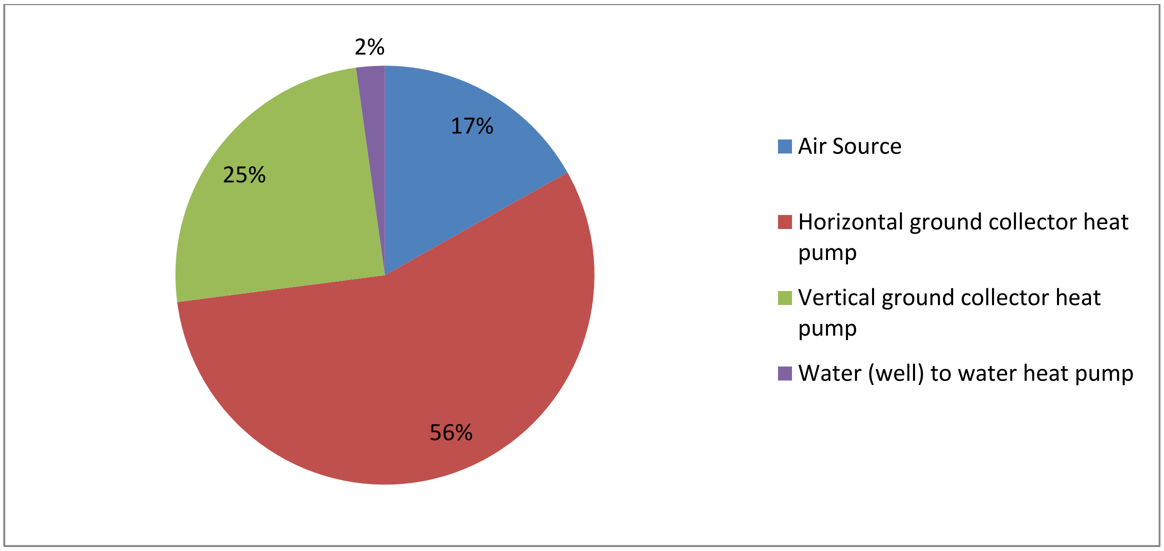


Figure 1.3.4.2.1 Types of Heat Pumps in Stalled in Ireland's 2010

Source:SEAI

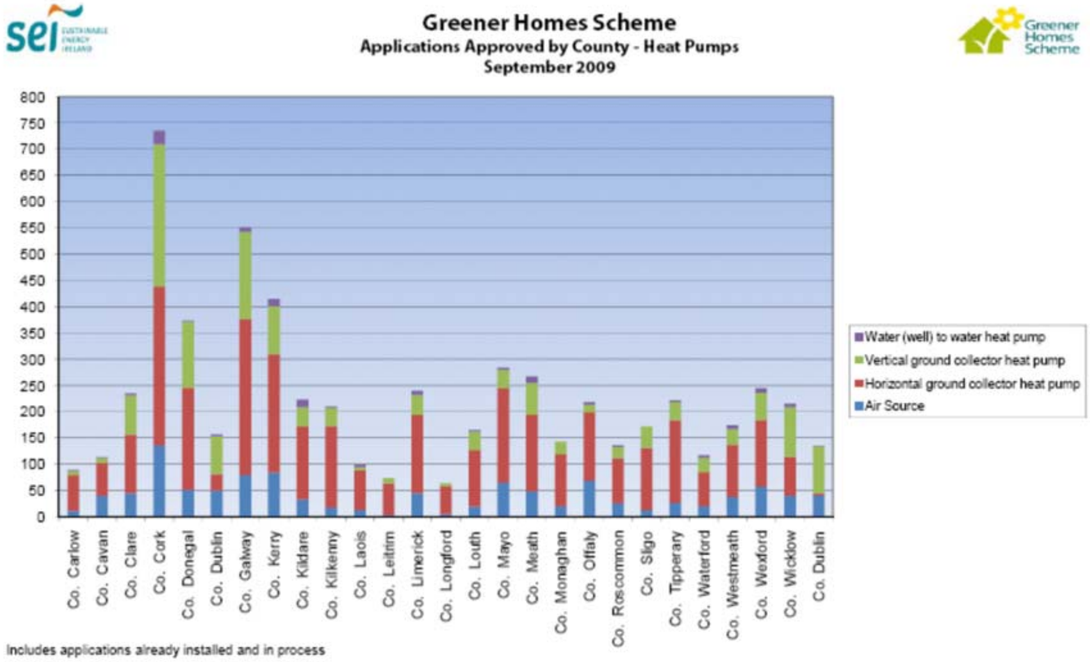


Fig 1.4.3.2.2 Total Heat Pump Sales in Ireland's by county

Source: SEAI

The market is dominated by ground source heat pumps. However, in line with European markets, the demand for air source heat pumps is growing, as more competition enters the market.

It is generally accepted that heat pumps are viable when being installed in a new builds and thus to current regulation standards and also where attention has been paid to the air tightness of the structure and where the heat pumps can be installed with low temperature underfloor heating. However Ireland's is now in a recession and new house building is at a virtual standstill, indeed there is an excess of housing on the market. The available market for heat pumps thus lies within the renovation sector where packaged solutions with a reasonable COP can be used. The target market for heat pumps includes detached houses and large buildings (>4000m2). These segments have been estimated by SEAI at approx 20,000 units a year. (EHPA 2008)

While ground source heat pumps have traditionally had a higher coefficient of performance (COP) they are more suited to new build applications rather than retrofits due to the extensive ground works required for installation. Also the capital costs associated are much higher than for air-source heat pumps.

Additionally, GHGS II ceased on 7.7.08 and GHGS III was launched on 22.7.08. This is because the inclusion of some form of renewable energy sources in new homes is compulsory. The GHGS III only provides government support for house older than one year.

The central question to this study is therefore:

Can heat pumps be retrofitted successfully into a fabric improved existing housing and if so what are the resulting running cost and CO_2 savings in the Irish Climate?

With respect to Ireland's housing stock pre-existing 2006 the following was found in this study:

- 43 % of the housing in Ireland's is detached, of which 72% is rurally located;
- 70% of the detached housing was constructed prior to the 1979 building regulations;
- 68% of housing in Ireland's is heated by fuel oil[4] and 82% have a radiator heating system.

Detached rural housing with oil fired central heating and radiator space heating constitutes the biggest housing type in Ireland's and so becomes the focus of this study.

This study therefore has this aim:

An Investigation into the Retrofitting of Air Source Heat Pumps into, Fabric Improved, Detached, Oil Centrally Heated Dwellings in rural Ireland

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[4] Only 1.2 % of rurally located dwelling have a piped gas supply, and the rest generally have only solid fuel type heating. Oil is more expensive that gas, so a heat pump would compare more favourably for most rural housing.

This investigation will be progressed by addressing the following objectives

Objectives

a) To model the heat losses from the existing centrally heated detached rural housing stock in Ireland's by age band with respect to outdoor temperature. The age bands and thermal property characteristics shall be based on national energy rating procedure methodology DEAP (Dwelling Energy Assessment Procedure);
b) To remodel the heat losses from the same dwellings assuming that the occupant has availed of either The National Insulation Scheme in line with Ireland's National Energy Efficiency Action Plan;
c) Calculate the CO_2 emission savings arising from the fabric improvement measures and with the installation of a high efficiency condensing boiler and associated controls (The Standard Solution);
d) Assuming the radiators satisfied the previous heat loss calculated in (a), to hence calculate the lower flow and return temperatures now required of the heating system to satisfy the improved heat loss characteristics calculated in (b);
e) To plot the output for a sample set of the most efficient heat pumps currently on the market against heat losses established in (b);
f) To calculate the output from the heat pumps based on the revised flow and return temperatures calculated in (d) for the Irish Climate and hence assess the requirement for supplementary heating;
g) Calculate the running cost savings of the heat pump compared with a high efficiency condensing boiler;
h) Calculate the CO_2 emission savings resulting from heat pump use, over and above those established in (c) or with respect to 'The Standard Solution';
i) Investigate the paybacks associated with retrofitting this technology into Ireland's existing detached housing stock;
j) Establish the overall cost and CO_2 emission saving potential from the installation of heat pumps and post fabric improvement measures in this sector of housing in Ireland.

2.0 Literature Review

2.0 Literature Review

2.1 Heat Pumps

Whilst there is a plethora of papers based on optimizing the refrigeration or vapour compression cycle with respect to heat pump performance, a review of the literature has revealed a distinct lack of papers relating the actual performance of a heat pump over a weather year and with respect to the building energy consumption and heating flow and return temperature requirements. There are no papers relating the performance of heat pumps in the Irish climate and no papers on the use of heat pumps in Irish domestic sector.

Only two studies exist which report data on the use of heat pumps in the UK domestic sector exist, One study (Pither A 2006) was commissioned by the 'Heat to Treat Group of Energy Efficiency Partnership for Homes' to look at the application of heat pumps in the UK and to develop guidance for local authorities architects and house builders (a); and the other was published to Harrogate Borough Council in 2007 (b).

a) The majority of heat pump installations surveyed were in new build rather that existing housing and the study found that only a few have been subjected to monitoring to establish their effectiveness and running costs. The same study also found that there has been little or no research into the views of those landlords and end users who have had heat pumps installed.

   (Pither A 2006) surveyed domestic heat pump users with only 18 responses received. The majority of those that responded (72%) lived in bungalows with the remainder being houses. Furthermore, the overwhelming majority of responses came from housing association residents (89%) with only two responses from owner occupiers. The vast majority of those that responded were generally happy with the heating system in their home, with (33%) giving it the highest score possible. However, 17% of the residents rated it as only average (and two of the respondents gave it a very low score. Just as importantly, residents viewed the fuel costs as "very reasonable" or "affordable" in the majority of cases (66%) with a significant minority (34%) indicating that the system was "slightly expensive" or "too expensive".

b) Recently Harrogate Borough Council reported the results of a yearlong (2005-2006) GSHP trial in eight fabric improved existing elderly people's homes (Harrogate_Borough_Council 2007). The residents initially complained about the lower hot water temperature of 55°C [5]and the warmer night temperatures caused by the 24h

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[5] Most heat pumps, ASHP, have an operating temperature of 50–55 °C and may not prevent the growth of Legionella bacteria, which requires a minimum temperature of 60 °C to kill it, BSEN 15450:2007 guideline for the design of heat pumps recommends a DHW storage temperature of 50°C as it reduces the load on the heat pump whilst maximising the COP

running of the heat pumps to maintain the indoor climate. The eight properties reduced their CO_2 emissions by 64% and the heat pumps led to owners no longer being in fuel poverty by reducing their space and water heating bills from 12% of their income to 3.8%.

On an international scale, a paper published in 2004 (Marcic 2004) describes an energy efficient house in Slovenia which was provided with good thermal insulation and heated by an air-to-water split-type heat pump. The house was heated up to an ambient (outdoor) temperature of 0°C using an air-to-water heat pumps and a condensing oil heating furnace if the ambient temperature dropped below O°C. The results of the nine year test showed that the heat pumps was used during most of the heating season, The average COP in nine heating seasons was 3.16, indicating that over 68% of the heat was obtained from the ambient air. The advantage of an air-to-water heat pump, the study found, was in its simple design and wide range of applications. The study concluded that, in comparison to the boiler, the heat pump yielded considerable savings in fuel and money, which justifies its home heating application in the Central European climatic area. It worth reiterating, that the heat pump was installed in an energy efficient home.

As mentioned in the introduction, uptake of heat pumps in Ireland compared with European countries is low, and the same applies to the UK market. Despite their excellent performance heat pumps are not the primary choice of the general UK and Ireland's domestic consumer. (Singh 2010) published a paper reviewing the factors influencing the uptake of heat pump technology by the UK domestic sector, Singh concluded that more reliable performance prediction tools need to be established to avoid the over and under sizing of heat pumps for regions in the UK which no past knowledge exists. This conclusion confirms the importance of this study as the performance of the domestic heat pumps is simulated against a design weather file for Ireland's, with respect to prevailing conditions and the actual flow and return temperatures required of the heating system. The data from this study can act as a prediction performance tool for heat pumps in Ireland.

There is a significant limitation to the scope of this study arising from this literature review and this is that; in humid climates such as are experienced in the UK and Ireland there is a tendency for frost formation on the outdoor heat exchanger (evaporator) coil surfaces. ((Jones_&_Parker 1975; Yasuda_et_al 1990; Payne_&_O'Neal 1993; Hewitt_&_Huang 2008; Singh 2010). The COP of a particular ASHP system is reported to have reduced from 2.81 in frost free conditions to 2.11 after 4 h consecutive frosting (Hewitt_&_Huang 2008; Singh 2010).

The presence of frost on the outdoor heat exchanger degrades the thermal performance of the air-source heat pump by reducing air-flow areas as a result of the blockage caused by a layer of frost. Also an insulating layer of frost is built up over the evaporator coils, reducing their ability to absorb heat from the outdoor environment. The frost needs to be removed

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due to the lower flow temperature required. The water shall periodically have to heated to 60°C they guide however does not state what this period is.

periodically to improve the efficiency of the operation ((Hewitt_&_Huang 2008). Common methods employed to minimise this problem.

1. **Compressor shut down defrosting** -Used on where the ambient temperature is 1°C or higher, so for critical winter conditions the compressor shut down method will not be suitable - (Hewitt_&_Huang 2008);
2. **Electric heat defrosting** - Usually involves heating the surface of outdoor heat exchanger to melt the frost on it, it usually requires 1→1.5 times longer defrost period than hot gas methods and is costly (O'Neal_et_al 1991; Hewitt_&_Huang 2008);
3. **Reverse-cycle defrosting** - Most common method; however the disadvantage is that the heat supplied to defrost the outdoor coil is taken from inside the building which may result in deteriorated indoor quality if a buffer vessel is not employed. (Hewitt_&_Huang 2008);
4. **Hot gas defrost –** Reliable and effective method for air source heat pump defrosting as it gives the least number of defrost cycles and the highest total heating capacity (Hewitt_&_Huang 2008).

The above listed defrost cycle operational functions is not explored as part of this study due to following reasons

- There was a lack of information from the manufacturers; Applications for additional information on the defrost cycle methods were made to various manufacturers however the manufacturer's were not willing to divulge more information than was contained on their sales literature as they did not wish competitors to gain an edge on their technology by publishing this information.
- A range of manufacturers were chosen for this study each employing differing defrost methods and due to time constraints it was not possible to build this phenomenon into the model.

The fact that this phenomenon is not factored into this study will lead to an overestimation of the energy savings available, the only true way of establishing the actual performance is to test units under the same operating conditions over a longer period. It is therefore an area where more study is certainly required as there are no papers published in this area. The standard method (EN_14511-2 2007) of certifying heat pump COP's does not take account of this aspect of heat pump performance, the output and COP's of the heat pumps are determined at various set point temperatures under steady state conditions, therefore the COP is not a actually a true indicator of the system over time. However, it is understandable why this is not included in the standard test method as it will vary from climate to climate. The results from the (Hewitt_&_Huang 2008) study could possibly be used to model against the results of this study in future works in this important area. This is discussed further in Chapter 5.

Two other disadvantages of heat pumps are noise and the issue of aesthetics;

- Noise has also been identified as a possible problem with the existing class of ASHPs (Shackelton_et_al 1994; Singh 2010). ASHP noise problems can be mitigated by housing them in enclosures with improved acoustic performance and employing less noisy fans and parts. Design improvements aimed at achieving lower noise levels and reducing the frosting problems increase the capital and running cost of the ASHPs.

- The issue of aesthetics may arise for a street in which each house has an ASHP evaporator installed on an outside wall.

2.2 The Irish Residential Sector

As outlined in the introduction, it is generally accepted that heat pumps are viable when being installed in a new build to current regulation standards so it is important that we establish the current state of our housing stock from and energy efficiency point of view.

2.2.1 State of the Stock

A number of factors shape the patterns of energy usage in the home. Some of the variables such as the number of dwellings will be expected to increase the demand for energy while other factors such as the Building Regulations will be expected to reduce demand. The variables are summarised here in Fig 2.2.1.1

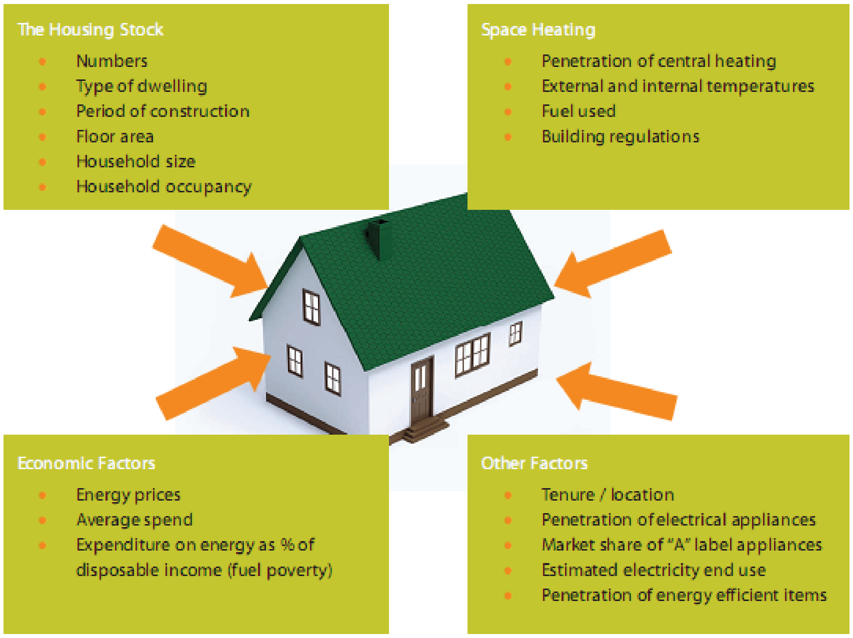

Figure 2.2.1.1 Drivers of Energy Usage and CO_2 emissions

Source: SEAI

In 1999, The Energy Action Charity commissioned the Energy Research Group in UCD to carry out a review of the Irish Housing Stock, the review was carried out for the year of 1997 and this is the latest review of the housing stock from an energy efficiency point of view available (Brophy 1999). The report was undertaken to establish: the extent of remedial work required to bring standards of the existing housing stock up to the standards which have applied to the newer houses since the introduction of the '1997 Building Regulations', insofar as they are concerned with insulation and energy conservation; the costs and benefits associated with such remedial work; the outline strategy to address the challenge. The key findings of the report as relate to this study are as follows:

- Ireland's has been shown to have among the least energy-efficient housing standards and the highest levels of fuel poverty (the inability to heat ones home to a safe and comfortable temperature) at 12% in Northern Europe (Whyley 1997);
- Irish Housing standards are amongst the lowest in Northern Europe from the point of view of thermal efficiency.

This report quantified the projected benefits from the following energy saving measures:

- Lagging Jacket
- Roof Insulations
- Roof Insulation Upgrade
- Draught Stripping
- Cavity-Wall Insulation
- Controls Upgrade
- Double Glazing
- Low-e Glazing

Unfortunately the report does not state U-values adopted for the calculations. The report based its calculations on eight sample type dwellings (detached two-storey, bungalow etc.), 12 levels of insulation and 19 heating system types.

The report recommended the establishment a subcommittee at cabinet level to mobilise the key agencies and policy actors, a role that has now been fulfilled by SEAI and the energy saving measures outlined are promoted through The Greener & Warmer Homes Scheme.

In 2001, the authors of the above report published a paper (CJ.P. Clinch 2001) carrying out a bottom-up assessment of the technical potential for energy saving in the domestic sector using Ireland's dwelling stock as a case study. The report stated that it is not reasonable to assume that all the savings from energy efficient programmes will take the form of reduced energy bills and reductions in environmental emissions, if a portion of the housing stock has a sub-optimal level of warmth. A domestic energy-efficiency programme which improves, for example, insulation levels, is likely to result in some of the energy savings (predicted on the basis of fixed internal temperatures) being forgone in exchange for increased comfort temperatures. Therefore residents of formerly highly inefficient homes, who could not afford to heat them adequately, would likely forgo some of the energy savings in exchange for a more comfortable internal temperature once their houses were made more energy efficient. In addition to this trend as the housing stock has become more energy efficient residents have started to use all of the rooms.

Historical data on comfort levels or internal temperature is currently not available for Ireland's but estimates are available for the UK and are presented in figure 2.2.1.1. The data for the graph has been sourced from the Building Research Establishment (BRE) and are based on a number of surveys carried out at irregular intervals. The data indicated that homes heated by central heating tend to be 2.5°C warmer that those heated by stand alone room heating systems

The internal temperature increase over the period 1970 to 2004 was 4.4°C for both centrally and non-centrally heated buildings in the UK but the weighted average temperature rose by 5.9°C because of the increasing numbers of dwelling which have central heating. It may be reasonable to assert that there has been a similar increase in Ireland's given the comparable increase in central heating. However, the actual internal temperature levels may be different between Ireland's and the UK.

The figure shows that the desired 20°C[6] internal comfort temperature (t_c) is rarely achieved; the max being 18.8°C. This will affect the CO_2 calculation, as there might be no actual energy reduction just an increase in comfort levels.

In 2004 the same authors of aforementioned reports (Brophy 1999), (CJ.P. Clinch 2001) published a paper (J.P Clinch 2004) which among other things looked at the reasons for non-investment in energy-saving measures in Ireland: The penetration of hot water cylinder lagging jackets has increased dramatically (by over a third) from 1998 to 2001, with 86% of the 2001 housing stock (1.3 million dwellings) equipped with this measure. Levels of floor insulation have remained relatively static over the period, with a quarter of Irish Houses so equipped. The penetration of roof insulation is good in Ireland's, with almost four fifths of the stock possessing this energy efficiency measure. Much of this success is due to the State-funded attic-insulation scheme of the 1980's. Levels of cavity wall insulation in Ireland's are low (42%) and remain static over the period 1996-2001. Draught stripping of doors and windows also remains similarly low (40%). See Table 2.2.1.1

In 2008 Dublin City Council in association with Codema with published an "Action Plan on Energy for Dublin – Consultation Draft".(CODEMA 2008). In said report the Dublin housing stock was examined by built form (i.e. detached, semi-detached etc.), age profile, floor area and building fabric. Fuel mix was also considered although detailed information on the breakdown was not available for Dublin city. Rates of construction of new dwellings and demolition of older dwellings were also examined. While there are some projections for rates of construction within Dublin city, Codema found that estimating the rate of demolition was a more difficult task. The information was used to create a model of Dublin city housing for the period 2006 to 2020.

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[6] BSEN_12831 (2003). Heating systems in buildings - Method for calculation of the design heat load, BSi.

The CODEMA report concluded that the residential sector offers the greatest potential for energy and CO_2 savings, 42% and 51% respectively. The report found that approximately 80% of the current Dublin city housing stock would achieve an E1 rating on the national Dwelling Energy Assessment Procedure (DEAP) and concluded that the refurbishment of the existing housing stock is essential if the potential savings and national targets are to be realized. The measures included, low energy light bulbs, attic insulation, wall insulation, high efficiency boilers and energy efficient windows for all existing units that require them.

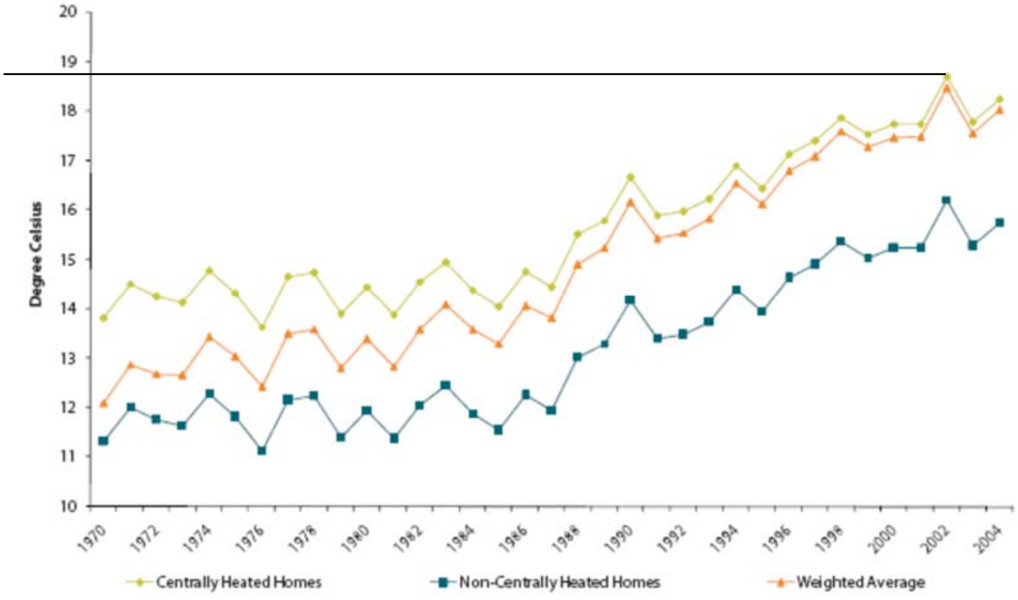

Figure 2.2.1.2 UK Internal Temperatures 1970 to 2004

Source BRE

Table 2.2.1.1 Percentage of Irish Households with various energy-saving measures (1996-2001)

	1996	1998	2001
Lagging Jacket	—	64	86
Floor Insulation	22	24	25
Roof Insulation	72	72	78
Wall Insulation	42	42	42
Double Glazing	33	37	64
Draught Stripping	—	37	40
Low-energy Light bulbs	—	—	29
Central Heating	74	80	86

Source:(J.P Clinch 2004) 1996 data from Eurostat (1999);1998 from Clinch and Healy (1999)

(CJ.P. Clinch 2001) found that there is considerable scope for improving the energy efficiency standards of the Irish dwelling stock, especially with regard to floor and wall insulation. It was also found that 12.7% of households (165,000) have some difficulties (intermittent) in heating their homes, 4.7% (62,000) were chronically fuel poor with 17.4% (227,000) being totally fuel poor

The only government sponsored review of the housing stock was carried out by the Economic and Social Research Institute (ESRI) in 2001-2002 entitled 'The Irish National Survey of Housing Quality (INSHQ). The survey gathered information from a sample of over 40,000 household characteristics. The study found that 63% of dwellings built before 1940 have no wall insulation, 40% have no roof insulation and double glazing was also less common. The report also found that 35% of homeowners who had been at their address for more than five years had undertaken some form of home improvement. The most common measures were window repairs (22%), external doors (19%), adding or replacing central heating boiler (15%). Only 3% of homeowners added wall insulation and 7% added roof insulation. The report concluded that energy efficiency is strongly affected by dwelling age.

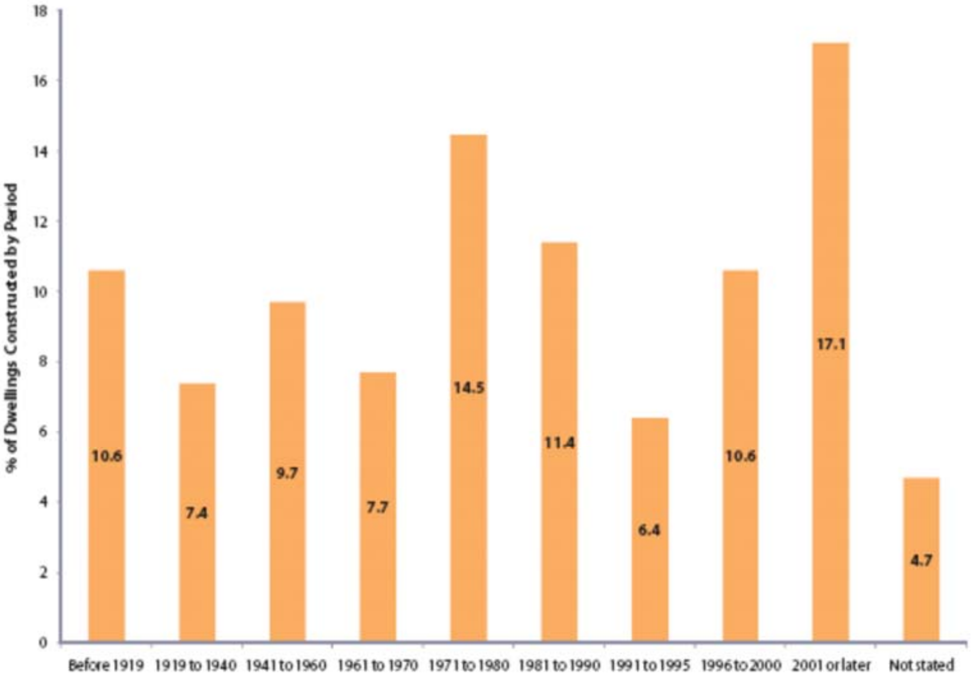

Figure 2.2.1.3 % of Dwelling Constructed by Period

Source SEAI

A factor contributing to the poor efficiency of our housing stock is that 50% of the stock was built before the first thermal insulation requirements came into effect in 1979. It can be reasonably assumed that pre-1980 housing stock has a poorer standard of insulation than those built after the introduction of the thermal building requirements.

However, it is worth noting that, according to the European Housing Review 2010 (RICS 2007) Ireland's has the youngest dwelling stock in the EU, as 28% of the total housing stock has been build since 1996. This is due to pace of building activity in Ireland's in recent years which has contributed to a positive shift in average efficiency.

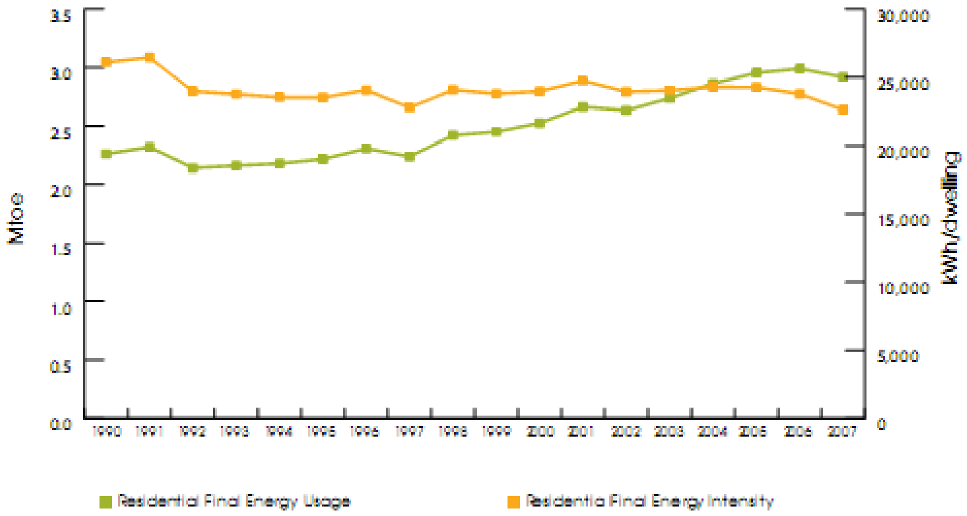

Figure 2.2.1.4 Energy Usage in the Residential Sector 1990 – 2007 (Final Energy Consumption)

Source SEAI

Energy usage grew by 29% in the residential sector over the period 1990-2007, as illustrated in Fig 2.2.1.4, with the number of households increasing by 49%. Energy intensity (average energy usage per household) decreased by 13% over the period, reflecting and improvement in energy efficiency of the housing stock, much of it due to the greater efficiency standard of new housing.

For the same standard of comfort and amenity a house built in 2007 typically has a 70% lower energy demand for space and hot water heating than its counterpart built 20 years ago. However as new homes will have an extended lifetime, it is important to ensure more efficiency performance standards are set to achieve the maximum achievable performance. These dwelling should be more energy efficient as they have been subject to more stringent Building Regulations.

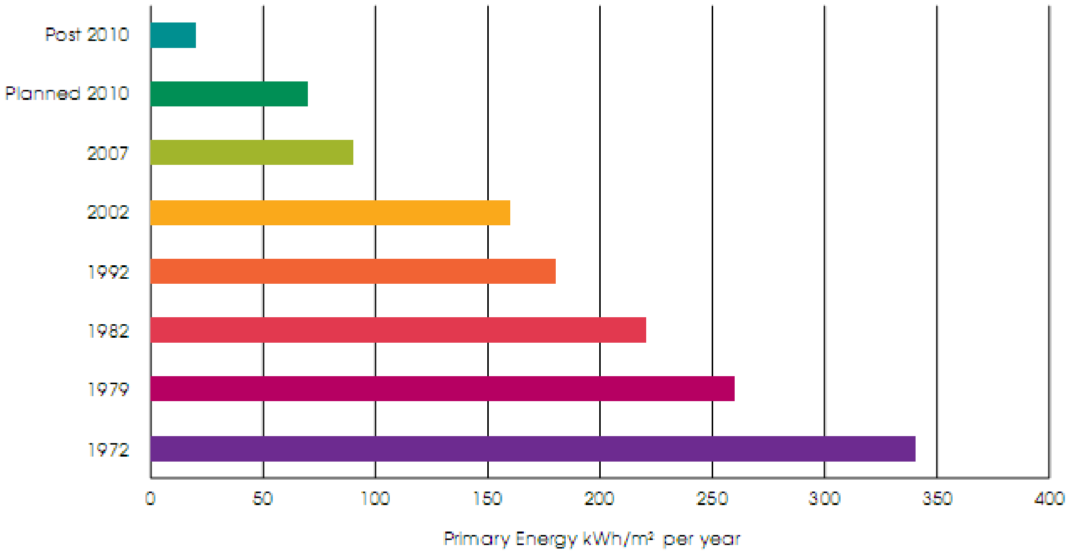

Figure 2.2.1.5 Trend in Energy Performance of Housing (Primary Energy kWh/m^2/year)

Source NEEAP

Another large contributing factor to the poor efficiency of the typical Irish home is that our housing stock is quite large, the average (useful floor area) size of an Irish dwelling being 104m^2 in 2003 representing the fourth largest figure in Europe behind Luxembourg, Denmark, and Malta. Also Ireland has on average the greatest number of rooms in Europe at 5.6 rooms per person in 2002. The average m^2/person in 2002 was 35m^2. (Federcasa 2006). In addtition as time goes on we are tending towards bigger and bigger properties which have a corresponding large building envelope and greater heat loss on a kWh/m^2 basis.

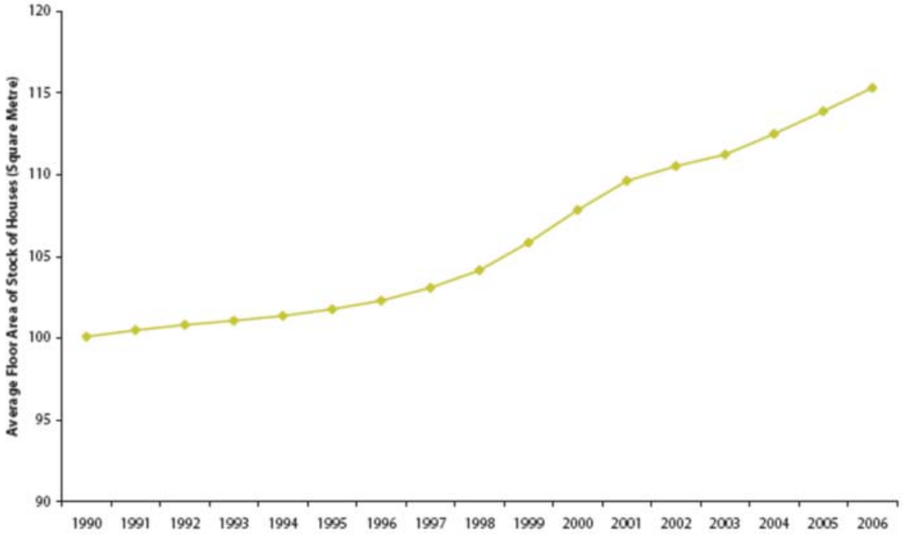

Figure 2.2.1.6 Average Floor Areas of Stock of Housing (m^2)

Source: SEAI

2.2.2 Predominant house type in Ireland's, Location & Fuel Type

In addition to the number of households and dwelling size, a key variable impacting on energy consumption in the residential sector is the type of dwelling. Flats or apartments are typically expected to have the lowest heat loss (as a result of their smaller size) and fewer external walls, party walls allow for a sharing of heat, while detached houses will have the largest as a result of having a larger surface to internal volume ratio. It has been estimated that up to 25% of the heat from a dwelling can be lost though the walls (SEI 2008). Detached houses have a greater internal volume and hence more air to heat up. It follows that a dwelling with a large surface area and large internal volume will be expected to have a greater potential for heat loss.

The Central Statistics Office carried out a census in 2006 and is the latest census data available at the time of writing (2010). The sample set data analysis was carried out on a sample set of 212,006, the aforementioned 'Irish National Survey of housing quality (INSHQ)' carried out in 2001-2002, asked much more detailed questions pertaining to the heating, hot water and comfort systems than the CSO.

Part of the literature review therefore involved employing the use the statistical software SPSS® to review both the CSO and INSHQ datasets. By this means it was established that, the predominant house type in Ireland's is detached housing representing 42.8% of the total stock. See Fig 2.2.2.1 and Table 2.2.2.1, on the basis that detached housing is predominant house type and would also theoretically exhibit the greatest heat loss, it is considered a good test case and so becomes the focus of this study. The rational being, if it can be shown that heat pumps can be retrofitted into the detached stock it follows that they can also be successfully integrated into the other housing types with a theoretically lower heat loss/m^2.

Table 2.2.2.1 Quantities of House Type in Ireland's in 2006

Dwelling Type	2006 Number	2006% of Total
Detached House	625,988	42.8
Semi-Detached House	398360	27.2
Terraced House	257,522	17.6
Flat/Apartment	139,872	9.6
Bed-sit	8,751	0.6
Not Stated	31,803	2.2
	1,462,296	100

Source: CSO 2006

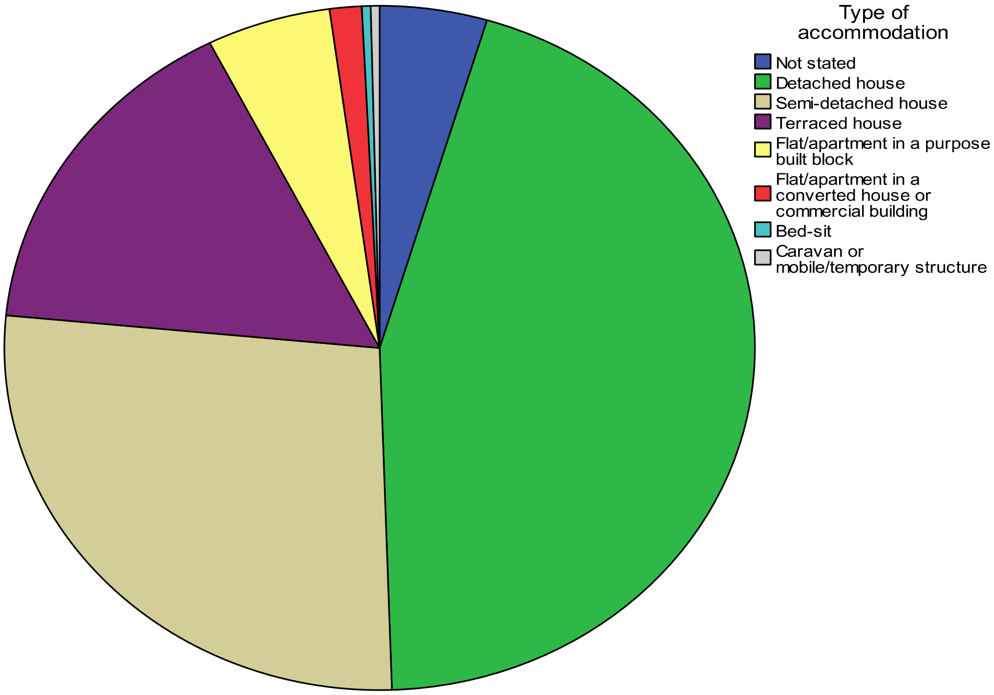

Figure 2.2.2.1 Quantities of House Type in Ireland's in 2006

Source: CSO 2006

If we isolate the data for the detached housing stock, we find that over 70% of the detached housing was constructed prior to the 1979 building regulations (this is compared to fewer than 50% for the entire housing stock). See Fig 2.2.2.2

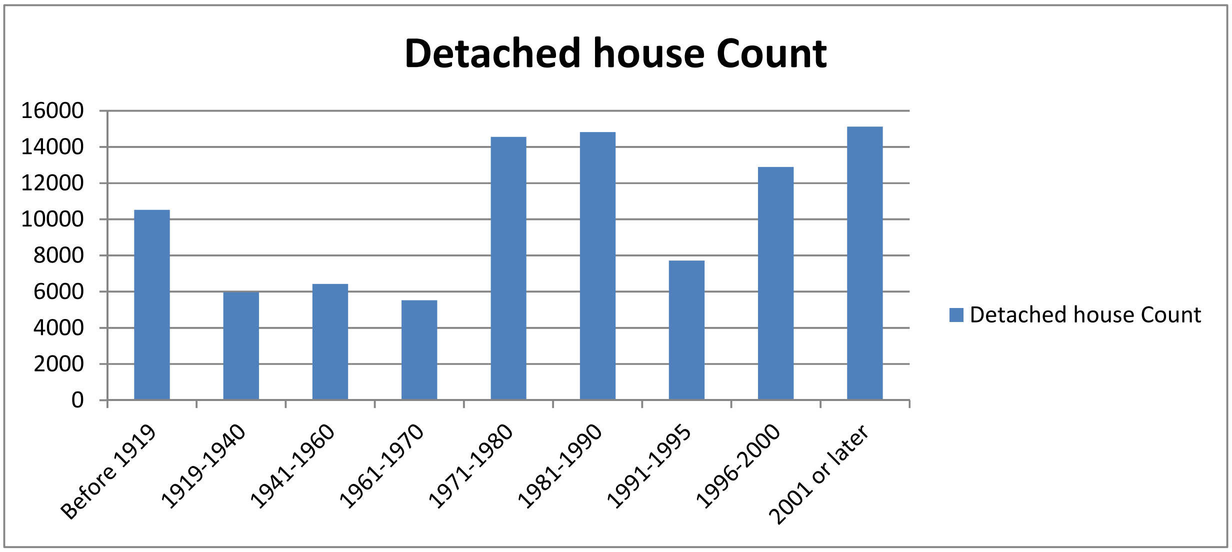

Figure 2.2.2.2 % of Detached Dwellings Constructed by Period

Source CSO 2006 (SAR Sample Set)

2.2.2.1 Rural Vs Urban

In order to get a clearer picture of the distribution of the detached housing stock, dwellings were redistributed by location; Rural Vs Urban. See Fig 3.1.1 it is evident from the graph that the greatest housing type in Ireland's is detached housing, 72% of which is rurally located.

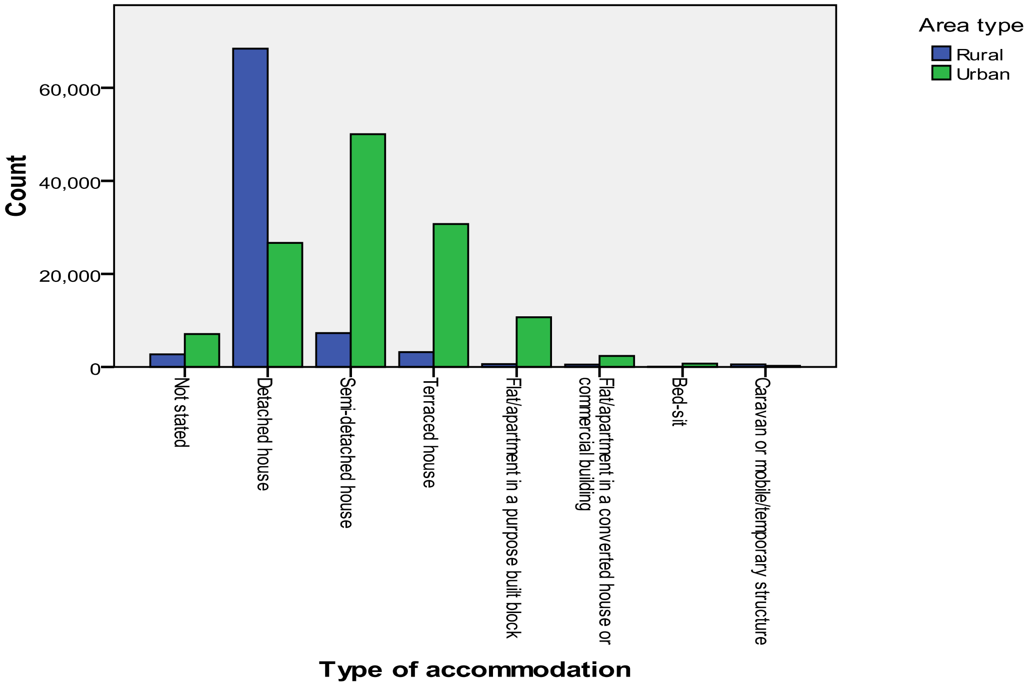

Fig 2.2.2.1.1 Distribution of Urban and Rural Housing in Ireland's by Dwelling Type

Source: CSO 2006

In light of this and in recognition of the fact that studies have been carried out into the energy efficiency of Dublin's predominantly gas centrally heated terraced (43%) urban housing stock, (CODEMA 2008) this study is limited to reviewing Rural Detached Housing in Ireland's[7].

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[7] The CSO defines 'Rural' and 'Urban' as 'Aggregate Town Areas' and 'Aggregate Rural Areas ' respectively The CSO classifies the population residing in all areas outside clusters of 1500 or more inhabitants as belonging to the Aggregate Rural Area.

2.2.2.2 Fuel Type

Next we have recourse to the INSHQ to establish the predominant heating fuel for the various housing types in both Urban and Rural Ireland's[8]. See Table 2.2.2.2.1 and Fig 2.2.2.2.1

It was found that 63% of rurally located detached households use oil heating with only 1% gas heating (the balance being made up of solid fuel systems). Interesting there was found to be no correlation between housing type and heating fuel type.

Table 2.2.2.2.1 Rural House Type and Fuel Type

	Rural (Population Density < 1500)											
	Detached Housing /Bungalow		Semi-Detached/ Bungalow		Terraced House		Purpose built flat/apart		Flat/Apartment in converted		Caravan/ Mobile Home	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Oil	11270	63	636	55	304	56	11	32	19	61	9	56
Gas	105	1	76	7	28	5	4	12	3	10	0	0
LPG/Bottled Gas	246	1	9	1	8	1	2	6	2	6	3	19
Solid Fuel Open Fire Only	1641	9	160	14	94	17	1	3	0	0	0	0
Solid FuelCooker/Stove	3954	22	208	18	79	14	4	12	1	3	3	19
Electricity	640	4	58	5	33	6	12	35	6	19	1	6
Solar/Heat Pump	9	0	0	0	0	0	0	0	0	0	0	0
Don't know	9	0	0	0	0	0	0	0	0	0	0	0
Total	**17874**	**100**	**1147**	**100**	**546**	**100**	**34**	**100**	**31**	**100**	**16**	**100**

Source: INSHQ 2001-2002

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[8] Unfortunately the CSO only asked the respondents whether they had central heating or not, the only data available for fuel type in Ireland's is from the Irish National Survey of Housing Quality (INSHQ) carried out in 2001-2002. It was therefore necessary to gather the relevant data from the INSHQ and apply the percentages found to the more up to date 2006 CSO data. In order to compare like with like between the two datasets, the parameters for the cross tabulation were modified to comply with the larger CSO dataset (i.e. Rural < 1500; Urban > 1500). Refer to Appendix A for detailed tables.

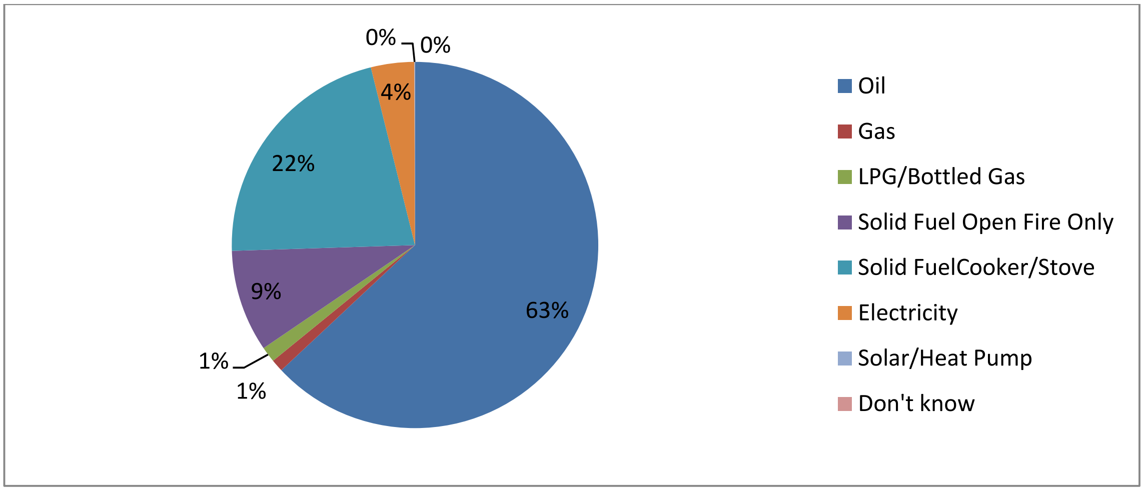

Figure 2.2.2.2.1 Distribution of Heating Fuel Type in Rural Ireland's

Source: INSHQ 2001-2002

Of the 451,035 rurally located detached dwellings in Ireland's, 90% or 406,438 have central heating[9]. If we apply the analysis yielded by the cross tabulation of the INSHQ to the heated housing stock we can surmise the following:

Table 2.2.2.2.2 Rural Housing Quantities by fuel type

Distribution of Heating Fuel Type in Rural Ireland			
Oil	63	406438	256056
Gas	1	406438	4468
LPG/Bottled Gas	1	406438	5585
Solid Fuel Open Fire Only	9	406438	36579
Solid FuelCooker/Stove	22	406438	87895
Electricity	4	406438	15514
Solar/Heat Pump	0	406438	186
Don't know	0	406438	42

Source: Table A1 Appendix A/INSHQ 2001-2002/CSO 2006

With only 1% of detached rural dwelling heated by Gas, and the balance mainly heated by solid fuel, it is decided to compare calculations and cost benefits with respect to fuel oil (kerosene) only. Interestingly there is still a predominance of oil fired central heating in urban areas (62%), this may have changed in the intervening years due to favourable gas prices compared to oil, but no study has been carried out since the INSHQ survey 2001-2002. Reference Appendix B for more detailed figures.

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[9] The 'not stated' data was redistributed to ascertain a figure of 406, 910 centrally heated rural detached houses. Ref Table A1 Appendix A

3.0 Research Methodology

3.0 Research Methodology

This chapter is broken down into the objectives as outlined in Chapter 1.0

a) *To model the heat losses from the existing centrally heated detached rural housing stock in Ireland's by age band with respect to outdoor temperature.*

The age bands and thermal property characteristics shall be based on Ireland's national energy rating procedure methodology DEAP (Dwelling Energy Assessment Procedure).

To calculate the heat load of the dwellings and hence the required capacity of the heat pumps the following European Design Standard was used:

- BS EN 15450:2007 Heating systems in buildings – Design of Heat pump heating systems; this was used to calculate the heat loss and water load of the dwellings,
- BSEN 12831:2003 Heating Systems in buildings – Method for calculation of design heat load which is referenced in BS EN 15450:2007

Various load factors as outlined in this standards were adopted, rationale for adoption of same is further outlined in the sub chapters.

In order to carry out the heat loss equation it was necessary to gather information pertaining to the building envelope characteristic and building shape. The following datasets[10] were used to gather the necessary information;

i. The Central Statistics Office carried out a census in 2006 and is the latest census data available at the time of writing (2010). The sample set data analysis was carried out on a sample set of 212,006 and provided information on the following parameters;

    - Number of centrally heated detached rural housing in Ireland's
    - Dwelling age
    - Typical Number of Persons in the Household (for domestic hot water load calculation)
    - The Central Statistics Office carried out a census in 2006 (CSO 2006) and is the latest census data available at time of writing (2010).

ii. The Irish National Survey of housing quality (INSHQ) dataset was used, to establish the following parameters

    - Single or Two Storey (established from presence of a stairs)
    - Floor areas
    - Window Type

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[10] The statistical software SPSS® was used to manipulate information contained in the datasets. The datasets were provided by the UCD Energy Research Institute

- Type of Heating System
- Heating Fuel
- Number of external doors present

The figures and percentages found in this study were then applied to the larger sample set CSO data.

iii. The DEAP manual describes the Dwelling Energy Assessment Procedure (DEAP), which is the Irish national procedure for calculating and assessing the energy performance of dwellings. This dataset was used to extrapolate typical:

- U-values for the different age bands of the existing housing stock.
- Internal temperature

iv. Unfortunately our DEAP software does not provide information on typical glazing ratios for different age bands of dwellings. The equivalent UK SAP software does however, so this information was applied to the Irish figures, on the assumption that the UK and Irish Housing Stock are similar. This assumption is supported by a study carried out by a study carried out by South West College in 2001 (South_West_College 2001)

v. Weather files provided through the validated design software, Integrate Environmental Solutions (IES) database shall be used to simulate the heat loss at for every hour for a statistical year annually

vi. Ventilation/Infiltration Rates were established from a BRE database

b) To remodel the heat losses from the same dwellings assuming that the occupant has availed of National Insulation Program in line with Ireland's National Energy Efficiency Action Plan and brought the building envelope in line with current day building regulations

The calculation established in a) was simply rerun with U-values as prescribed in the current Building Regulations (Part L)

c) To calculate the cost and CO_2 savings resulting from the fabric improvement measures calculated in B

Cost and CO_2 savings were calculated based on current day pricing standards and current electricity and oil CO_2 emissions

d) To calculate the revised flow and return temperatures of the heating system for the revised load.

This is established by drawing a heat a balance with building heat loss and heat emission from the terminals and the required heating flow and return temperature such that;

Building Heat Loss = Output from radiators = Required Heat output from heating flow and return

$$Q = \left|\left(\sum UA + \tfrac{1}{3}NV\right)(t_o - t_C)\right| = KA\,(t_{m-}t_c)^n = mc\left(t_f - t_r\right) = \mathrm{kW}$$

Ignoring the constants U, A, N, V, K, A, m, c

The relationship can between the prevailing outdoor conditions such that;

$$\frac{(t_o - t_c)_p}{(t_o - t_c)_o} = \frac{(t_m - t_c)_p}{(t_m - t_c)_o} = \frac{\left(t_f - t_r\right)_p}{(t_o - t_i)_o}$$

Where

Notation	Symbol	Description	Source
o		Original condition	
p		Prevailing condition (post insulation improvement measures)	
t_o	°C	Outdoor temperature determined	Design weather file provided through the internationally validated IES (Integrated Eonvironment Software). Outdoor condition - 3°C (CIBSE Guide A - approximate method)
t_c	°C	Indoor comfort temperature	Original condition 76°C (BSEN12831_2003)
t_m	°C	Mean water temperature of radiators	Original condition 76°C (CIBSE Guide B1)
n	1.3	empirical value for the output of the emitter	1.3 Radiators (CIBSE Guide B1)
t_f	°C	Heating water flow temperature	Original condition 82°C (CIBSE Guide B1)
t_r	°C	Heating water return temperature	Original condition 70°C (CIBSE Guide B1)

e) *To plot the output for a sample set of the most efficient heat pump currently on the market against heat losses established in (b)*

Heat Pump Data from the following manufacturers was established and performance curves extrapolated;

- Climaventa/DeLonghi (Grandezza Range)
- Dimplex
- Oschner
- Envirotech (Freat 12)
- Mitsubishi (Ecodan)

The best performing heat pumps within defined output bands was established and that heat pump curve was plotted against the heat loss characteristic for that house. As previously stated, the heating capacity of an air source heat pump depends upon the outdoor temperature. The heating load also depends on the outdoor temperature. When the heating capacity and the heating load are shown on the same graph as in Fig 3.0.1, their intersection is known as the balance point (Stoecker&Jones 1982).

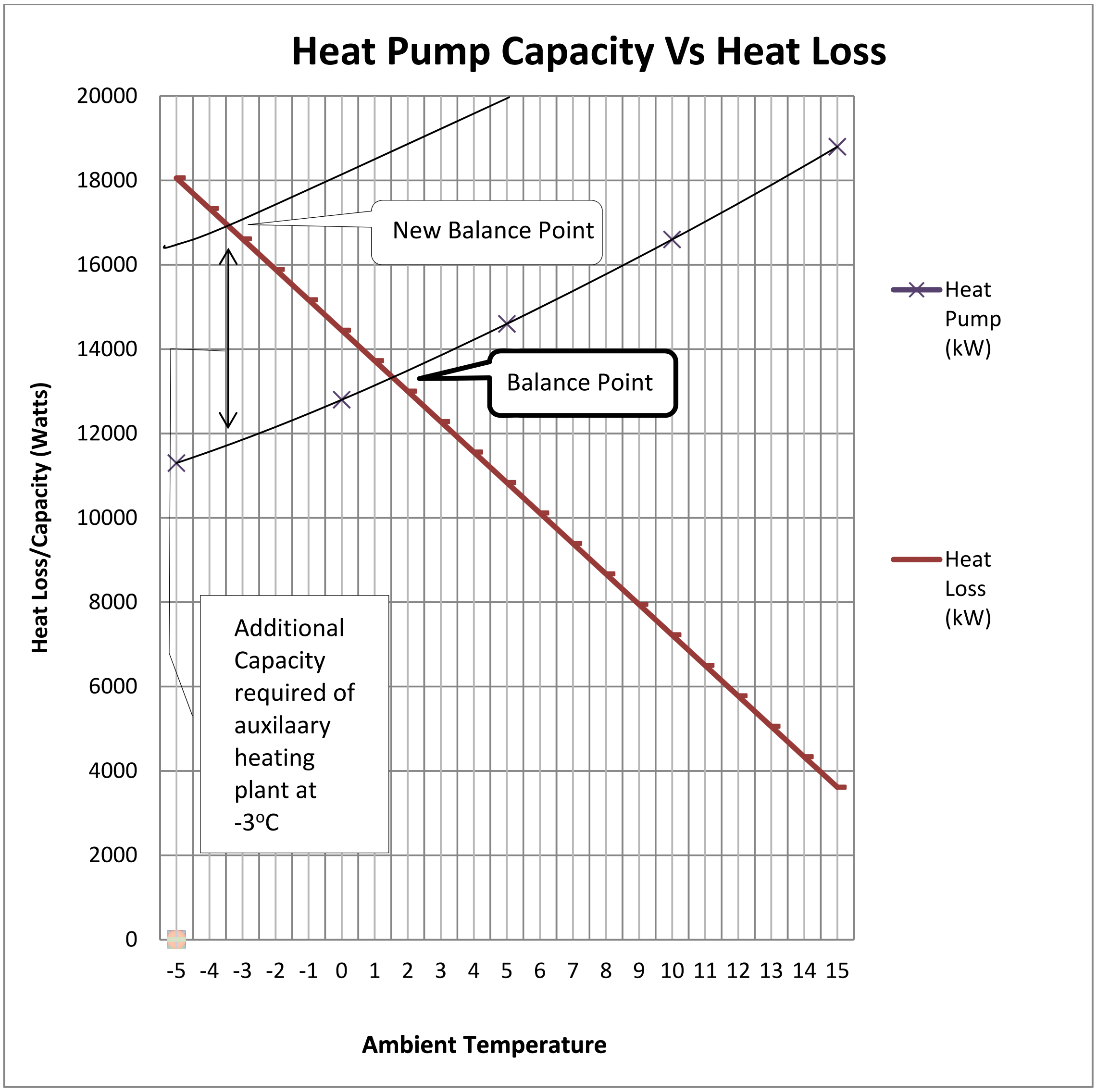

Figure 3.0.1 Balance point of heating capacity and heating load

Again referencing Fig 3.0.1; At outdoor temperatures higher than 1.5°C the heat pump has a greater capacity than needed and cycles on and off as necessary to match the load. At outdoor temperatures below the balance point, the capacity of the heat pumps is less than is needed and the comfort temperature of the building would fall unless some additional heating capacity was provided. A typical method of providing the supplementary heating capacity is by using resistance heaters. If approx 4.5kW of capacity heaters is available, that additional capacity will shift the new balance point to -3°C. The supplementary heating capacity can also be supplied through an oil fired boiler. When the additional capacity required is very low i.e. <5kW direct resistance heaters are used, and when the additional capacity required is greater than this figure an oil fired boiler is used. This is reasonable as the property analysed already has and oil fired boiler installed.

It is aimed to produce similar graphs to that shown in Fig 1.3 for each age band of Ireland's detached housing stock, the same heat pump curves shall be plotted against each house type and the results analysed.

f) *To calculate the output from the heat pumps based on the revised flow and return temperatures calculated in (c) in the Irish Climate and hence assess the requirement for supplementary heating.*

Using the Irish weather file from the IES database, the required output from the heat pumps was calculated for each hour. It was necessary to calculate a typical occupancy profile. In 2005 the Economic and Social Research Institute carried out a study entitled Time-Use in Ireland's (McGinty 2005), rather amazingly this study did not establish typical occupancy times for homes, it rather established how many hours one watches TV etc, but not at what time of the day they carried out this activity. Bord Gais[11] carry information on typical usage patterns for gas users; the same information is not available for oil users. As can be seen from Figure 3.0.2 and tabulated in Table 3.0.1

Interestingly there is always a minimum load of 1GWh on the network; this can most likely be attributed to shift workers, dwellings with young families, and houses with under floor heating who would have heating on at night.

It was necessary to establish a typical occupancy profile from this dataset this was done as follows, please reference Table 3.0.1 and Figure 3.0.2;

- The base load occurs between 2am and 3am in the morning, the peak load occurs at 6pm in the evening;
- The base load is attributed a value of 0% and the peak a value of 100%, all values were interpolated between these extremes,
- The average consumption was 55%, if the demand ratio was greater than 55% the heating was assumed to be on and if the demand ratio was less that 55% the heating was assumed to be off.

This is not a perfect solution to establish occupancy patterns as some of the load will be attribute to cooking in the evenings, but it is the best information available.

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[11] Irelands main gas utility company

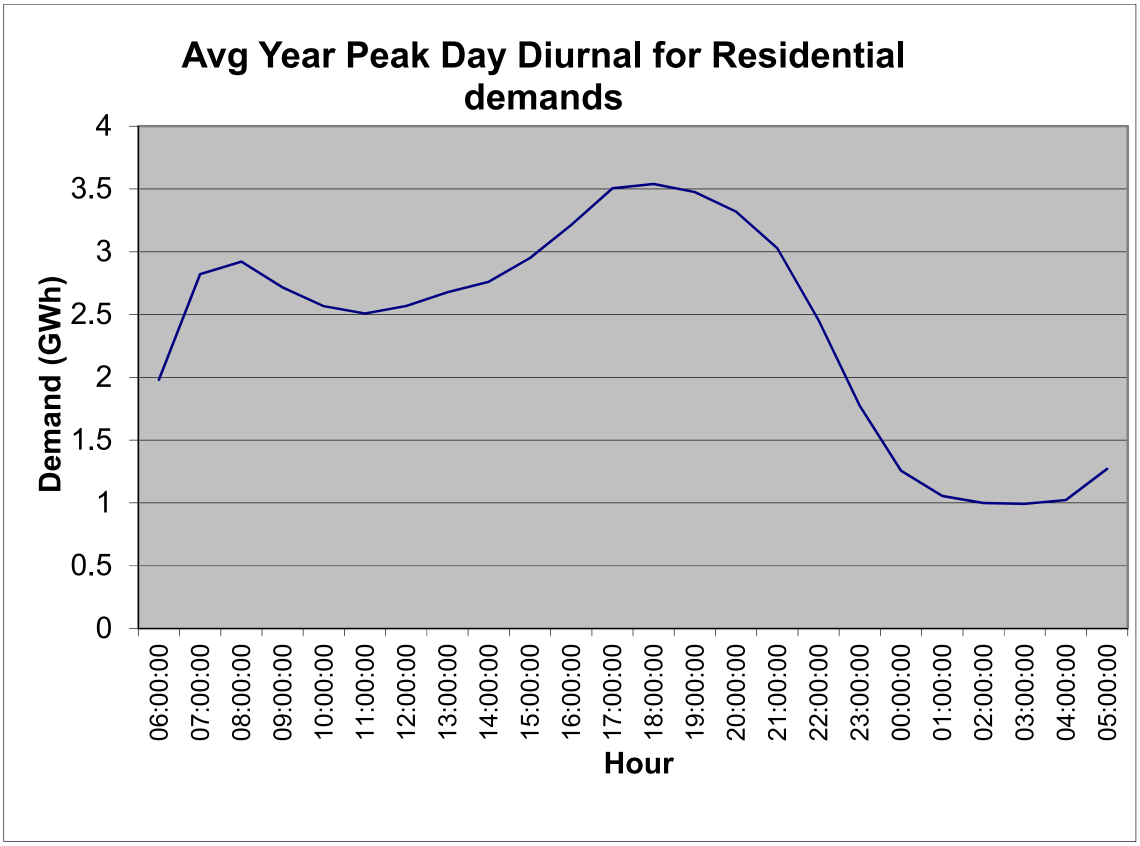


Figure 3.0.2 Average Year Peak Day for residential gas users

Source Bord Gais (BGE)

The typical occupancy pattern was thus established to be from 7am to 10pm. Also in accordance with The Chartered Institute of Building Services Engineering (CIBSE) guidelines (CIBSE Guide F), it was also assumed that the heating is not required when the outdoor temperature is greater than 15^{o}C.

g) *Calculate the CO_2 emission savings resulting from heat pump use, over and above those established in (c) or with respect to 'The Standard Solution'*

The calculation was run for each of the dwelling age bands with each of the heat pumps chosen and the resultant savings established.

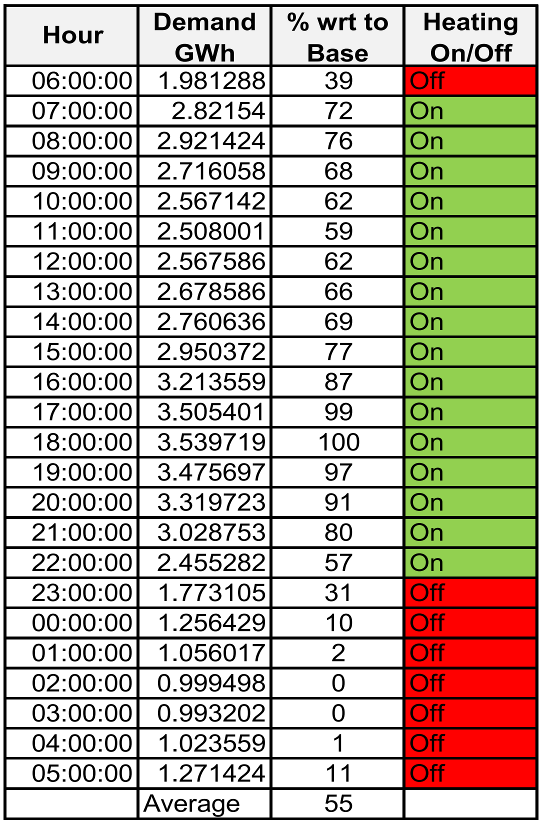
h) *Investigate the viability of retrofitting this technology into Ireland's existing detached housing stock.*

The payback for the units was established and the best performing unit was used in the overall calculation for (g)

i) *Establish the overall cost and CO_2 emission saving potential from the installation of heat pumps post insulation-improvement measures in this sector of housing in Ireland's.*

The results from i) were collated into an overall saving potential from this sector

Table 3.0.1Average year peak day for residential gas users



Hour	Demand GWh	% wrt to Base	Heating On/Off
06:00:00	1.981288	39	Off
07:00:00	2.82154	72	On
08:00:00	2.921424	76	On
09:00:00	2.716058	68	On
10:00:00	2.567142	62	On
11:00:00	2.508001	59	On
12:00:00	2.567586	62	On
13:00:00	2.678586	66	On
14:00:00	2.760636	69	On
15:00:00	2.950372	77	On
16:00:00	3.213559	87	On
17:00:00	3.505401	99	On
18:00:00	3.539719	100	On
19:00:00	3.475697	97	On
20:00:00	3.319723	91	On
21:00:00	3.028753	80	On
22:00:00	2.455282	57	On
23:00:00	1.773105	31	Off
00:00:00	1.256429	10	Off
01:00:00	1.056017	2	Off
02:00:00	0.999498	0	Off
03:00:00	0.993202	0	Off
04:00:00	1.023559	1	Off
05:00:00	1.271424	11	Off
	Average	55	

Source Bord Gais (BGE)

3.2 Limitations of this study

- Defrost cycle analysis is ignored as outlined in Section 2.1 of the literature review.
- The heat loss calculation outlined in BS EN 12831:2003 Heating Systems in buildings is a steady state heat loss calculation meaning heat gains are not included. This will lead to somewhat of an overestimation of the energy saving potential of the heat pump as the actual running hours of the system could be less. Heat Gains as a result of solar penetration into the dwelling will reduce the heating energy requirement, a dynamic simulation could have been carried out, however, the typical dwelling would have had to be orientated through 360° and time would not allow for this. However the general trends shall give an insight in the scale of cost savings achievable.
- Fuel Poverty and the fact that a lot of houses are not achieving current comfort levels are ignored, a fixed internal temperature is assumed. This shall result in an overestimation of the potential savings.
- It is also assumed that the entire house, meaning all rooms, is heated for the duration of defined occupancy period.

- The calculation does not account for user habits in the operation of heating system. It is considered unlikely that a household will turn on the heating for an hour in June for a 1 degree temperature difference, however, it is necessary to allow this to ensure the model was working within the parameters outlined in Section 3.0
- The use of a buffer vessel with the heat pump is not considered in the model, this would further improve the resultant savings potential
- Night time electricity is not used accept for the domestic hot water (DHW)
- Type of Tenure is ignored, as previously stated 21% of dwellings in Ireland's are occupied by tenants. Landlords who, by and large, do not pay the energy costs of heating are not motivated to invest in the energy efficiency of the property, while tenants who pay the bill are not motivated to invest in the fabric of a building they do not own.

Notwithstanding the above, the data presented here are intended to provide a reference for determining the broad performance of the different heat pumps on the market today, with respect to one another whilst operating in the Irish Climate versus 'The Standard Solution'. The study shall also ascertain whether a heat pump which has the capacity to cope with the heat load at the outdoor design temperature (monovalent operation); or a heat pump coping with a portion of the load and a secondary heat source coping with low outdoor temperatures (bivalent operation) is more or less cost effective or carbon friendly. The study will indicate the potential cost and CO_2 savings relative to that of 'The Standard Solution' post insulation improvement measures.

3.3 Preamble to Main Report

This Report has been split into 3 parts

Part 1 – Profiling of detached housing, heat loss calculations, results and analysis

Part 2 - Heat pumps performance modeling, results and analysis.

Part 3 – Overall economic analysis across housing sector and investigation conclusions

Part 1 – Profiling of Detached Housing, Heat Loss Calculations, Results and Analysis

4.0 Profiling the Thermal Properties of Detached Housing Sector

4.0 Profiling the Thermal Properties of Detached Housing Sector

The heat supply system shall be designed to satisfy the design heat load of the dwelling and the requirements of any attached system (e.g. domestic hot water production). The design lead shall be calculated in accordance with EN 12831.

The following parameters are required to carry out this calculation

- U-values
- Areas of fabric elements
- Infiltration Rates
- Thermal Bridging Factors
- Internal Temperature
- External Temperature

4.1 Dwelling Age

The dwellings shall be grouped into age bands based on period of construction and hence similar characteristics of construction.

The age bands used by DEAP differ from the age bands quoted in the CSO dataset, so an adjustment had to be made. The average number of houses built in that period was found and then the number of houses was redistributed in line with DEAP age groups so that U-values as ascribed in DEAP could be attributed to the actual housing data numbers.

Table 4.1.1 Housing Age Band by Quantity (correct for DEAP age band)

CSO Year of Construction Inclusive of not stated	Total No of Detached Houses built in that period	DEAP Age Band	DEAP Year of Construction	Total No of Detached Houses built in that period
before 1919	61802	A	before 1900	44784
1919 to 1940	35068	B	1900-1929	34552
1941-1960	33154	C	1930-1949	32453
1961-1970	23350	D	1950-1966	32245
1971-1980	61596	E	1967-1977	52457
1981 -1990	56693	F	1978-1982	29817
1991-1995	24798	G	1983-1993	60233
1996-2000	44719	H	1994-1999	45694
2001 or later	65730	I	2000-2004	52764
		J	2005-2006	21910
	406910			406910

Source: Table A1 Appendix A, CSO 2006 Table 32C, DEAP

4.2 Estimated Building Envelope Areas

The CSO Planning Permission office holds data on floor areas from the present day to 1980. In 2001 the CSO began to distinguish between all house types and 'one-off' or detached type housing, prior to this all housing figures were lumped together. Using the data available from 2001 to the present day, it was found that detached or 'one-off' housing was on average 28.45% larger than the average house. See Table 4.2.1. This average percentage of 28.45% was then applied to the group figures available from 1980 to 2001.

Table 4.2.1 Detached Housing Floor Areas

CSO Data - Average House Size 1980-2009

DEAP Age Band	Year	All Houses	One-Off Houses	% Diff between 'All Houses' and 'One Off' Houses	Average % Diff	Average Size of Detached House	Average Size for DEAP Age Band	Average Window Area Based on SAP Formula	Average Window Size for DEAP Age Band
J+	2009	164.28	252.65	35	28.45	252.65		36	
	2008	168.45	247.6	32	28.45	247.6		35	
	2007	164.28	238.03	31	28.45	238.03		34	
J	2006	158.7	224.3	29	28.45	224.3	219	32	31
	2005	149.1	213.6	30	28.45	213.6		30	
I	2004	147.8	204.7	28	28.45	204.7	194	29	27
	2003	147.1	198.9	26	28.45	198.9		28	
	2002	144.2	186.2	23	28.45	186.2		26	
	2001	149.2	192.2	22	28.45	192.2		27	
	2000	144.55	—	—	28.45	185.67		26	
H	1999	147.08	—	—	28.45	188.92	174	27	25
	1998	139.5	—	—	28.45	179.19		25	
	1997	138.7	—	—	28.45	178.16		25	
	1996	127.8	—	—	28.45	164.16		23	
	1995	129.2	—	—	28.45	165.96		23	
	1994	129.2	—	—	28.45	165.96		23	
G	1993	125.8	—	—	28.45	161.59	156	23	22
	1992	127.6	—	—	28.45	163.90		23	
	1991	126.7	—	—	28.45	162.75		23	
	1990	130.2	—	—	28.45	167.24		24	
	1989	122.5	—	—	28.45	157.35		22	
	1988	122.9	—	—	28.45	157.87		22	
	1987	118.4	—	—	28.45	152.08		21	
	1986	113.1	—	—	28.45	145.28		20	
	1985	109.1	—	—	28.45	140.14		20	
	1984	113	—	—	28.45	145.15		20	
	1983	122.8	—	—	28.45	157.74		22	
F	1982	116.6	—	—	28.45	149.77	151	21	21
	1981	117.7	—	—	28.45	151.19		21	
	1980	118.9	—	—	28.45	152.73		22	

Source: CSO Planning Permission Office, Rathmines

For floor areas predating 1980 it was necessary to refer to the INSHQ. A three way cross tabulation in SPSS® of Rural Housing Type, Construction Period and Size only yielded a sample set of 120; this was considered insufficient to extrapolate data from. A cross tabulation was therefore carried out with the Rural/Urban filter off this yielded 6483 valid counts which was deemed more accurate. The INSHQ adopted size bands See Table 4.2.2; the mean sizes adopted for the calculation is shown are Table 4.2.3. The mean weight floor area for INSHQ age bands was calculated, see Table 4.2.1.3. Primary Data is shown in Appendix C Primary data is included in Appendix C.

Table 4.2.2 Average House Floor Area for years 1940-1990

INSHQ Data - Average House Size Pre 1940 - 1990				
	% within size in Sq meter grouped Ref Table E1 Appendix E	Mean Floor Area m^2	Weighted Floor Area (m^2)	Mean Weighted Floor Area (m^2)
Pre 1940	25.5	72	1836	
	15.6	103	1606.8	
	10	125	1250	
	20.6	162	3337.2	
	28.2	218	6147.6	
			14177.6	142
1941-1970	18.1	72	1303.2	
	18.6	103	1915.8	
	15.5	125	1937.5	
	22.4	162	3628.8	
	25.4	218	5537.2	
			14322.5	143
1971-1990	7.7	72	554.4	
	16.2	103	1668.6	
	24.5	125	3062.5	
	26.9	162	4357.8	
	24.7	218	5384.6	
			15027.9	150
After 1990	4.1	72	295.2	
	8	103	824	
	19.2	125	2400	
	31.7	162	5135.4	
	37	218	8066	
			16720.6	167

Table 4.2.3 INSHQ Floor Area Size Bands

Size Band m^2	Mean Size Adopted for Calculation
>93	72
92-112	103
113-137	125
138-185	162
Over 185	218

Source: INSHQ 2001-2001

Table 4.2.4 was corrected in accordance with the DEAP Age Band, and combined with the CSO Results to produce a summary table[12]. See Table 4.2.4

Table 4.2.4 Summary Floor Area for DEAP age bands

DEAP Age Band	Period	Average Floor Area (m^2)
A	Before 1900	142
B	1900-1929	142
C	1930-1949	142
D	1950-1966	143
E	1967-1977	147
F	1978-1982	152
G	1983-1993	156
H	1994-1999	174
I	2000-2004	194
J	2005-2006	219

4.2.1. Estimated Ground Floor Area

To establish the ground floor area, the above calculation in section 4.2 must be further refined to reflect whether the detached dwellings are single story or two stories. The INSHQ asked respondents whether they have a staircase present in the home; this data was used to establish whether the dwelling is single storey or two stories.

Crosstabs between year of construction, housing type and presence of a staircase See Appendix C With the rural filter on, the analysis only yielded 929 correct results, which was considered inadequate. The rural filter was removed from the analysis and this yielded 18792 results so the figures yielded from this cross tabulation were used going forward.

It was found that 39.7% of detached houses have a staircase whereas 60.3% do not. See Table 4.2.1.1 for summary data and Appendix C for primary data.

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[12] For the age bands, F, G & H it was possible to compare INSHQ weighted average floor area with CSO planning permission data, the data compares favourably with only a 1.56% difference which confirms that the assumptions made were correct.

Table 4.2.1.1 Single Storey or Two Storeys by CSO Age Band, Deap Age Band, Quantity

CSO Year of Construction Inclusive of not stated	Total No of Detached Houses built in that period	DEAP Age Band	DEAP Year of Construction	Total No of Detached Houses built in that period	% Single Storey	% Two Storey	Total No of Single Storey Detached Houes built in period	Total No of Two Storey Detached Houses built in period
before 1919	61802	A	before 1900	44784	49	51	21899	22885
1919 to 1940	35068	B	1900-1929	34552	60	40	20731	13821
1941-1960	33154	C	1930-1949	32453	63	37	20446	12008
1961-1970	23350	D	1950-1966	32245	87	26	28053	8480
1971-1980	61596	E	1967-1977	52457	87	26	45638	13796
1981 -1990	56693	F	1978-1982	29817	66	39	19709	11659
1991-1995	24798	G	1983-1993	60233	66	39	39814	23551
1996-2000	44719	H	1994-1999	45694	42	58	19192	26503
2001 or later	65730	I	2000-2004	52764	42	58	22161	30603
		J	2005-2006	21910	42	58	9202	12708
	406910			406910			246845	176013

On average 42% of the detached dwelling stock is single story and 58% is two storeys.

The dwellings are assumed to be rectangular in construction where x is the width and 2x is the length. See Fig 4. 2.1.1. This assumption is confirmed by an analysis of Rural OS maps which can be accessed freely on the Ordnance Survey Ireland's website, please see Appendix C for snapshots taken randomly, it can be seen from these snapshots that the vast majority of dwelling are rectangular in shape. In this manner the Ground Floor Area was established. See Table 4.2.1.2

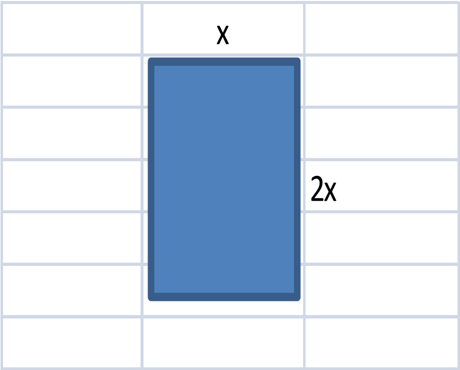


Fig 4.2.1.1Assumed Building Dimensions

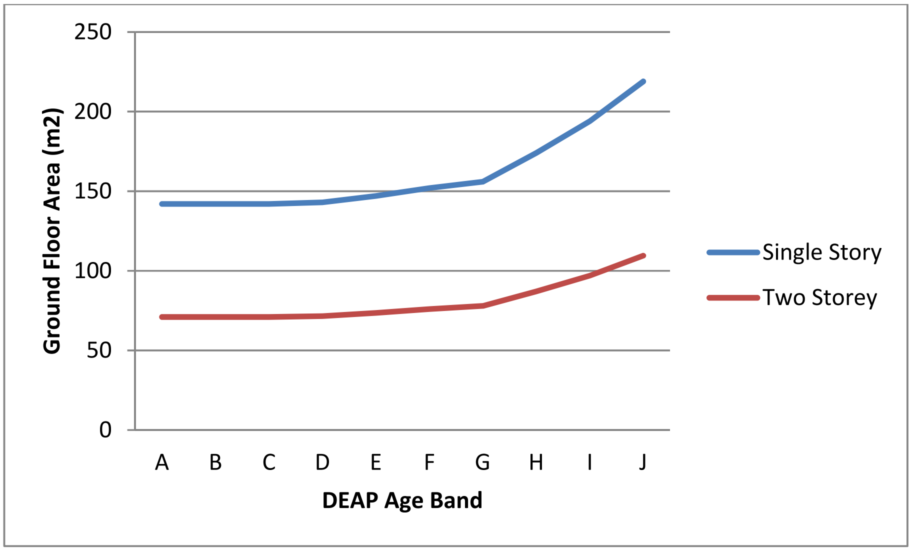
In Figure 4.2.1.2 we plot the ground floor areas of single and two-storey detached housing by DEAP age band. It is clear that the trend of increasing floor area with time is followed within this housing category.

Table 4.2.1.2 Single and Two Storey Ground Floor Areas

DEAP Age Band	Period	Average Single Storey Ground Floor Area (m^2)	Average Two Storey Ground Floor Area (m^2)
A	Before 1900	142	71
B	1900-1929	142	71
C	1930-1949	142	71
D	1950-1966	143	72
E	1967-1977	147	74
F	1978-1982	152	76
G	1983-1993	156	78
H	1994-1999	174	87
I	2000-2004	194	97
J	2005-2006	219	110

The above analysis contradicts the previous Irish housing study (CJ.P. Clinch 2001) which determined the average floor area of a typical detached one storey as being 130m^2 and a detached two-storey as being 95m^2, however the data collection in this study is accurate.

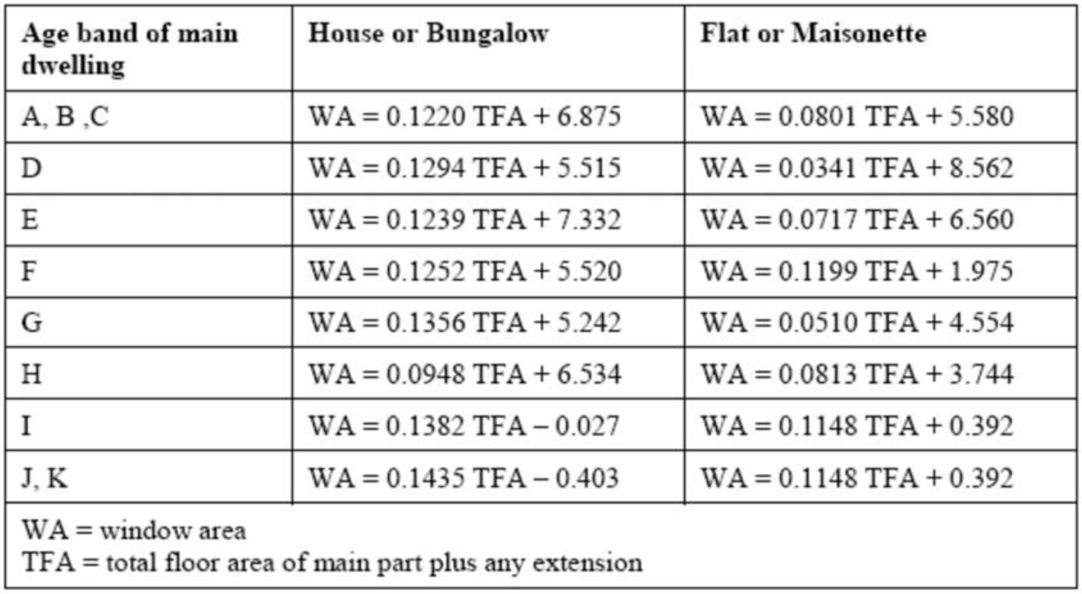
Figure 4.2.1.2 Deap Age Band by Ground Floor Area



4.2.2 Glazing Ratio

Unfortunately DEAP does not contain a calculation which allows for typical glazing ratios by dwelling age. However the equivalent British Software SAP does. The age bands for the SAP and DEAP calculations differ and the values for DEAP age bands were corrected. See Figure 4.3.1 for results

Table 4.2.2.1 Typical Glazing Ratios by Dwelling Age Band

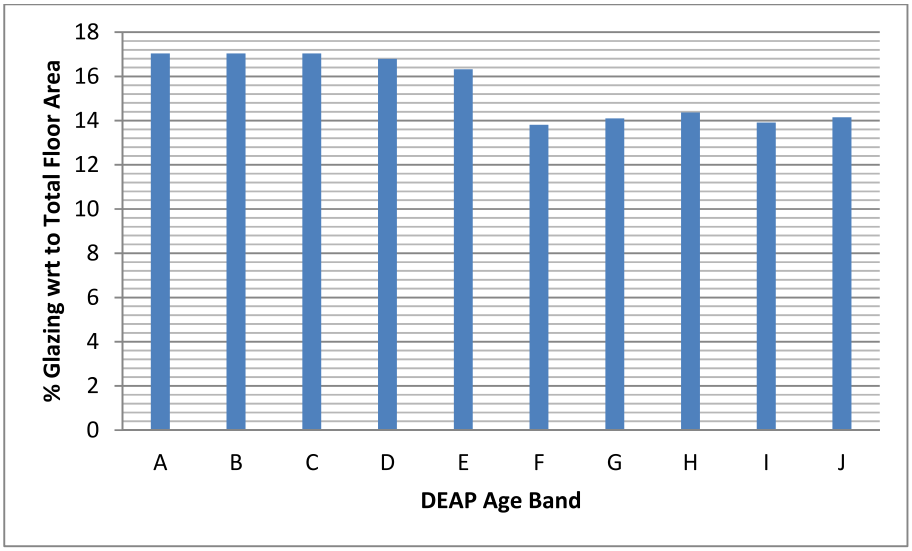


Age band of main dwelling	House or Bungalow	Flat or Maisonette
A, B ,C	WA = 0.1220 TFA + 6.875	WA = 0.0801 TFA + 5.580
D	WA = 0.1294 TFA + 5.515	WA = 0.0341 TFA + 8.562
E	WA = 0.1239 TFA + 7.332	WA = 0.0717 TFA + 6.560
F	WA = 0.1252 TFA + 5.520	WA = 0.1199 TFA + 1.975
G	WA = 0.1356 TFA + 5.242	WA = 0.0510 TFA + 4.554
H	WA = 0.0948 TFA + 6.534	WA = 0.0813 TFA + 3.744
I	WA = 0.1382 TFA – 0.027	WA = 0.1148 TFA + 0.392
J, K	WA = 0.1435 TFA – 0.403	WA = 0.1148 TFA + 0.392

WA = window area
TFA = total floor area of main part plus any extension

Source: SAP

Figure 4.2.2.1 % Glazing Ratios as a percentage of Total Floor Area



4.2.3 Roof Area

All roofs are assumed to have an 18° typical pitch[13] to allow for the roof area to be greater than the floor area, resulting in dimension 'y' which typically made the roof 5% bigger than the floor area.

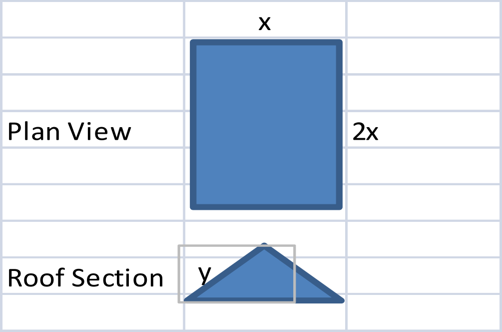


Figure 4.2.3.1 Roof Area with respect to ground floor area

4.2.4 Wall Area

A room typical storey height of 2.4m[14] was assumed, and thus wall area net of glazing could then be calculated

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[13] Part L Building Regulations

[14] Part L Building Regulations

4.2.5 Estimated Window, Wall & Roof Areas

Table 4.2.5.1 Calculated Window Wall & Roof Areas

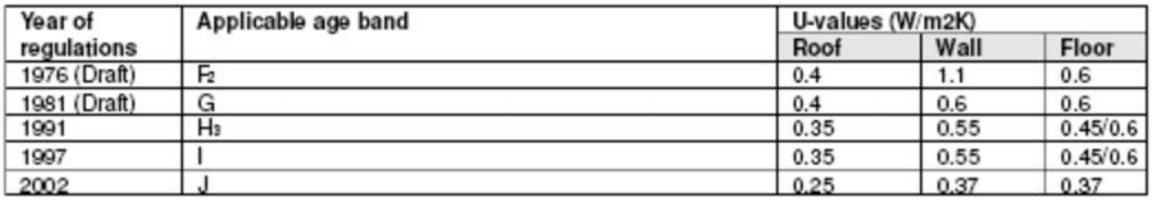
								Single Storey			Two Storey				
DEAP Age Band	Period	Average **Single** Storey Ground Floor Area (m^2)	Average **Two** Storey Ground Floor Area (m^2)	Total Glazed Area wrt TFA (m^2)	Wall Area 'x' Single Storey (m^2)	2x	Wall Area (Including windows) (m^2)	Wall Area Net of Glazing (m^2)	Wall Area Single Storey (m^2)	Wall Area (Including windows) (m^2)	Wall Area Net of Glazing (m^2)	Length 'y' m	Average Single Storey Roof Area (m^2)	Average % increase wrt to floor area	Average **Two** Storey Roof Area (m^2)
A	Before 1900	142	71	24	8.43	16.85	121	97	5.96	172	147	4.43	149	5	75
B	1900-1929	142	71	24	8.43	16.85	121	97	5.96	172	147	4.43	149	5	75
C	1930-1949	142	71	24	8.43	16.85	121	97	5.96	172	147	4.43	149	5	75
D	1950-1966	143	72	24	8.46	16.91	122	98	5.98	172	148	4.45	151	5	75
E	1967-1977	147	74	24	8.57	17.15	123	99	6.06	175	151	4.51	155	5	77
F	1978-1982	152	76	21	8.72	17.44	126	105	6.16	178	157	4.58	160	5	80
G	1983-1993	156	78	22	8.83	17.66	127	105	6.24	180	158	4.64	164	5	82
H	1994-1999	174	87	25	9.33	18.65	134	109	6.60	190	165	4.91	183	5	91
I	2000-2004	194	97	27	9.85	19.70	142	115	6.96	201	174	5.18	204	5	102
J	2005-2006	219	110	31	10.46	20.93	151	120	7.40	213	182	5.5	230	5	115

Source: SAP/Part L/INSHQ 2001-2002

4.3 U-value's

From the mid-1970s, constructional changes have been caused primarily by amendments to draft or actual Building Regulations for the conservation of fuel and power, which have called for increasing levels of thermal insulation. The dates provided by DEAP are generally two or three years after a change in regulations based on indicative figures of likely transition periods. This allows for the dwellings to be completed after the regulations came into force. The Building Regulations assign U-values to different building elements as outlined in the following table.

Table 4.3.1 Building Regulations Summary



Year of regulations	Applicable age band	U-values (W/m2K)		
		Roof	Wall	Floor
1976 (Draft)	F_2	0.4	1.1	0.6
1981 (Draft)	G	0.4	0.6	0.6
1991	H_3	0.35	0.55	0.45/0.6
1997	I	0.35	0.55	0.45/0.6
2002	J	0.25	0.37	0.37

Source Table S2 DEAP Help Manual

4.3.1 Window U-value, Window Type and prevalence within DEAP Age Bands

Table S9 in the DEAP Help manual specifies the following default U-values for various window construction types. Note that default values for timber frame and PVC are the same. See Table 4.3.1.1

An analysis of the window types versus year of construction using INHSQ was carried out. See table 4.3.1.1 and Reference tables in Appendix D.

Table 4.3.1.1 Default U-values for various window construction types

	Timber Frame		PVC		Steel		Aluminium		Table S9 DEAP All Double Glazing assumed to be Air Filled with 6mm Gap
	Single	Double	Single	Double	Single	Double	Single	Double	
U-Value	4.8	3.1	4.8	3.1	5.7	3.7	5.7	3.7	

Source: DEAP

4.3.1.1 Window Type

Table 4.3.1.1.1 Dwelling Age by Window Type

	Timber Frame		PVC		Steel		Aluminium		Other		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Pre-1940	3405	48	2854	41	66	1	706	10	7	0	7038	100
1941-1970	1715	37	2255	49	77	2	600	13	1	0	4648	100
1971-1980	2466	44	2631	47	9	0	468	8	6	0	5580	100
1980-1996	2067	37	3001	54		0	461	8	7	0	5536	100
After 96	141	9	1323	89		0	24	2	4	0	1492	100
	9794	40	12064	50	152	1	2259	9	25	0	24294	

Source: INSHQ 2001-2001

The predominant window types across all age bands is timber and PVC, the presence of steel and aluminium windows are considered to be negligible. Therefore the U-value for all double glazing is taken as 3.1 W/m^{2o}C and the U-value for all single glazing is taken as 4.8 W/m^{2o}C.

4.3.1.2 Prevalence of Double Glazing within DEAP Age Band

Next an analysis was carried out to establish the prevalence of double glazing. See Table 4.3.1.2.1 and Appendix D for primary data.

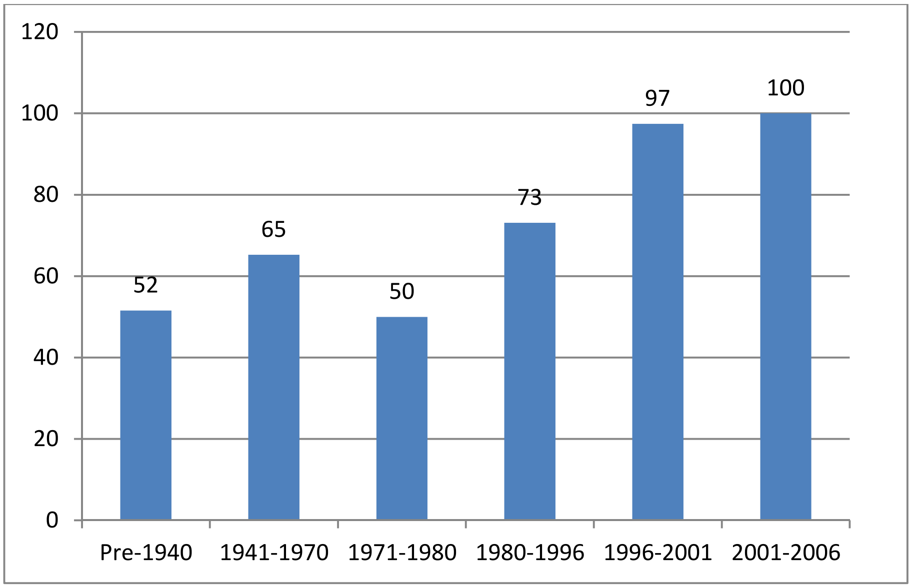
Table 4.3.1.2.1 Dwelling Age by presence of single or double glazing

	Double Glazing		Single Glazing		Total	
	Count	%	Count	%	Count	%
Pre-1940	3156	52	2966	48	6122	100
1941-1970	2646	65	1410	35	4056	100
1971-1980	3184	50	3184	50	6368	100
1980-1996	3829	73	1409	27	5238	100
After 96	1442	97	38	3	1480	100
	14257	61	9007	39	23264	

Source: INSHQ 2001-2002

Notably the prevalence of double glazing increases with time; however, interestingly there is evidence of a large degree of retrofitting in pre-1940 houses which would have been originally constructed with single glazing. INSHQ data only goes to 2001; it is assumed that all houses built after 2001 are double glazed and compliant with the building regulations at time of construction. See Figure 4.3.1.2.1

Figure 4.3.1.2.1 Dwelling Age by % presence of double glazing



Source: INSHQ 2001-2001

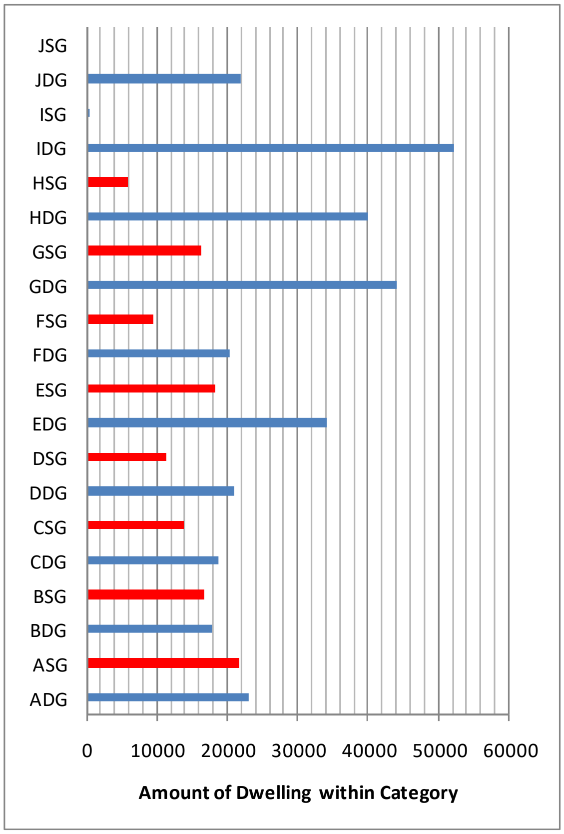
The percentages established from the INSHQ were then applied to CSO 2006 dataset to obtain the quantities of rural detached houses by glazing type and hence the data was corrected to DEAP age bands. The subscripts SG & DG denote single glazing and double glazing respectively, see Table 4.3.1.2.2. Figure 4.3.1.2.2 depicts quantities of housing with single and double glazing by category.

Table 4.3.1.2.2 Dwelling Age by Window Type by DEAP Age Band

INSHQ Year of Construction	% Single Glazed	% Double Glazed	DEAP Age Band (Double Glazed)	DEAP Year of Construction	Corrected No of Double Glazed Houses in that DEAP Age Band	DEAP Age Band (Single Glazed)	Corrected No of SinlgeGlazed Houses in that DEAP Age Band
Pre 1940	51.6	48.4	A_{DG}	before 1900	23109	A_{SG}	21675
	51.6	48.4	B_{DG}	1900-1929	17829	B_{SG}	16723
	51.6	48.4	C_{DG}	1930-1949	18775	C_{SG}	13678
1941-1970	65.2	34.8	D_{DG}	1950-1966	21024	D_{SG}	11221
	65.2	34.8	E_{DG}	1967-1977	34116	E_{SG}	18341
1971-1980	65	35	F_{DG}	1978-1982	20300	F_{SG}	9518
1980-1996	73.1	26.9	G_{DG}	1983-1993	44030	G_{SG}	16203
	73.1	26.9	H_{DG}	1994-1999	39923	H_{SG}	5772
			I_{DG}	2000-2004	52246	I_{SG}	517
			J_{DG}	2005-2006	21910	J_{SG}	0

Source: INSHQ 2001-2001/CSO 2006

Figure 4.3.1.2.2 Quantities of Glazing Type by DEAP Age Bands



4.3.2 Wall U-value

DEAP provides default U-values by date of construction based on the typical construction type prevailing at the time. See Table 4.3.2.1. Note that there is only an appreciable difference in the thermal characteristics of stone[15] and cavity walls where insulation is present. Therefore it was necessary to quantify the presence of cavity insulation by age band and the INSHQ was used to correlate year of construction with presence of a cavity wall and cavity insulation. See Appendix E for calculation data and primary data.

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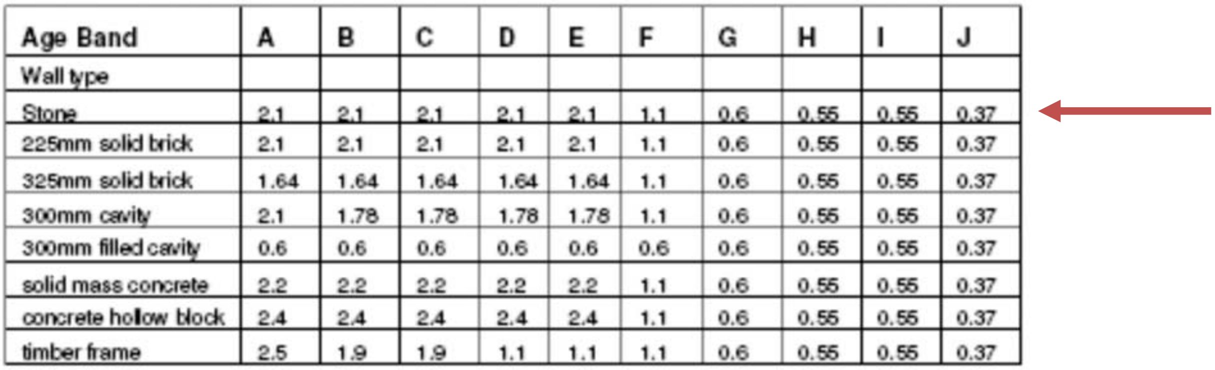
[15] DEAP states that if the wall type cannot be identified or does not fit into any categories in Table 4.3.2.1 assume wall type is 'stone'

Table 4.3.2.1 DEAP Default U-values



Age Band	A	B	C	D	E	F	G	H	I	J
Wall type										
Stone	2.1	2.1	2.1	2.1	2.1	1.1	0.6	0.55	0.55	0.37
225mm solid brick	2.1	2.1	2.1	2.1	2.1	1.1	0.6	0.55	0.55	0.37
325mm solid brick	1.64	1.64	1.64	1.64	1.64	1.1	0.6	0.55	0.55	0.37
300mm cavity	2.1	1.78	1.78	1.78	1.78	1.1	0.6	0.55	0.55	0.37
300mm filled cavity	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.55	0.55	0.37
solid mass concrete	2.2	2.2	2.2	2.2	2.2	1.1	0.6	0.55	0.55	0.37
concrete hollow block	2.4	2.4	2.4	2.4	2.4	1.1	0.6	0.55	0.55	0.37
timber frame	2.5	1.9	1.9	1.1	1.1	1.1	0.6	0.55	0.55	0.37

Source: DEAP

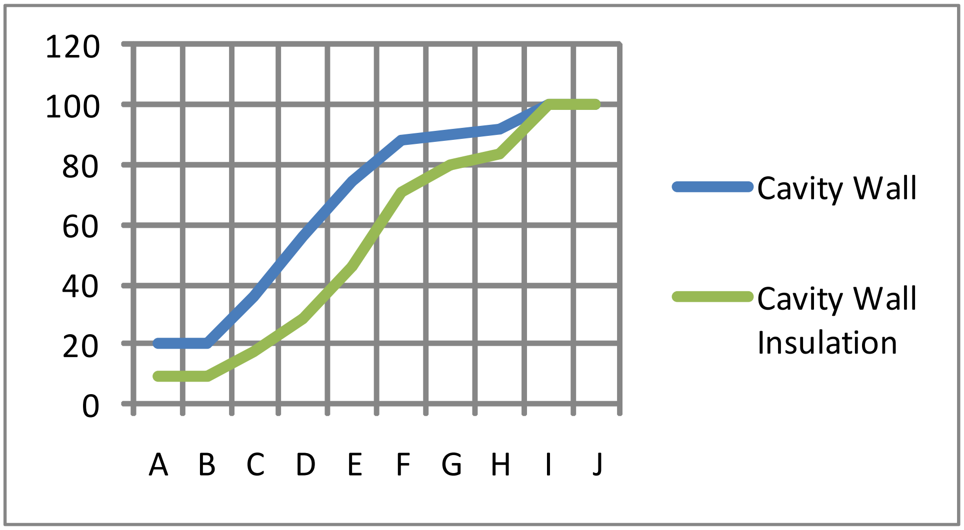


Figure 4.3.2.1 Prevalence of Cavity Wall and Cavity Wall Insulation by DEAP age band

The presence of cavity walls steadily increases over time; the presence of cavity insulation however is slow to catch up. The presence of the insulation is what makes the appreciable difference to the default U-value. Timber frame and concrete block of solid mass concrete construction are not usual in Ireland. The ‘stone and 225mm ‘solid ‘brick values are the same

You can see the effect that the Building Regulations had when they came into force in the mid 1970’s as the presence of cavity walls jumped to over 70%, with the presence of insulation at approx 90%

The results analysis on cavity wall (without insulation) corresponds with that of stone type wall, which supports DEAP’s assumption that unidentified/unknown wall types can use the default values of stone. The default U-value of stone is used in the heat loss calculation.

Table 4.3.2.2 Wall U-values used for calculation in this study

DEAP Age Band	Period	U-Value W/mk		
		No Cavity	Cavity - No Inuslation	Insulated Cavity Wall
A	Before 1900	2.1	2.1	0.6
B	1900-1929	2.1	1.78	0.6
C	1930-1949	2.1	1.78	0.6
D	1950-1966	2.1	1.78	0.6
E	1967-1977	2.1	1.78	0.6
F	1978-1982	0.6	1.1	0.6
G	1983-1993	0.6	0.6	0.6
H	1994-1999	0.55	0.55	0.55
I	2000-2004	0.55	0.55	0.55
J	2005-2006	0.37	0.37	0.37

Source: DEAP

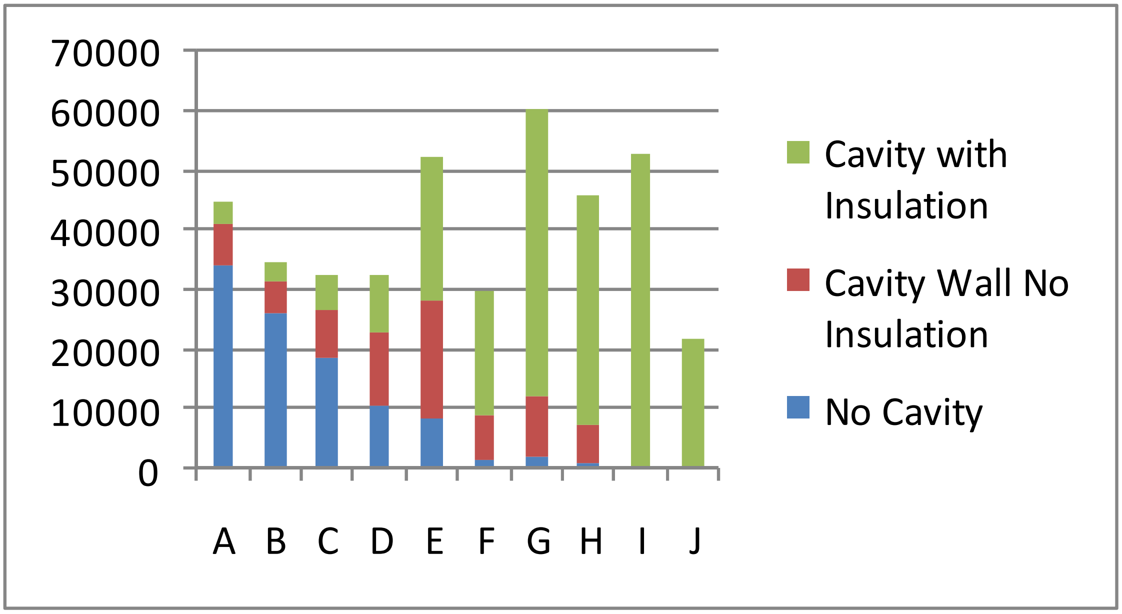


Figure 4.3.2.2 Quantity of Houses by Wall Type

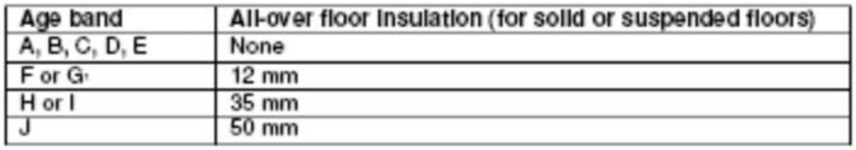
Source: INSHQ 2001-2002

4.3.4 Floor U-value

The floor U-value in DEAP is calculated according to I.S. EN ISO 13370 using its area and exposed perimeter and rounded to two decimal places. The ratio of floor perimeter to area is known as the P/A ratio. The following parameters are used for solid ground floors;

- Wall thickness assumed at 300mm for U-value calculations
- Soil type: default (thermal conductivity 2.0 W/m.K)
- R_{si}- 0.17 m^2K/W
- R_{se} – 0.04 m^2K/W
- Floor type with 50mm screed
- All-over floor insulation of thickness as per Table 4.3.4.1

Table 4.3.4.1 Basis for DEAP U-value Calculation



Age band	All-over floor insulation (for solid or suspended floors)
A, B, C, D, E	None
F or G	12 mm
H or I	35 mm
J	50 mm

Source: DEAP (Table S6)

Using the wall area ratios (x and 2x) calculated in Section 4.2.1, the P/A ratio was calculated and the U-value was interpolated from Table S8 in DEAP (Ref: Table F1 in Appendix F). The Floor U-values were calculated for single storey and two storey dwellings. See Summary Table 4.3.4.2

Table 4.3.4.2 Ground Floor U-value by P/A Ratio

		Single Storey						Two Storey					
DEAP Age Band	Period	Average Ground Floor Area (m^2)	Wall Area 'x' (m)	Wall Area 2x (m)	Perimeter 'P' (m)	P/A Ratio	U-Value (W/m.K)	Average Ground Floor Area (m^2)	Wall Area 'x' (m)	Wall Area 2x (m)	Perimeter 'P' (m)	P/A Ratio	U-Value (W/m.K)
A	Before 1900	142	8.43	16.85	50.56	0.36	0.68	71	5.96	11.92	35.75	0.50	0.84
B	1900-1929	142	8.43	16.85	50.56	0.36	0.68	71	5.96	11.92	35.75	0.50	0.84
C	1930-1949	142	8.43	16.85	50.56	0.36	0.68	71	5.96	11.92	35.75	0.50	0.84
D	1950-1966	143	8.46	16.91	50.73	0.35	0.67	72	5.98	11.96	35.87	0.50	0.84
E	1967-1977	147	8.57	17.15	51.44	0.35	0.67	74	6.06	12.12	36.37	0.49	0.83
F	1978-1982	152	8.72	17.44	52.31	0.34	0.52	76	6.16	12.33	36.99	0.49	0.63
G	1983-1993	156	8.83	17.66	52.99	0.34	0.52	78	6.24	12.49	37.47	0.48	0.63
H	1994-1999	174	9.33	18.65	55.96	0.32	0.37	87	6.60	13.19	39.57	0.45	0.43
I	2000-2004	194	9.85	19.70	59.09	0.30	0.36	97	6.96	13.93	41.79	0.43	0.42
J	2005-2006	219	10.46	20.93	62.79	0.29	0.31	110	7.40	14.80	44.40	0.41	0.34

Source: DEAP Table S8 (Ref Table F1 Appendix F)

4.3.5 Roof U-value

In 2001 there was an average 82% penetration of roof insulation for detached housing in Ireland's. See Table 4.3.5.1

Table 4.3.5.1 Presence of Roof Insulation by year

	Have Roof Insulation %
Pre 1940	62
1941-1970	78
1971-1980	90
1980-1996	95
After 96	98
Average	82

Source: INSHQ

DEAP does not quote U-values for uninsulated roofs, therefore all roofs are assumed to be insulated. DEAP states that if the insulation thickness is not known, the default U-value should be taken. See Table 4.3.5.2 for summary roof U-values assumed in this calculation.

Table 4.3.5.2 Assumed U-values when roof insulation thickness is unknown

Age Band	Assumed Roof U-Value W/moC (applies to all roof types)
A, B, C, D, E	2.3
F,G	0.4
H,I	0.35
J	0.25

Source: DEAP

4.3.6 External Door U-value, No of External Doors and Door Type

The INSHQ was used to establish the typical number of doors present by dwelling type and dwelling age. Refer to Appendix H for primary data

DEAP states that single doors can be assumed to have an area of 1.85m^2 with double doors being twice that.

DEAP Lists 3 categories of doors

- single glazed PVC U-value 4.8W/mK
- single glazed metal frame U-value 5.7W/mK
- solid wooden door, U-value 3 W/mK

For this study, doors are assumed to be solid wooden doors with a U-value of 3W/m^2. INSHQ was used to calculate the number of external doors present, also one door is assumed to be double with the balance being single. See Appendix H for Primary Data

Table 4.3.6.1 No of External Doors by INSHQ Age Band

INSHQ Age Band	Average No of Doors
Pre 1940	2.13
1941-1970	2.2
1971-1980	2.3
1980-1996	2.22
After 96	2.66

Source: INSHQ

Table 4.3.6.2 Number and Area of External Doors by Age Band

DEAP Age Band	Period	Average No of Doors	Total Area of Doors (m^2)
A	Before 1900	2.1	5.7
B	1900-1929	2.1	5.7
C	1930-1949	2.2	5.9
D	1950-1966	2.2	5.9
E	1967-1977	2.3	6.1
F	1978-1982	2.3	6.1
G	1983-1993	2.2	5.9
H	1994-1999	2.4	6.3
I	2000-2004	2.7	6.8
J	2005-2006	2.7	6.8

Source: INSHQ

(CJ.P. Clinch 2001) assumed opaque door area for houses to be 3.4m2 this is an underestimation of the amount of doors however Clinch did not have the benefit of the INSHQ study at time of publishing

4.4 Infiltration Rates and Irish Dwellings

Only two large scale databases for air infiltration rates in UK dwellings are known: one held by British Gas plc covering some 200 dwellings and the other held by BRE covering 471 dwellings and 87 large panel systems (LPS) flats. The sample covers a range of dwelling types, ages and construction. The LPS flats have been excluded from the main sample because they represent only 1% of the total housing stock, full details can be found in the reference (Cornish 1989). The published data from the British Gas database compares well with BRE data but is somewhat limited in detail (Stephen, 1998).

A widely held belief is that older dwellings are draughtier and therefore less airtight than modern dwellings because they have more chimneys and leaky window systems. Although Fig. 4.4.1 shows there is no evidence to support such a trend in the BRE database, although most of the measurements were taken with chimneys sealed and no allowances were made in the results for them. In fact, the oldest dwellings tend to be more airtight; the average air leakage rate rose in the 1920's at a time when sash windows were being used but cavity walls were being introduced. Whether cavity walls are truly responsible for this trend can only be conjecture (Stephen 1998).

On average dwellings built since about the 1980's seem to be more airtight that those built since the 1930's. There is little or no information to explain the trends of air tightness with the date built, but clearly the fact that a house is new does not necessarily mean it will be airtight. (Stephen 1998)

(Stephen 1998) concluded that the number of storeys in a building does not significantly influence air leakage rates. Additionally window type does not have a significant influence, probably because the effect is swamped by other contributing factors

Figure 44.1 outlines the results of air leakage tests which do not provide a measure of the air infiltration rate (ac/hr) in a building, and therefore cannot be used to estimate directly the infiltration heat loss. The test pressure of 50 Pa is much higher than the pressure differences that drive infiltration due to weather conditions. A calculation can be carried out to relate the air leakage at 50Pa to the air infiltration rate, but this will require some knowledge of the air leakage paths. If a direct measure of air infiltration is required it involves a lengthy and complex test using tracer gases.

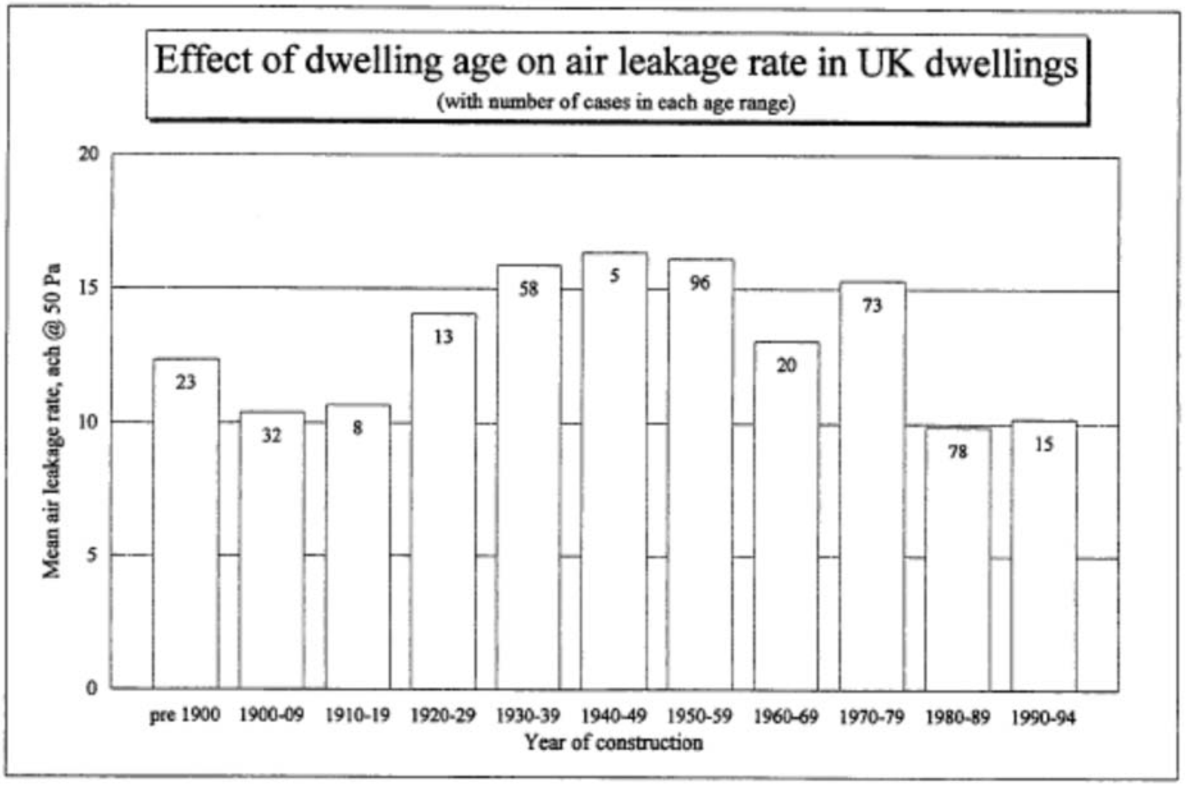


Figure 4.4.1 Effect of dwelling age on air leakage rate in UK dwellings

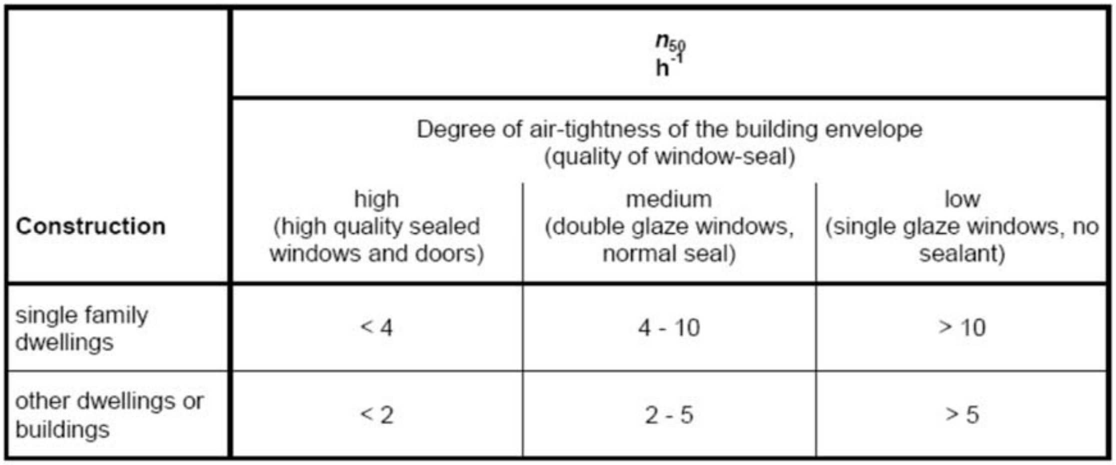
Source: (Stephen 1998)

Table 4.4.1 Air Change Rates at 50Pa (n_{50}) by DEAP Age Band

DEAP Age Band	Period	Infiltration Rate n_{50} h^{-1}
A	Before 1900	12
B	1900-1929	12
C	1930-1949	16
D	1950-1966	14
E	1967-1977	14
F	1978-1982	12
G	1983-1993	10
H	1994-1999	10
I	2000-2004	10
J	2005-2006	10

Source: BRE

Table 4.4.2 Whole building air exchange rate (n_{50})



	n_{50} h^{-1}		
	Degree of air-tightness of the building envelope (quality of window-seal)		
Construction	high (high quality sealed windows and doors)	medium (double glaze windows, normal seal)	low (single glaze windows, no sealant)
single family dwellings	< 4	4 - 10	> 10
other dwellings or buildings	< 2	2 - 5	> 5

Source: Table D.7 EN12821:2003 (E)

This infiltration rate of homes generally lies between 10 and 16 ac/hr at a test pressure of 50Pa with reference to Table 4.4.2 this indicates that the degree of air tightness of Irish Dwellings is low EN 12831:2003 (E) is low

Aside

From a large number of measurements carried out on dwellings (and usually of similar volumes) it has been found that air infiltration rate in air changes per hour (ac/hr) is approximately 1/20 of the 50 Pa air leakage rate expressed as air changes per hour.(TM23 2000)

The air leakage is defined as:

$$ACH = \frac{Q_{50}}{V}$$

Where

Q_{50} = leakage airflow rate at 50Pa (AC/hr)

V = internal volume surrounded by the building envelope (m^3)

To establish the internal volume, the depth of wall must be established

(CJ.P. Clinch 2001) estimated the mean air-change rate with no draught stripping is assumed to be 1.10 air changes per house (ac/h) for one-storey dwelling and 1.20 ac/h for two storey dwellings. Based on the BRE test data this is quite high as the worst house tested has and air change rate of 0.8 ac/hr.

4.5 Thermal Bridging

A thermal bridge is created when materials that are poor insulators come in contact, allowing heat to flow through the path created. Insulation around a bridge is of little help in preventing heat loss or gain due to thermal bridging.

Appendix K of the DEAP manual allows for default values to account for thermal bridges within the structure.

The quantity which describes the heat loss associated with a thermal bridge is its linear thermal transmittance, '*psi* '. This is a property of a thermal bridge and is the rate of heat flow per degree per unit length of bridge that is not accounted for in the U-values of the plane building elements containing the thermal bridge.

The transmission heat loss coefficient associated with non-repeating thermal bridges is calculated as:

$$H_{TB} = \sum (L\ x\ p_{si})$$

where L is the length of the thermal bridge over which *psi* applies. If details of the thermal bridges are not known, use

$$H_{TB} = y \sum A_{exp}$$

where A_{exp} is the total area of exposed elements, m^2.

A default value of y = 0.15 W/m^2K applies for all dwellings

4.6 External Design Temperature

The approximate method for determination of outdoor temperature is as outlined in CIBSE Guide A

The method requires the following data:

- average monthly minimum dry bulb temperature for the coldest month (e.g. for January, the average over a period of years of the lowest temperature in each January within that period)
- average daily minimum dry bulb temperature (e.g. for January, the average over a period of years of the highest temperatures for each January day within that period; i.e. for a 30-year period, the average of the maximum temperatures on all 930 January days within that period)
- average daily minimum relative humidity (e.g. for January, the average over a period of years of the lowest relative humidity for each January day in that period).

The data used is for the period 1961-1990 and is available from the climate data section of the Met Eireann website:

Table 4.6.1 Winter External Design Data

Month	Mean Monthly Min Temp (°C)	Mean Relative Humidity @ 9.00 hrs	Mean Daily Min. Temp
Jan	-3.42	0.86	2.50
Feb	-2.04	0.84	2.50
Mar	-1.72	0.82	3.10
Apr	-0.58	0.79	4.40
May	2.33	0.76	6.80
Jun	5.01	0.76	9.60
Jul	7.11	0.78	11.40
Aug	6.82	0.81	11.10
Sep	4.52	0.82	9.60
Oct	2.24	0.85	7.60
Nov	-1.48	0.86	4.20
Dec	-2.50	0.86	3.40

Source: Met Eireann

The design temperature is obtained as follows (please see Appendix I for copy of pyschrometric chart):
:

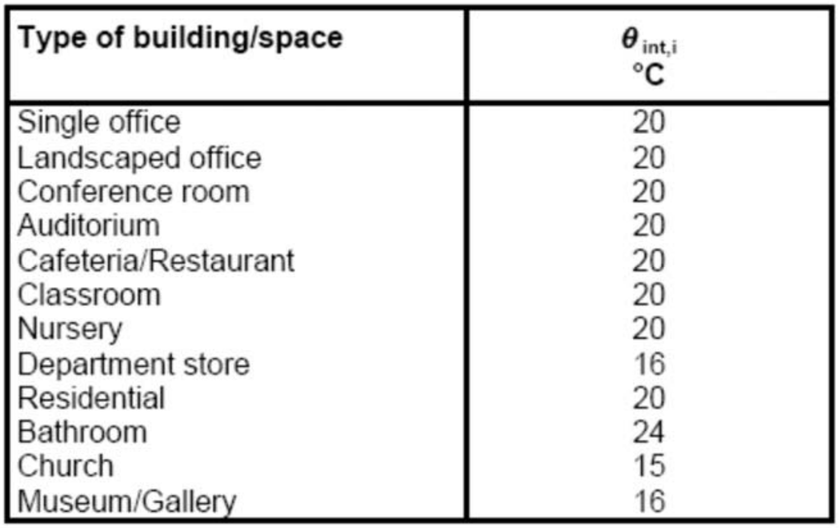
1. January being the month with the lowest average monthly minimum dry bulb temperature is selected; this lowest average monthly minimum dry bulb temperature is taken as the design dry bulb temperature = -3°C.
2. Using the psychrometric chart, a moisture content, dew-point temperature or vapour pressure is determined for the average daily minimum dry bulb temperature and average daily maximum relative humidity = 2.5°C of 86%
3. The moisture content, dew-point temperature or vapour pressure determined in step 2 is combined with the lowest average monthly maximum dry bulb temperature determined in step 1 to give a screen wet bulb temperature, which is taken as the design wet bulb temperature = 100%

Therefore the outdoor design condition is -3°C at 100% RH

4.7 Internal Design Temperature

The objective of calculating the design heat load is to ensure an acceptable internal thermal environment at design exterior conditions. Default internal temperature for heating is given in Annex D (Table D.2) of EN 12831:2003.

Table 4.7.1 Recommended Internal Design Temperatures

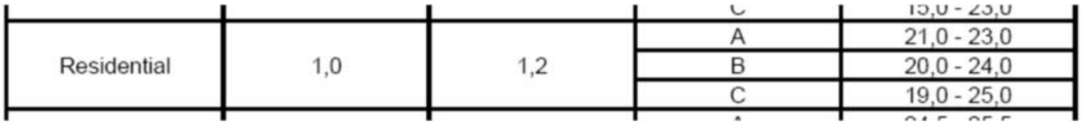


Type of building/space	$\theta_{int,i}$ °C
Single office	20
Landscaped office	20
Conference room	20
Auditorium	20
Cafeteria/Restaurant	20
Classroom	20
Nursery	20
Department store	16
Residential	20
Bathroom	24
Church	15
Museum/Gallery	16

Source: Table D2 EN 12831:2003

It is worth noting that this temperature can drop to 19°C with the predicted percentage dissatisfied still remaining under 15% (Category C in Table 4.7.2).

Table 4.7.2 Recommended Internal Design Temperatures



Residential	1,0	1,2	A	21,0 - 23,0
			B	20,0 - 24,0
			C	19,0 - 25,0

Source: Table D3 EN 12831:2003

The default value of 20°C will be used in calculation going forward. This allows us some capacity in the system if the outdoor temperature drops to -4oC the internal temperature will fall to 19°C, which is acceptable considering houses are generally only currently achieving a maximum indoor temperature of 18.8 °C as outline in Fig 2.2.1.1

5.0 Housing Heat Loss Calculations

5.0 Housing Heat Loss Calculations

The dwelling heat loss calculations were carried out in accordance with the heat loss calculation method as prescribed in BS EN 12831:2003 *Heating Systems in Buildings – Method for calculation of Design Heat Load* and using the building design parameters established in sections 4.3 to 4.8 of this report.

The heat losses were calculated for the dwelling before and after fabric improvement measures. Fabric improvement measures that were considered were as follows;

- Wall Insulation
- Roof Insulation
- Floor Insulation
- Replacing single glazing with double glazing
- Increasing the air tightness of the structure

A practical approach was taken with improvement measures. For instance, due to the high cost of replacement floor coverings and in line with the findings of (J.P Clinch 2004), it was assumed that floor U-values remain static. Whereas roof insulation is a lot easier to retrofit so it is assumed that all roof U-values are brought to 0.3W/m^{2o}C. It is assumed that due to the high cost of replacing glazing that if the house already has fitted double glazing, then no adjustment was made (even if the U-value is relatively poor compared to the modern double glazing available on the market today), however, if the house is single glazed the glazing is replaced with modern double glazing achieving a U-value of 2.2 W/m^{2o}K. All wall U-values were brought to 0.3W/m^{2o}C with the exception of house type J which was reduced to 0.27 W/m^{2o}C, it is assumed that cavity wall infill insulation or external insulation cladding is employed to achieve this reduced wall U-value. Full analysis can be found in Appendix K, please see Table 5.5.1 and Figure 5.1.1 for summary results. Due to inherent difficulties in achieving an air tight construction in existing buildings it is assumed that the ventilation rate due to infiltration also remains static.

5.1 Heat Loss Calculations (Before and After Fabric Improvement Measures)

Full heat loss calculations and summary calculation data can be found in Appendix J, tables J1 through to J13 and Appendix K, tables K1 to K10, for before and after fabric improvement measures respectively.

5.1.1 Heat Loss Calculation Results (Before Fabric Improvement Measures)

Summary results are shown in Figure 5.1.1.1 and Table 5.1.1.1 The heat losses have been plotted/tabulated according to DEAP Age Bands (A→H), an explanation of the subscripts used is as follows:

- 1S and 2S denote single storey or two storey dwellings respectively and;
- SG and DG denotes single glazing and double glazing respectively.

For example;

A_{1SDG} – House Type A, Single Storey, Double Glazed or

J_{2SSG} – House Type J, Two Storey, Single Glazed

Table 5.1.1.1 Summary Heat Loss Calculations Results

House Type	1SDG	1SSG	2SDG	2SSG
	W/°C	W/°C	W/°C	W/°C
E	1708	1789	1472	1553
C	1675	1757	1449	1531
D	1647	1756	1443	1525
B	1647	1728	1421	1503
A	1647	1728	1421	1503
F	876	948	844	915
I	787	847	698	758
G	779	854	692	767
H	768	778	690	700
J	760	N/A	660	N/A

It is found that as expected, a single storey house has a greater heat loss that a two storey house of the same internal volume due to the greater amount of exposed surface area in a single storey construction. The presence of single glazing results on average results in a 6% increase in the heat loss per °C than the same house with double glazing.

There is a high degree of variance (225%) between the dwelling with the worst heat loss characteristic (E) and the house with the best heat loss characteristic (J)

The relationship between increasing house size and heat loss is clearly shown with heat loss steadily increasing with time from Age Band A to E. It is also evident from the Figure 5.9.1 the positive effect that the Building Regulations had on the heat loss characteristics, which came into effect in 1979 in time for DEAP age band F. The upper tier of lines with a steep characteristic depicts the heat losses of houses constructed prior to the building regulations (house types A through to E inclusive) and the lower tier of curves depicts the heat loss characteristics post building regulations (house types F to J inclusive).

It is also clear from Table 5.1.1.1 that improvement in U-values brought about via the updating of the national Building Regulations over time (Ref Table 4.3.1) in general outweighs the trend towards increasing floor areas over time.

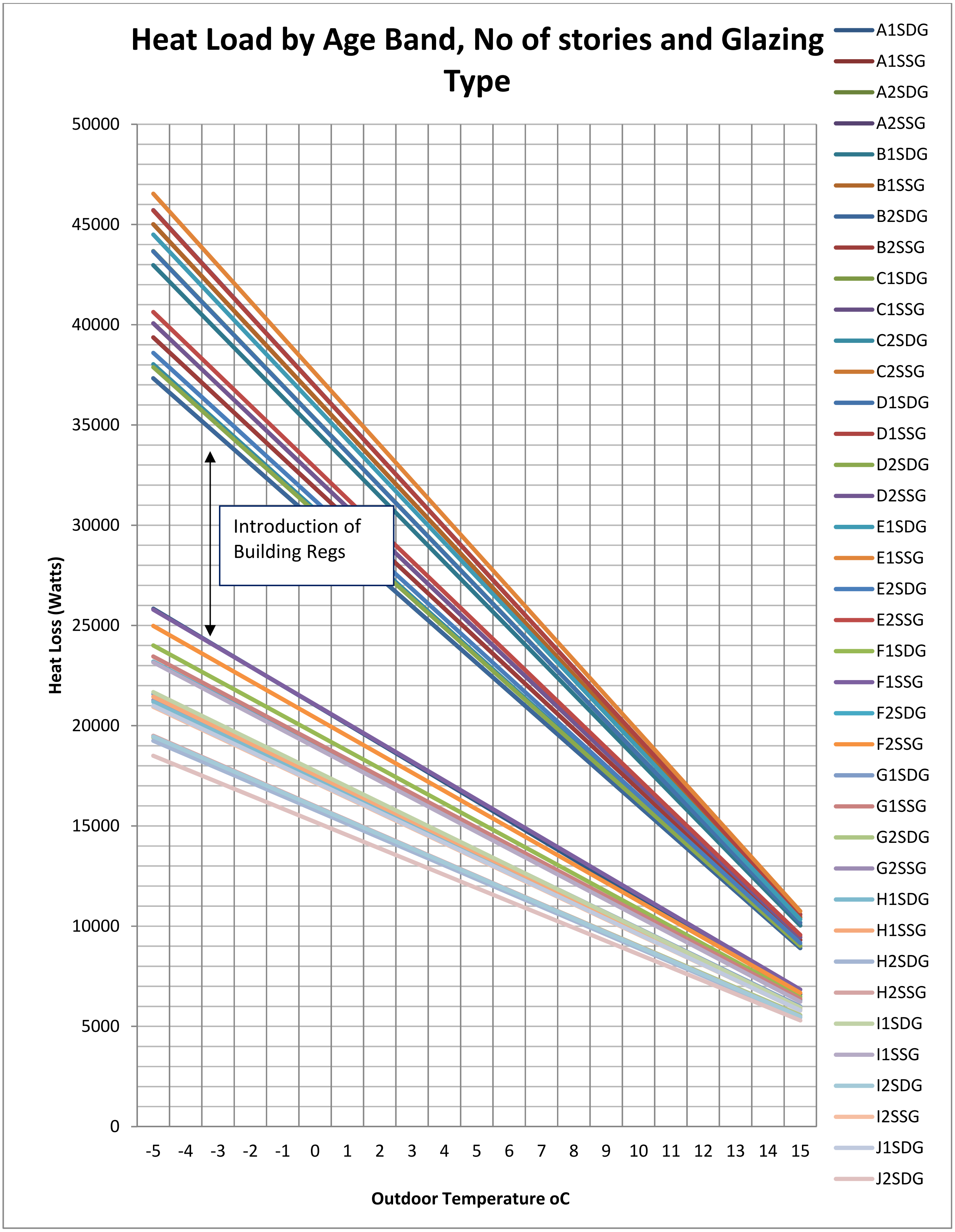


Figure 5.1.1.1 Heat Load by Age Band, Number of Stories and Glazing Type

5.1.2 Heat Loss Calculation Results (Post Fabric Improvement Measures)

Table 5.1.2.1 Summary Heat Loss Post Fabric Improvement Measures

House Type	1SDG	1SSG	2SDG	2SSG
	W/°C	W/°C	W/°C	W/°C
E	753	710	642	599
C	751	708	641	598
D	739	693	632	589
J	737	N/A	625	N/A
B	722	679	613	569
A	722	679	613	569
I	713	713	604	604
H	698	653	601	556
G	687	647	585	545
F	686	648	586	549

With the heat loss properties of the building envelope homogenised, the variance between the best and worst dwelling from a heat loss point of view is now much less at 9.8% (versus 225% before measures).

Interestingly, post fabric improvement measures, house type E still exhibits the greatest heat loss; further analysis found that this can be attributed to the large floor area which is assumed to have a static U-value. It can be concluded therefore that with all houses approximating the same insulations standard, the floor area and the floor U-value has a much greater influence on the heat loss characteristic.

Let us now examine the order of the other house types in Table 5.1.2.1; House Types A, B, C, D & E have high glazing ratios with respect to relatively small floor areas and also have poor floor U-values which secures their place at the top of the list.

It was however surprising to find that house type J now has the 4th largest heat loss, on examination it was found that house type J has the greatest amount of glazing in m^2 (Figure 5.1.2.1) and the greatest amount of doors totalling on average 2.7 doors (versus 2.1 doors for house types A&B, Ref: Table 4.3.6.2). The presence of a high degree of glazing and doors with their relatively poor thermal properties adversely affects the heat loss characteristics of newer housing.

It can be concluded therefore, as fabric improvement measures are employed; house size, window & door area become increasingly important factors in the heat loss characteristic of the dwelling.

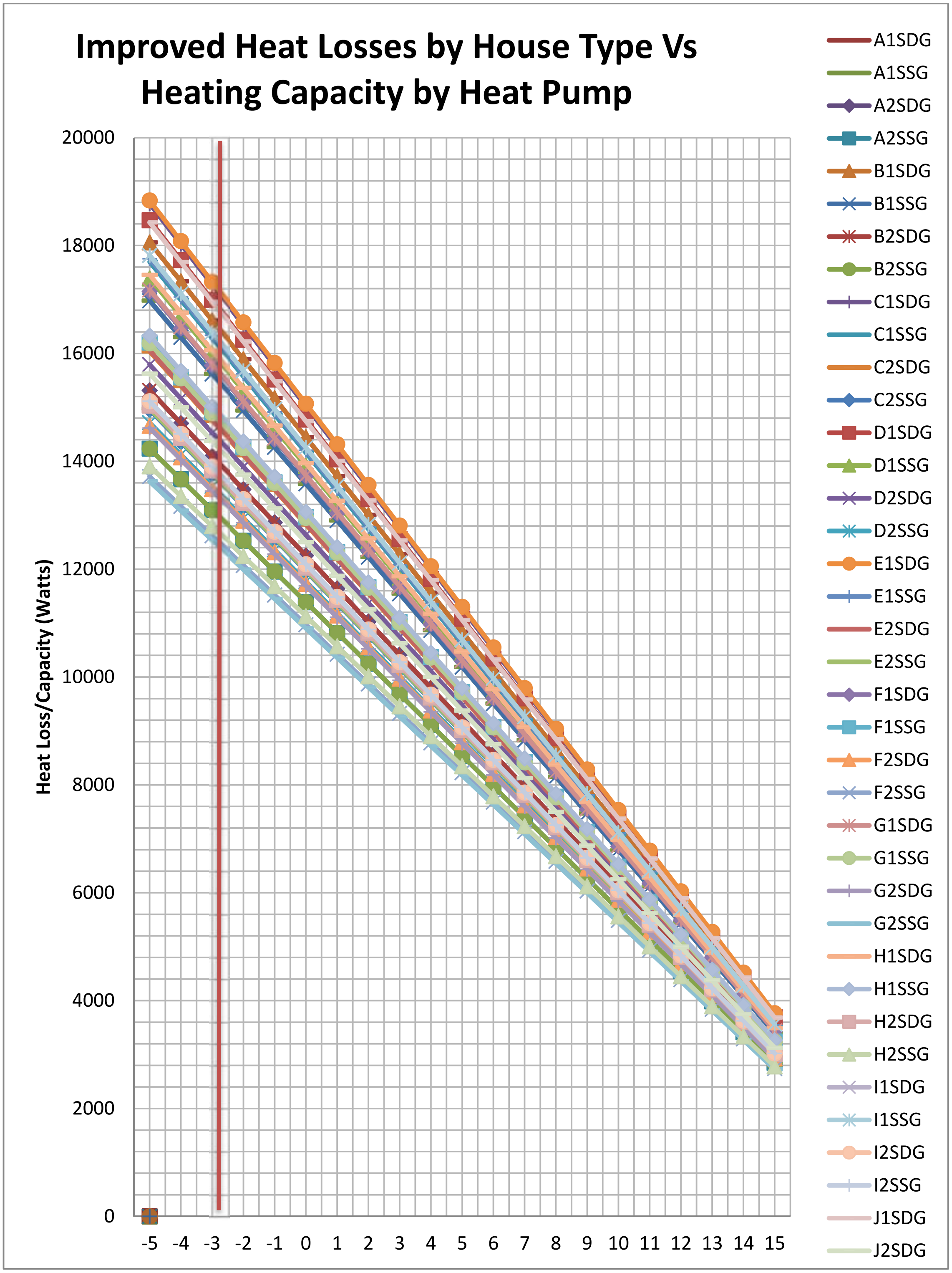


Figure 5.1.2.1 Heat Losses (Post Fabric Improvement Measures)

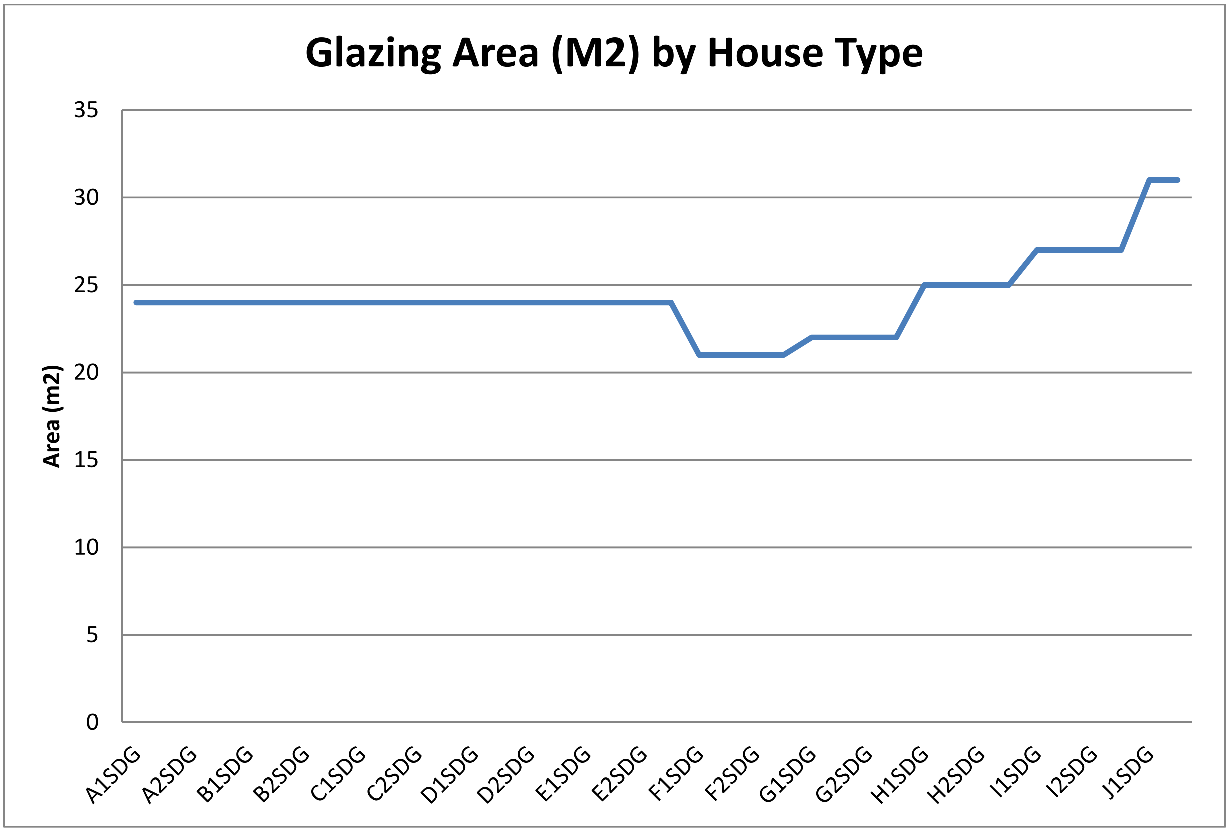


Figure 5.1.2.2 Window Area by House Type

It is apparent from Figure 5.1.2.2 that the introduction of the building regulations had the effect of reducing the amount of glazing present/m^2 of floor area, this is because a high percentage of glazing with its realtively poor U-value would have caused the dwelling to fail the overall U-value compliance check.

Figure 5.1.2.3 to 5.1.2.6 illustrate the scale of energy that can be potenially saved for detached housing in Ireland via the National Insulation programme. House types A to E can potentially realise the greatest savings due to their poor base point, according to CSO 2006, there are 164,246 centrally heated houses in this category. It also follows that due to large difference in the original versus the post fabric improvement heat loss characteristic, and as per equation 3.1, that lower flow and return temperatures can now be employed than in that of house types F to J (again on the assumption that comfort temperature were being reached prior to the fabric improvement measures).

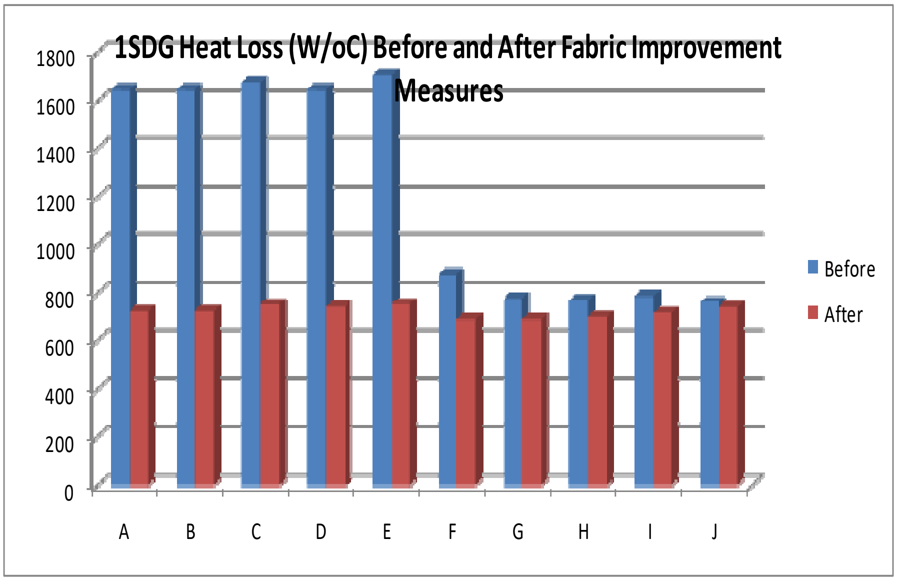


Figure 5.1.2.3

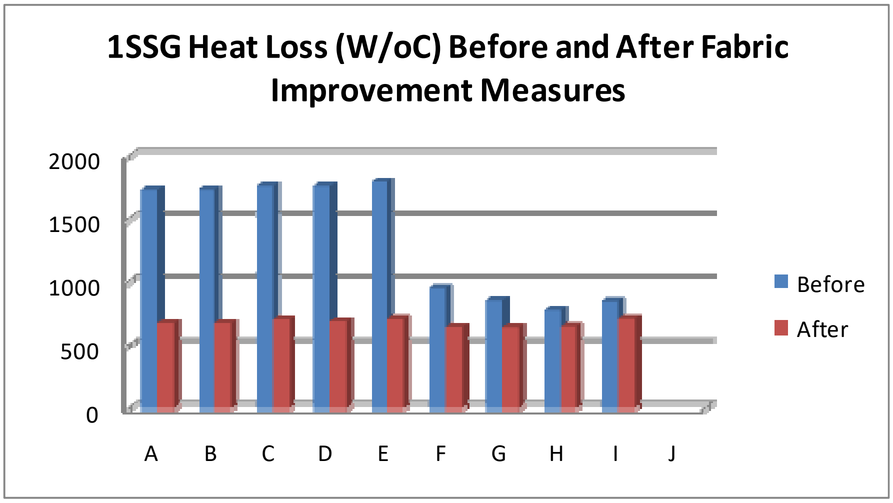


Figure 5.1.2.4

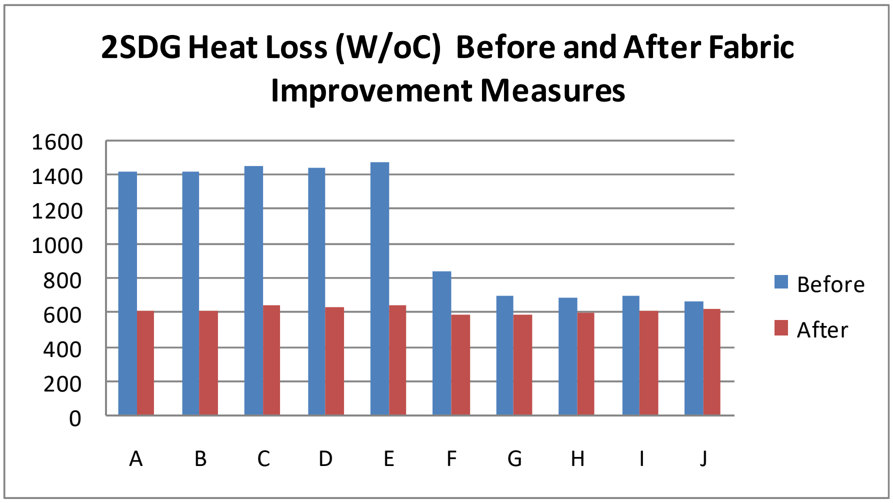


Figure 5.1.2.5

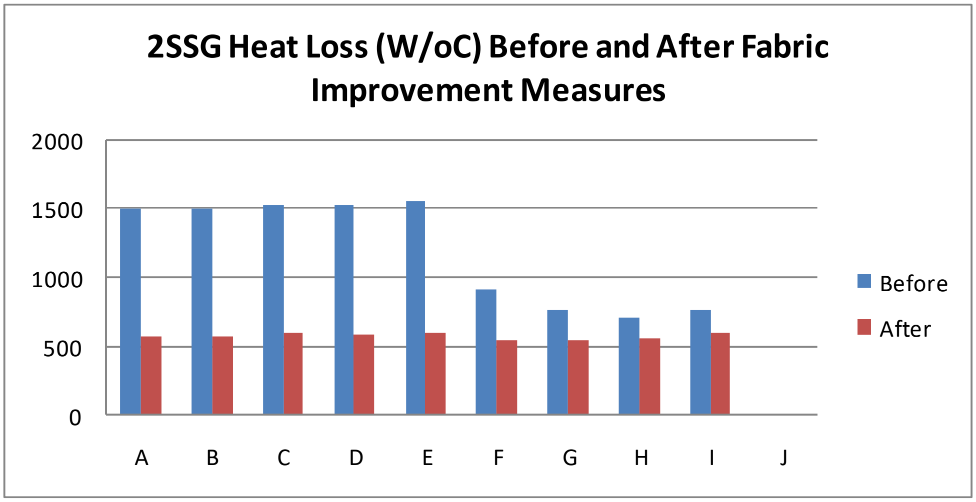


Figure 5.1.2.6

5.2 Revised Flow and Return Temperatures

As already outlined in chapter 3, if it assumed that the radiator system installed in the dwelling was capable of matching the heat loss characteristic of the space and hence comfort conditions, once the fabric elements are upgraded it follows that the radiators are now oversized for the new heat loss characteristic and so the system can realise the energy benefit of lower flow and return temperatures.

It is possible to ascertain the revised flow (t_f) and return temperature (t_r) by drawing a heat a balance with building heat loss and heat emission from the terminals and the required heating flow and return temperature such that;

Q= Building Heat Loss = Output from radiators = Required Heat output from heating flow and return

Therefore

$$Q = \left|\left(\sum UA + \tfrac{1}{3}NV\right)(t_o - t_C)\right| = KA\ (t_{m-}t_c)^n = mc\left(t_f - t_r\right) = \mathrm{kW}$$

Eqn 3.0

Ignoring the constants U, A, N, V, K, A, m, c

The relationship can between the prevailing outdoor conditions such that;

$$\frac{(t_o - t_c)_p}{(t_o - t_c)_o} = \frac{(t_m - t_c)_p}{(t_m - t_c)_o} = \frac{\left(t_f - t_r\right)_p}{(t_o - t_i)_o}$$

Eqn 3.1

Table 5.2.1.1 Data for Revised Heating Flow and Return Temperatures Calculation

Notation	Symbol	Description	Source
o		Original condition	
p		Prevailing condition (post insulation improvement measures)	
t_o	°C	Outdoor temperature determined	Design weather file provided through the internationally validated IES (Integrated Eonvironment Software). Outdoor condition - 3°C (CIBSE Guide A - approximate method)
t_c	°C	Indoor comfort temperature	Original condition 76°C (BSEN12831_2003)
t_m	°C	Mean water temperature of radiators	Original condition 76°C (CIBSE Guide B1)
n	1.3	empirical value for the output of the emitter	1.3 Radiators (CIBSE Guide B1)
t_f	°C	Heating water flow temperature	Original condition 82°C (CIBSE Guide B1)
t_r	°C	Heating water return temperature	Original condition 70°C (CIBSE Guide B1)

Older dwelling would have been originally constructed with single glazing; double glazing would have been retrofitted at some stage. It therefore assumed that the radiators were fitted to satisfy the original heat loss which would have included single glazing. Ironically, therefore the currently single glazed units do better under this scenario with respect to lower flow and return temperatures.

Table 5.2.1.2

Heating Water Flow Temperature by House Type (tf) °C			
A_{1SDG}	A_{1SSG}	A_{2SDG}	A_{2SSG}
51	50	50	49
B_{1SDG}	B_{1SSG}	B_{2SDG}	B_{2SSG}
51	50	50	49
C_{1SDG}	C_{1SSG}	C_{2SDG}	C_{2SSG}
51	50	51	50
D_{1SDG}	D_{1SSG}	D_{2SDG}	D_{2SSG}
51	50	51	49
E_{1SDG}	E_{1SSG}	E_{2SDG}	E_{2SSG}
51	50	51	49
F_{1SDG}	F_{1SSG}	F_{2SDG}	F_{2SSG}
64	62	61	59
G_{1SDG}	G_{1SSG}	G_{2SDG}	G_{2SSG}
67	65	65	63
H_{1SDG}	H_{1SSG}	H_{2SDG}	H_{2SSG}
71	69	69	67
I_{1SDG}	I_{1SSG}	I_{2SDG}	I_{2SSG}
69	69	67	67
J_{1SDG}		J_{2SDG}	
79		73	

Part 2 - Heat Pump Performance Modelling, Results and Analysis

6.0 Heat Pump Analysis

6.0 Heat Pump Analysis

It was necessary to select a number of heat pumps with a range of outputs so it was possible to compare the cost and CO_2 savings of the heat pumps operating in both monovalent and bivalent modes, see definitions below for clarification:

- **Monovalent Operation**

  Monovalent operation of the heat pump is considered when the capacity of the heat pump exceeds the heat load at design outdoor conditions i.e. -3°C

- **Bivalent Operation with Direct Electrical Heat Source**

  This is considered when the heat pump is operating close to monovalent with a secondary heat source required for only a small proportion of the year and where the load required is too small to justify a boiler installation.

- **Bivalent Operation with Condensing Boiler**

  This is considered when the heat pump is operating with a reasonable load required of the boiler

The full range of heat pumps for the following manufacturers was studied;

- Dimplex
- Mitsubishi
- DeLonghi/Climaventa
- Oschner
- Envirotech

Table 6.0.1 summarised the heat pump explored. The highest heating water temperature (t_f) of approximately 50°C shall be required of the heat pump when the prevailing outdoor temperatures (t_o) are low; conversely the lowest heating water temperature of approximately 35oC (t_f) shall be required when the outdoor temperatures (t_o) are high (i.e. approaching the balance temperature of 15°C). Therefore table 5.0.1 quotes the output and COP at t_o = -5°C with a t_f of 50°C and the output and COP at t_o = +15°C with a t_f of 35°C

Table 6.0.1 Heat Pump Comparison

Heat Pump Comparision							
Manufacturer	Model No	Output (kW)		COP		Elec Connec - tion	Cost Exclusive of VAT, inclusive of ancillaries ie buffer/installation packs etc
		-5°C @ T_f=50°C	+15°C @ T_f=35°C	-5°C @ T_f=50°C	+15°C @ T_f=35°C		
Mitsubishi	Ecodan	1.61	8	1.6	3.8	1 Phase	€ 3,830.50
Dimplex	LIK8ME	4.7	10	2	4.5	1 Phase	€ 8,000.00
DeLonghi	**Grandezza 11**	**4.9**	**8.6**	**2.23**	**5.38**	**1 Phase**	**€ 4,721.90**
DeLonghi	**Grandezza 25**	**6.7**	**10.9**	**2.16**	**5.45**	**1 Phase**	**€ 5,207.20**
Oschner	**GMLW 9 plus**	**6.6**	**12.8**	**2.2**	**5.2**	**1 Phase**	**€ 15,802.34**
Envirotech	Freat-12	7.4	11.2	2.01	4.124	1 Phase	€ 5,730.00
DeLonghi	**Grandezza 31**	**8.5**	**13.7**	**2.32**	**5.48**	**3 Phase**	**€ 5,382.00**
Oschner	**GMLW 14 plus**	**9.1**	**17**	**2.4**	**5.3**	**1 Phase**	**€ 16,896.34**
DeLonghi	Grandezza 41	10.3	17	2.24	5.15	1 Phase	€ 5,897.20
DeLonghi	**Grandezza 51**	**11.3**	**20.1**	**2.26**	**5.29**	**3 Phase**	**€ 6,127.20**
DeLonghi	**Grandezza 61**	**13.3**	**22.4**	**2.46**	**5.33**	**3 Phase**	**€ 6,809.15**
Oschner	**GMLW 19 plus**	**13.4**	**24**	**2.4**	**4.9**	**3 Phase**	**€ 20,005.34**
Oschner	**GMLW25**	**16.4**	**30**	**2.3**	**5.1**	**3 Phase**	**€ 22,830.34**
Dimplex	LI 28TE	20	40	2	3.75	3 Phase	€ 10,000.00

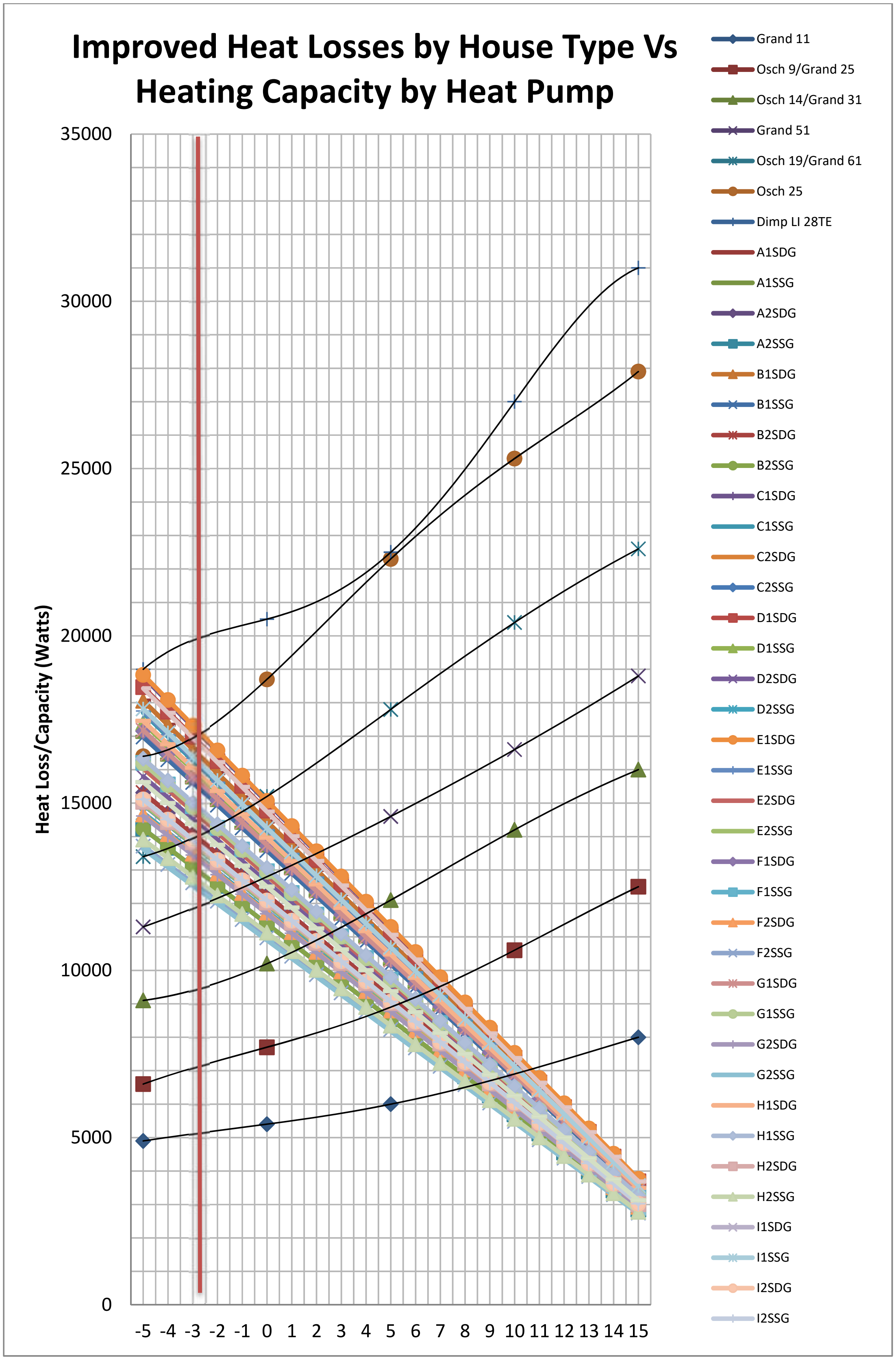
Table 6.0.1 also quotes the prices of the units; the Oschner units have the best COP's of any units to be found on the market today and so are selected for further analysis.

As is mentioned in the literature review Ireland is a location which experiences very high humidity and this causes the outdoor heat exchanger in to frost up periodically. Oschner maintain that their units have a better performance because they have a horizontal evaporator which prevents icing up (even in freezing fog!) and that their electronic expansion allows the system to control the expansion valve based on the air temperature meaning that the electrical elements typical of other units on the market today are designed out (Oschner_Blog 2009).

'Don't be fooled by air conditioning heat pumps on the market today, these cannot cope with the high levels of moisture in the air. So many 'heat pumps' have struggled to operate in previous winters, robbing their client of money by running a 6kW or 9kW electrical element with the COP dropped to 2, in an attempt to maintain operational, not to mention decrease in house temperatures.'

(Oschner_Blog 2009)

However, the high performance comes at a very high price and the Oschner units do not compare at all favourably with the other ranges it is therefore necessary to also review the next best performing units in each output range from the DeLonghi/Climaventa range. The Grandezza use an electrical defrost element in their units and their sales literature state that *'sophisticated controls...give a very short defrost cycle of 6mins'* it does not however state how big the electrical element is or how often it is necessary to run the defrost cycle and what temperatures!



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- Figure 6.0.1 Heat Loss Post Improvement Measures Vs Heat Pump Capacity

The Dimplex units are not analysed further as they have a poor COP compared to the Grandezza and Oschner units and still relatively costly.

The Mitsubishi Ecodan unit is simply too small with respect to the output required of the system.

Therefore Grandezza and Oschner units are analysed as they are the best performing units and are at different price points.

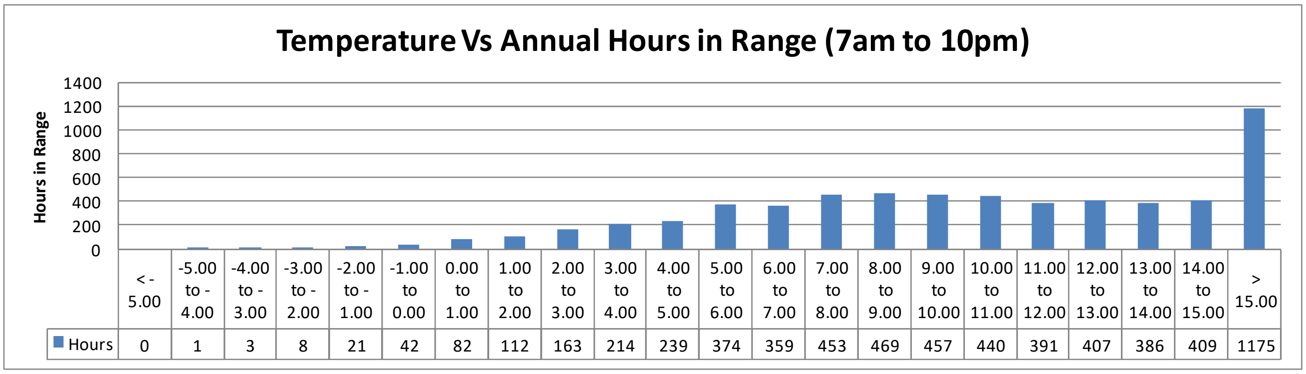
Due to time constraints it was not possible to model every heat pump, heat pumps were therefore grouped by similar performance characteristics (shown highlighted in the same colour in Table 6.0.1 and plotted against the heat loss characteristics in Figure 6.0.1) The COP and outputs for the Oschner units were used in the model.

The following units were selected for analysis:

- Low Range:	Grandezza 11
- Low to Mid Range:	Grandezza 25 and Oschner 9
- Mid Range:	Grandezza 31 and Oschner 14
- Mid to High Range :	Grandezza 61 and Oschner 19
- High Range:	Oschner 25

The heat pumps analysed are capable of delivering 60^{o}C flow water, over 60^{o}C the COP is very low, therefore it is assumed that an auxiliary boiler matches the heat load when a 60^{o}C flow temperature is required, the flow temperature shown in Figure 5.2.1.2 is the flow temperature required when the outdoor temperature is -3^{o}C.

It is therefore of interest to know therefore how often the temperature is below -3^{o}C in a statistical design year. Please see Fig. 6.0.2, the data for which was established again through the IES software for the occupied period of 7am to 10pm. Notwithstanding a cold snap as experience in December 2009 the outdoor temperature only falls below -3oC for 4 hours annually. This illustrates that the approximate method used for the calculation of outdoor temperature is conservative. IES uses a winter design temperature of 1.9^{o}C.



	< - 5.00	-5.00 to - 4.00	-4.00 to - 3.00	-3.00 to - 2.00	-2.00 to - 1.00	-1.00 to 0.00	0.00 to 1.00	1.00 to 2.00	2.00 to 3.00	3.00 to 4.00	4.00 to 5.00	5.00 to 6.00	6.00 to 7.00	7.00 to 8.00	8.00 to 9.00	9.00 to 10.00	10.00 to 11.00	11.00 to 12.00	12.00 to 13.00	13.00 to 14.00	14.00 to 15.00	> 15.00
■ Hours	0	1	3	8	21	42	82	112	163	214	239	374	359	453	469	457	440	391	407	386	409	1175

Figure 6.0.2

Figure 6.0.1 illustrates why heat pumps perform will in Ireland's climate as we have temperatures about 0ºC for 90% of the year over the occupied period. Total operating hours for the heat pump in a year are 5030, as previously stated this is a very high figure due to the assumption that dwelling is occupied from 10am to 7pm seven days a week, however due to the aforemention lack of information in respect of occupancy profiles of domestic houses it was necessary to assume so. Despite this however, this investigation compares 'The Standard Solution'with that of 'The Heat Pump Solution'and both are subjected to the same external conditions and heating water flow and return temperatures therefore the comparision is like with like. Therefore the scale of potential savings between the various technologies shall be accurate. Consequently the results shall be an indicator to the householder employing 'The Standard Solution'the potential for savings if a heat pump is retrofitted into the dwelling.

6.1 Domestic hot water production

The heat pump must satisfy the dwelling hot water load as well as cope withheat losses from the building envelop, BS 6700:1997 which is referenced in BS EN 15450:*2007* Heating systems in buildings states;

'Where the user requirements are not specified, and in particular where the user is not known, as in speculative housing developments for example, an assessment of user needs shall be made on the basis of the size and type of building, experience and convention.'

In the absence of national values, an average daily hot water demand of 1.45 kWh, corresponding to 25L at 60ºC per person per day, can be considered as a default for sizing domestic hot water systems. This corresponds to the average daily hot water consumption (Mandate M324 from the European Commission). Daily tapping patterns in residential building assume typically that the domestic hot water demand is required in the morning (35%), at noon (20%) and in the evening (45%), (BSEN15450:2007 2007)

BSEN 15450 outlines for two different strategies for DHW heating depending on electrical tariff, space available and cost effectiveness of design solutions.

Solution 1 – Accumulation – This solution results in a larger volume of DHW storage, which is sized on the maximum daily demand. The selected thermal capacity of the heat pump allows the DHW storage to be heated up during low cost tariff

Solution 2 – Semi-accumulation – This is the most general solution and requires that the heat pump is always available for hot water production. The designer shall check which period is most critical for maintaining the DHW storage at hot conditions.

It is necessary to determine typical occupancies by age band to determine the likely load on the dwelling by age band. Table 4.8.1 was established with a cross tabulation with the INSHQ dataset. The Full hot water calculations can be found in Appendix J, Please See Table 4.8.2 for summary data.

6.1.1 Household Size and Occupancy

Time Period	Total No of Rural Detached House Constructed in that period	Total No. of Occupants	Average No of Occupants	DEAP Age Band	DEAP Year of Construction	Average No of Occupants Corrected for DEAP Age Band
before 1919	74136	184853	2.49	A	before 1900	2.49
1919 to 1940	40418	100380	2.48	B	1900-1929	2.49
1941-1960	36,488	94018	2.58	C	1930-1949	2.53
1961-1970	25118	65448	2.61	D	1950-1966	2.59
1971-1980	65554	199210	3.04	E	1967-1977	2.88
1981 -1990	60593	216589	3.57	F	1978-1982	3.25
1991-1995	26533	99539	3.75	G	1983-1993	3.62
1996-2000	46844	169906	3.63	H	1994-1999	3.67
2001-2006	69436	221234	3.19	I	2000-2004	3.28
Sub Total	445120	1351177	3.04	J	2005-2006	3.19
Not Stated	5915	17265	2.92			
Total	**451035**					

Source:CS0 2006

Table 6.1.2 Summary Hot Water Calculations

Domestic Hot Water Load Calculations		DHW Storage Temp = θ_{DPset} = 60^{o}C				DHW Storage Temp = θ_{DPset} = 50^{o}C			
		Accumulation Sol^{n}		Semi-accumulation Sol^{n}		Accumulation Sol^{n}		Semi-accumulation Sol^{n}	
House Type	Average No of Persons	Size (Litres)	Thermal Energy needed (kW)	Size (Litres)	Thermal Energy needed (kW)	Size (Litres)	Thermal Energy needed (kW)	Size (Litres)	Thermal Energy needed (kW)
A,B,C,D, E	2.88	150	1.8	100	2.15	250	1.7	100	3.3
G, H	3.67	220	2.1	100	2.15	300	2	120	3.1
F,I, J	3.28	200	2	100	2.15	300	2	100	3.3

The semi-accumulation whilst resulting in smaller DHW cylinders is the least preferred solution as it reduces the most amount of thermal energy and thus reduces the potential heating capacity of the heat pump when it is required during the occupied period. The accumulation solution has the benefit of reducing the cost to the consumer and maximising the output from the heat pump during the occupied period. It is decided to run as per the BS EN guideline and employ a storage temperature of 50^{o}C as it reduces the load on the heat pump whilst maximising the COP due to the lower flow temperature required. The water shall periodically have to be heated to 60^{o}C, however the guide does not state what this period is. To simplify the calculation required this periodic heating to 60^{o}C has not been account for in the spreadsheet calculation.

The night time saver tariff in Ireland's runs at night from 12am to 8am in winter and from 11am to 7am during the summer. For the spreadsheet calculation, it is assumed that the entire volume of water required is heated at night, stored and then drawn off during the day.

6.2 Summary of Heat Pump Analysis Methodology

With respect to the outdoor/ambient temperature;

1. The COP and the output of the selected heat pumps were extrapolated from the manufacturer's data for flow temperatures of 35, 40, 45, 55 & 60 ^{o}C
2. The COP matching the flow temperature required of the system was then used in the calculation
3. If the flow temperature required was greater than 60^{o}C an oil fired boiler was engaged to meet the load
4. It is assumed that the heat pump meets the hot water requirement at night availing of the reduced electricity tariffs.
5. In bivalent operation either oil fired boiler or direct electric heating was employed to meet the load below the balance point temperature (t_b), see explanation below):

One of the issues identified with employing an oil boiler to meet a portion of the load in bivalent operation is that the smallest oil boiler available still has a very large capacity with respect to the load required. Three manufacturers of domestic oil boilers were reviewed, Firebird, Warmflow and Grant; Firebird's smallest condensing oil boiler is 20kW where Warmflow and Grant engineering smallest is 15kW. Not explored as part of this study, is the degradation of efficiency as such part load conditions, the boiler shall fire and as quickly switch off again so attention has to be paid to plant configuration and controls, therefore if the boiler load required is less that 5kW it is more pragmatic to assume the auxiliary heat input was supplied in the form of direct electric heaters

Full heat pump and condensing boiler analysis is available on the attached DVD

Section 6.2 presents a summary of findings from the model; an analysis follows in section 6.3

6.3 Heat Pump and Housing Analysis Results

6.3.1 House Type A & B

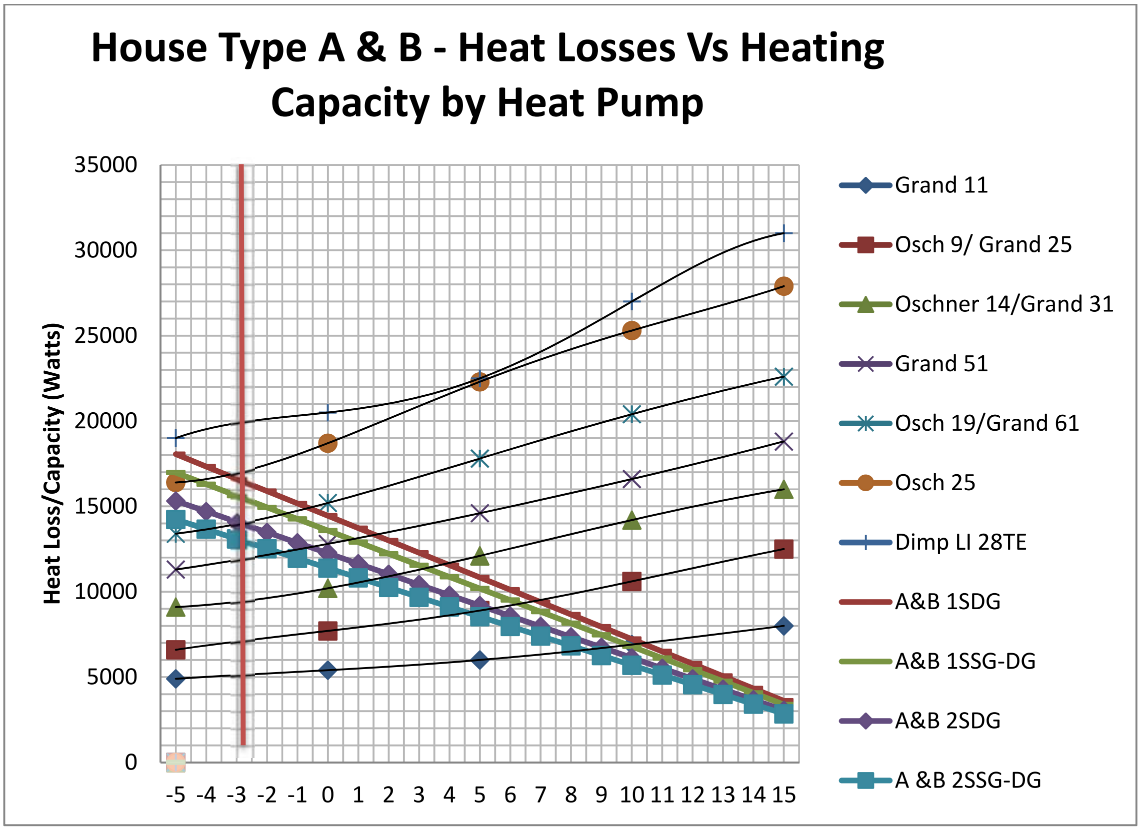


Figure 6.3.1.1

Table 6.3.1.1

Summary of Findings - House Type A&B - One Storey Double Glazed (A&B 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,322	€366	€ -	€ -	€ 6,688	158%	29119			29119	158%	N/A
Post Improvement Measures	€ 2,286	€302	€ -	€ -	€ 2,588	0%	11267			11267	0%	N/A
Oschner 25			€ 1,613	€ 114	€ 1,727	-33%		6233	887	7120	-37%	None
Oschner 19/Grand 61	€ 7	€ -	€ 1,582	€ 115	€ 1,704	-34%	26	6110	901	7037	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 69	€ -	€ 1,465	€ 105	€ 1,639	-37%	299	5660	822	6782	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 228	€ -	€ 1,416	€ 115	€ 1,759	-32%	991	5471	900	7362	-35%	Condensing Boiler
Grand 51	€ 15	€ -	€ 1,647	€ 117	€ 1,779	-31%	67	6363	912	7343	-35%	Condensing Boiler

Table 6.3.1.2

Summary of Findings - House Type A&B - One Storey Single Glazed to Double Glazed (A&B 1SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,633	€366	€ -	€ -	€ 6,999	179%	30473			30473	179%	N/A
Post Improvement Measures	€ 2,207	€302	€ -	€ -	€ 2,509	0%	10922			10922	0%	N/A
Oschner 25			€ 1,544	€ 114	€ 1,658	-34%		5966	887	6853	-37%	None
Oschner 19/Grand 61	€ 4	€ -	€ 1,509	€ 115	€ 1,629	-35%	15	5831	901	6747	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 54	€ -	€ 1,414	€ 105	€ 1,572	-37%	234	5461	822	6516	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 194	€ -	€ 1,375	€ 115	€ 1,684	-33%	846	5311	900	7057	-35%	Condensing Boiler
Grand 51	€ 11	€ -	€ 1,580	€ 117	€ 1,707	-32%	46	6103	912	7061	-35%	Condensing Boiler

Table 6.3.1.3

Summary of Findings - House Type A&B - Two Storey Double Glazed (A&B 2SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,456	€366	€ -	€ -	€ 5,822	160%	25342			25342	160%	N/A
Post Improvement Measures	€ 1,941	€302			€ 2,243	0%	9764	0	0	9764	0%	N/A
Oschner 19/Grand 61	€ -		€ 1,329	€ 115	€ 1,444	-36%	0	5134	901	6035	-38%	None
Oschner 14/Grand 31	€ 21		€ 1,265	€ 105	€ 1,392	-38%	93	4888	822	5802	-41%	Condensing Boiler
Oschner 9/Grand 25	€ 105		€ 1,261	€ 115	€ 1,481	-34%	456	4872	900	6228	-36%	Condensing Boiler
Grand 51	€ 5		€ 1,396	€ 117	€ 1,518	-32%	20	5395	912	6327	-35%	Direct Elec Heating

Table 6.3.1.4

Summary of Findings - House Type A&B - Two Storey Single Glazed to Double Glazed (A&B												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,769	€366	€ -	€ -	€ 6,135	192%	26713			26713	192%	N/A
Post Improvement Measures	€ 1,801	€302			€ 2,103	0%	9158	0	0	9158	0%	N/A
Oschner 19/Grand 61	€ -		€ 1,233	€ 115	€ 1,349	-36%	0	4765	901	5666	-38%	None
Oschner 14/Grand 31	€ 11		€ 1,182	€ 105	€ 1,298	-38%	48	4567	822	5436	-41%	Condensing Boiler
Oschner 9/Grand 25	€ 70		€ 1,193	€ 115	€ 1,378	-34%	305	4608	900	5813	-37%	Condensing Boiler
Grand 51	€ 2		€ 1,297	€ 117	€ 1,416	-33%	7	5012	912	5931	-35%	Direct Elec Heating

6.3.2 House Type C

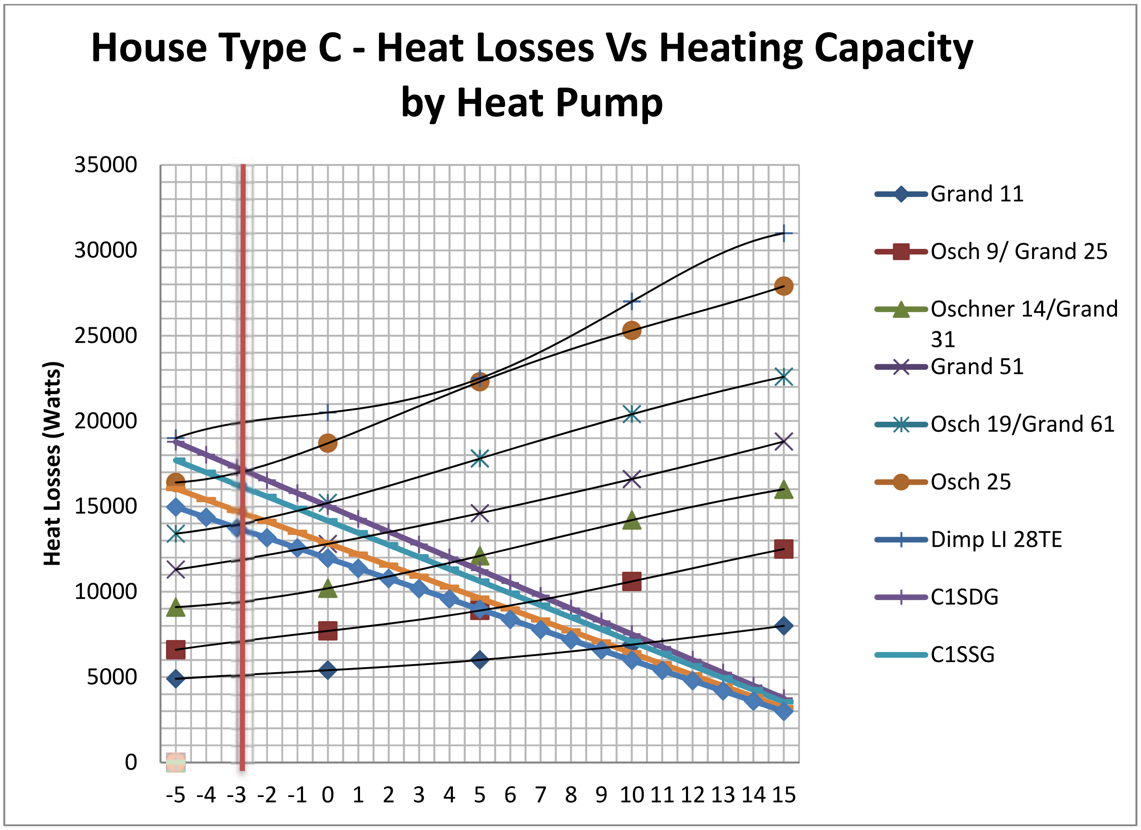


Figure 6.3.2.1

Table 6.3.2.1

Summary of Findings - House Type C - One Storey Double Glazed (C 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,430	€ 366	€ -	€ -	€ 6,796	154%	29587			29587	154%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,377	€ 302	€ -	€ -	€ 2,680	0%	11666			11666	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,678	€ 114	€ 1,792	-33%		6483	887	7370	-37%	None
Oschner 19/Grand 61	€ 11	€ -	€ 1,643	€ 115	€ 1,770	-34%	42	6349	901	7293	-37%	Direct Elec Heating
Oschner 14/Grand 31	€ 86	€ -	€ 1,512	€ 105	€ 1,703	-36%	375	5841	822	7038	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 267	€ -	€ 1,449	€ 115	€ 1,832	-32%	1164	5599	900	7663	-34%	Condensing Boiler
Grand 51	€ 23	€ -	€ 1,707	€ 117	€ 1,846	-31%	98	6595	912	7605	-35%	Condensing Boiler

Table 6.3.2.2

Summary of Findings - House Type C - One Storey Single Glazed to Double Glazed (C 1SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,744	€ 366	€ -	€ -	€ 7,110	180%	30957			30957	180%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,241	€ 302	€ -	€ -	€ 2,543	0%	11074			11074	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,569	€ 114	€ 1,682	-34%		6060	887	6947	-37%	None
Oschner 19/Grand 61	€ 5	€ -	€ 1,533	€ 115	€ 1,653	-35%	18	5921	901	6841	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 59	€ -	€ 1,432	€ 105	€ 1,596	-37%	256	5533	822	6611	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 208	€ -	€ 1,388	€ 115	€ 1,712	-33%	906	5363	900	7169	-35%	Condensing Boiler
Grand 51	€ 13	€ -	€ 1,603	€ 117	€ 1,732	-32%	55	6192	912	7159	-35%	Condensing Boiler

Table 6.3.2.3

Summary of Findings - House Type C - Two Storey Double Glazed (C 2SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjustment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjustment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,754	€ 366	€ -	€ -	€ 6,120	163%	25810			25810	154%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,029	€ 302	€ -	€ -	€ 2,331	0%	10150			10150	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,432	€ 114	€ 1,546	-34%		5534	887	6420	-37%	None
Oschner 19/Grand 61	€ 1	€ -	€ 1,406	€ 115	€ 1,523	-35%	5	5432	901	6339	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 31	€ -	€ 1,327	€ 105	€ 1,462	-37%	133	5125	822	6079	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 132	€ -	€ 1,313	€ 115	€ 1,560	-33%	576	5071	900	6547	-36%	Condensing Boiler
Grand 51	€ 10	€ -	€ 1,472	€ 117	€ 1,598	-31%	37	5686	912	6636	-35%	Direct Electric Heating

Table 6.3.2.4

Summary of Findings - House Type C - Two Storey Single Glazed to Double Glazed (C 2SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjustment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjustment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,887	€ 366	€ -	€ -	€ 6,253	185%	27180			27180	184%	N/A
Post Improvement Measures	€ 1,893	€ 302			€ 2,195	0%	9557	0	0	9557	0%	N/A
Oschner 19/Grand 61	€ -		€ 1,296	€ 115	€ 1,412	-36%	0	5008	901	5909	-38%	None
Oschner 14/Grand 31	€ 43		€ 1,237	€ 105	€ 1,385	-37%	166	4780	822	5767	-40%	Direct Elec Heating
Oschner 9/Grand 25	€ 92		€ 1,239	€ 115	€ 1,446	-34%	388	4785	900	6073	-36%	Condensing Boiler
Grand 51	€ 4		€ 1,363	€ 117	€ 1,483	-32%	14	5265	912	6191	-35%	Direct Elec Heating

6.3.3 House Type C

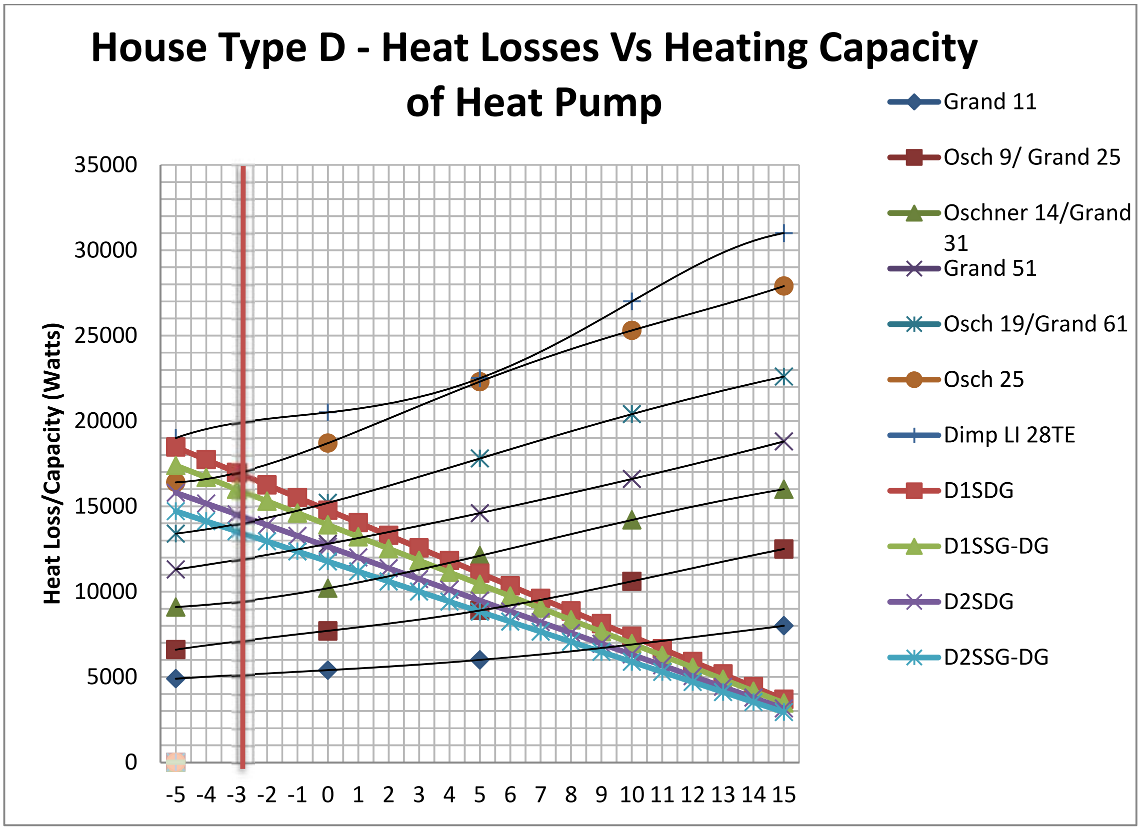


Figure 6.3.3.1

Table 6.3.3.1

Summary of Findings - House Type D - One Storey Double Glazed (D 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,426	€366	€ -	€ -	€ 6,792	157%	29570			29570	157%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,340	€302	€ -	€ -	€ 2,642	0%	11501			11501	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,651	€114	€ 1,765	-33%		6380	887	7266	-37%	None
Oschner 19/Grand 61	€ 9	€ -	€ 1,618	€115	€ 1,742	-34%	35	6250	901	7186	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 79	€ -	€ 1,493	€105	€ 1,677	-37%	343	5766	822	6932	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 251	€ -	€ 1,436	€115	€ 1,802	-32%	1091	5547	900	7538	-34%	Condensing Boiler
Grand 51	€ 48	€ -	€ 1,682	€117	€ 1,847	-30%	186	6499	912	7598	-34%	Direct Elec Heating

Table 6.3.3.2

Summary of Findings - House Type D - One Storey Single Glazed to Double Glazed (D 1SSG/DG)

	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,740	€366	€ -	€ -	€ 7,106	184%	30941			30941	192%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,203	€302	€ -	€ -	€ 2,505	0%	10581			10581	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,542	€114	€ 1,656	-34%		5957	887	6844	-35%	None
Oschner 19/Grand 61	€ 4	€ -	€ 1,507	€115	€ 1,626	-35%	15	5822	901	6738	-36%	Direct Elec Heating
Oschner 14/Grand 31	€ 53	€ -	€ 1,412	€105	€ 1,570	-37%	232	5454	822	6508	-38%	Condensing Boiler
Oschner 9/Grand 25	€ 193	€ -	€ 1,374	€115	€ 1,682	-33%	840	5306	900	7047	-33%	Condensing Boiler
Grand 51	€ 100	€ -	€ 1,578	€117	€ 1,795	-28%	100	6094	912	7107	-33%	Direct Elec Heating

Table 6.3.3.3

Summary of Findings - House Type D - Two Storey Double Glazed (D 2SDG)

	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,539	€366	€ -	€ -	€ 5,905	156%	25710			25710	156%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,001	€302	€ -	€ -	€ 2,303	0%	10026			10026	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,412	€114	€ 1,526	-34%		5456	887	6343	-37%	None
Oschner 19/Grand 61	€ 1	€ -	€ 1,387	€115	€ 1,503	-35%	4	5357	901	6262	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 27	€ -	€ 1,310	€105	€ 1,443	-37%	120	5061	822	6003	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 123	€ -	€ 1,300	€115	€ 1,539	-33%	537	5022	900	6459	-36%	Condensing Boiler
Grand 51	€ 8	€ -	€ 1,452	€117	€ 1,577	-32%	31	5609	912	6552	-35%	Direct Elec Heating

Table 6.3.3.4

Summary of Findings - House Type D - Two Storey Single Glazed to Double Glazed (D 2SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,854	€366	€ -	€ -	€ 6,220	187%	27080			27080	187%	N/A
Post Improvement Measures	€ 1,865	€302			€ 2,167	0%	9433	0	0	9433	0%	N/A
Oschner 19/Grand 61	€ -		€ 1,277	€115	€ 1,392	-36%	0	4933	901	5834	-38%	None
Oschner 14/Grand 31	€ 37		€ 1,220	€105	€ 1,363	-37%	145	4714	822	5681	-40%	Direct Electric Htg
Oschner 9/Grand 25	€ 85		€ 1,225	€115	€ 1,425	-34%	369	4731	900	6000	-36%	Condensing Boiler
Grand 51	€ 3		€ 1,343	€117	€ 1,462	-33%	11	5187	912	6110	-35%	Direct Elec Heating

6.3.4 House Type E

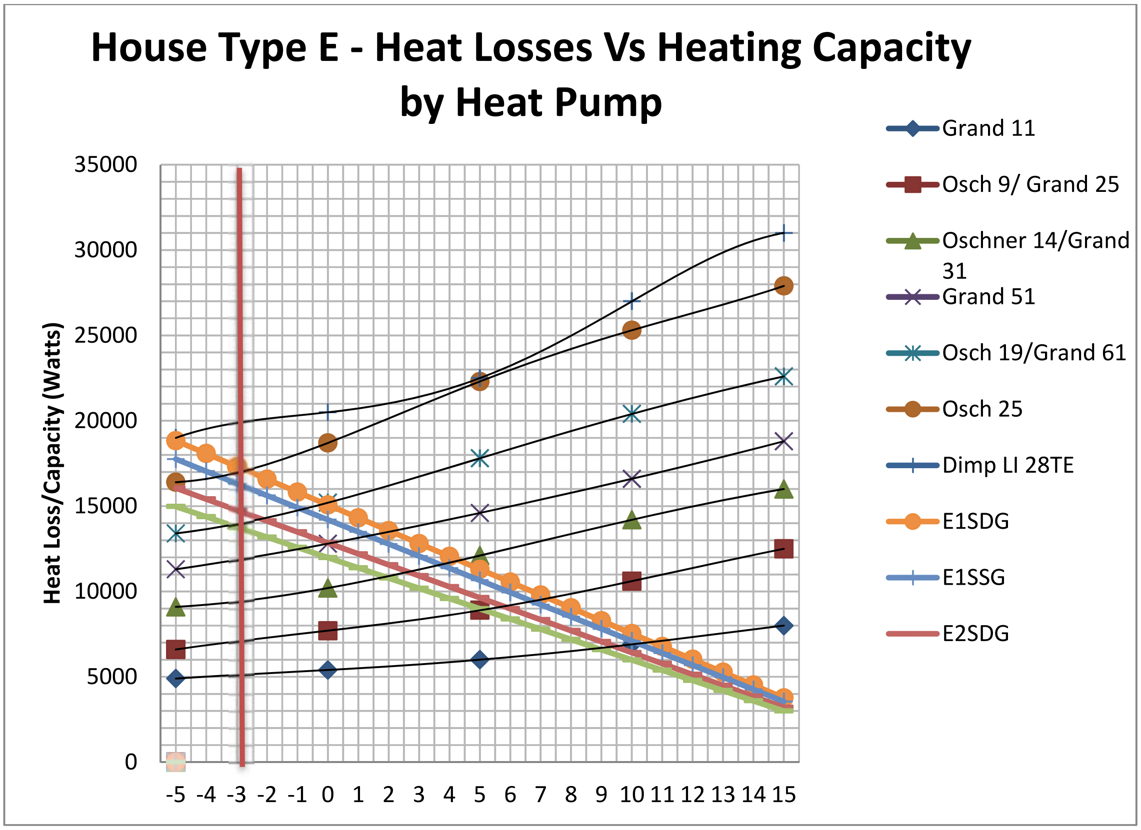


Figure 6.3.4.1

Table 6.3.4.1

Summary of Findings - House Type E - One Storey Double Glazed (E 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,556	€366	€ -	€ -	€ 6,922	158%	30139			30139	158%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,384	€302	€ -	€ -	€ 2,686	0%	11694			11694	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,668	€114	€ 1,782	-34%		6445	887	7332	-37%	None
19/Grand 61	€ 11	€ -	€ 1,628	€115	€ 1,754	-35%	41	6289	901	7232	-38%	Electric
Oschner 14/Grand 31	€ 83	€ -	€ 1,506	€105	€ 1,695	-37%	363	5819	822	7004	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 269	€ -	€ 1,440	€115	€ 1,824	-32%	1172	5562	900	7634	-35%	Condensing Boiler
Grand 51	€ 57	€ -	€ 1,695	€117	€ 1,869	-30%	221	6550	912	7683	-34%	Direct Electric Heating

Table 6.3.4.2

Summary of Findings - House Type E- One Storey Single Glazed to Double Glazed (E 1SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 6,867	€366	€ -	€ -	€ 7,233	184%	31492			31492	184%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,248	€302	€ -	€ -	€ 2,550	0%	11101			11101	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,587	€114	€ 1,700	-33%		6129	887	7016	-37%	None
Oschner 19/Grand 61	€ 6	€ -	€ 1,556	€115	€ 1,677	-34%	21	6010	901	6933	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 62	€ -	€ 1,446	€105	€ 1,613	-37%	270	5585	822	6676	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 212	€ -	€ 1,402	€115	€ 1,729	-32%	922	5416	900	7239	-35%	Condensing Boiler
Grand 51	€ 32	€ -	€ 1,622	€117	€ 1,771	-31%	125	6265	912	7302	-34%	Direct Elec Heating

Table 6.3.4.3

Summary of Findings - House Type E - Two Storey Double Glazed (E 2SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,650	€366	€ -	€ -	€ 6,016	136%	26195			26195	136%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,248	€302	€ -	€ -	€ 2,550	0%	11101			11101	0%	Condensing Boiler (97% efficiency)
Oschner 25			€ 1,587	€114	€ 1,700	-33%		6129	887	7016	-37%	None
Oschner 19/Grand 61	€ 6	€ -	€ 1,556	€115	€ 1,677	-34%	21	6010	901	6933	-38%	Direct Elec Heating
Oschner 14/Grand 31	€ 62	€ -	€ 1,446	€105	€ 1,613	-37%	270	5585	822	6676	-40%	Condensing Boiler
Oschner 9/Grand 25	€ 212	€ -	€ 1,402	€115	€ 1,729	-32%	922	5416	900	7239	-35%	Condensing Boiler
Grand 51	€ 32	€ -	€ 1,622	€117	€ 1,771	-31%	125	6265	912	7302	-34%	Direct Electric Heating

Table 6.3.4.4

Summary of Findings - House Type E - Two Storey Single Glazed to Double Glazed (E 2SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 5,961	€366	€ -	€ -	€ 6,327	188%	27548			27548	188%	N/A
Post Improvement Measures	€ 1,896	€302			€ 2,198	0%	9571	0	0	9571	0%	N/A
Oschner 19/Grand 61	€ -		€ 1,298	€115	€ 1,414	-36%	0	5016	901	5918	-38%	None
Oschner 14/Grand 31	€ 18		€ 1,239	€105	€ 1,362	-38%	77	4787	822	5685	-41%	Condensing Boiler
Oschner 9/Grand 25	€ 96		€ 1,240	€115	€ 1,451	-34%	404	4791	900	6095	-36%	Condensing Boiler
Grand 51	€ 4		€ 1,365	€117	€ 1,486	-32%	15	5274	912	6201	-35%	Direct Elec Heating

6.3.5 House Type F

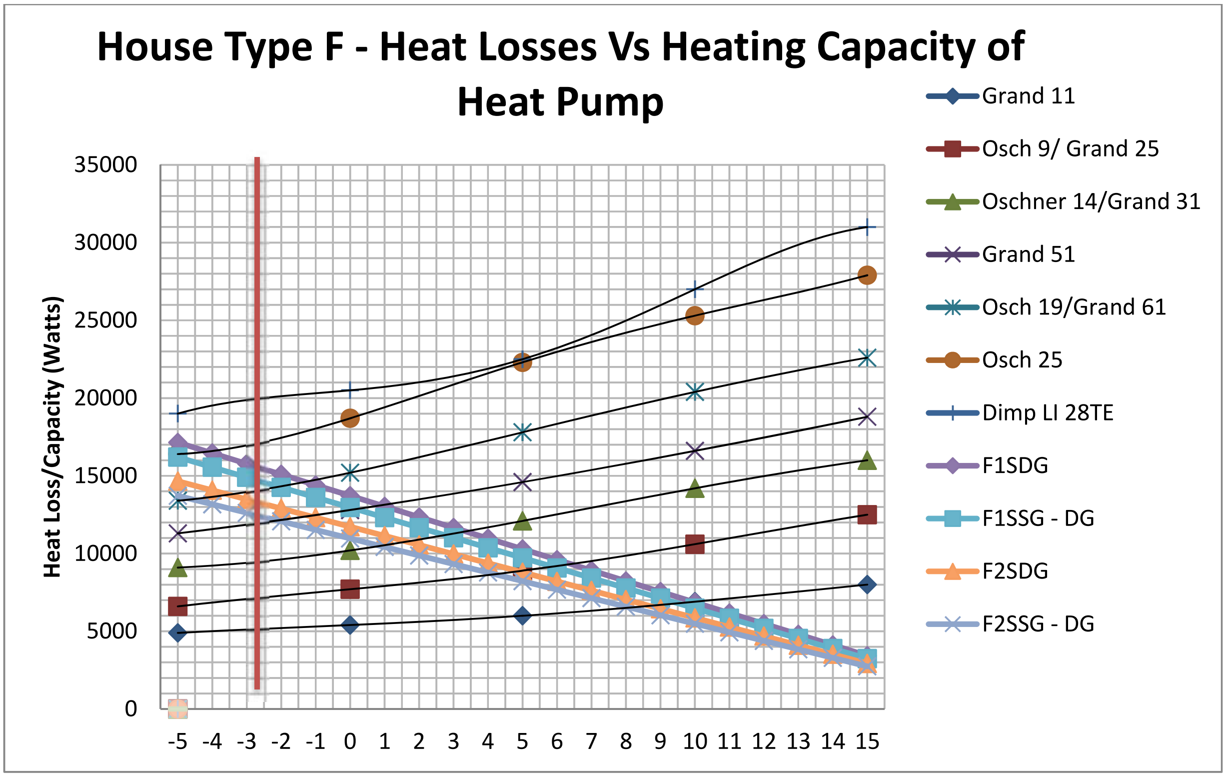


Figure 6.3.5.1

Table 6.3.5.1

Summary of Findings - House Type F - One Storey Double Glazed (F 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,363	€ 366	€ -	€ -	€ 3,729	51%	16234			16234	51%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,172	€ 302	€ -	€ -	€ 2,474	0%	10770			10770	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 59		€ 1,690	€ 114	€ 1,862	-25%	255	6528	887	7670	-29%	Condensing Boiler
Oschner 19/Grand 61	€ 59	€ -	€ 1,743	€ 115	€ 1,917	-23%	255	6733	901	7889	-27%	Condensing Boiler
Oschner 14/Grand 31	€ 96	€ -	€ 1,603	€ 105	€ 1,805	-27%	420	6193	822	7434	-31%	Condensing Boiler
Oschner 9/Grand 25	€ 239	€ -	€ 1,585	€ 115	€ 1,939	-22%	1041	6123	900	8064	-25%	Condensing Boiler
Grand 51	€ 60	€ -	€ 1,638	€ 117	€ 1,815	-27%	260	6328	912	7501	-30%	Condensing Boiler

Table 6.3.5.2

Summary of Findings - House Type F- One Storey Single Glazed to Double Glazed (F 1SSG/DG)

	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,639	€ 366	€ -	€ -	€ 4,005	70%	17438			17438	70%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,051	€ 302	€ -	€ -	€ 2,354	0%	10247			10247	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 18		€ 1,614	€ 114	€ 1,745	-26%	76	6235	887	7198	-30%	Condensing Boiler
Oschner 19/Grand 61	€ 18	€ -	€ 1,652	€ 115	€ 1,785	-24%	76	6384	901	7361	-28%	Condensing Boiler
Oschner 14/Grand 31	€ 50	€ -	€ 1,526	€ 105	€ 1,682	-29%	219	5896	822	6937	-32%	Condensing Boiler
Oschner 9/Grand 25	€ 171	€ -	€ 1,521	€ 115	€ 1,807	-23%	746	5876	900	7521	-27%	Condensing Boiler
Grand 51	€ 19	€ -	€ 1,577	€ 117	€ 1,713	-27%	84	6093	912	7089	-31%	Condensing Boiler

Table 6.3.5.3

Summary of Findings - House Type F - Two Storey Double Glazed (F 2SDG)

	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,240	€ 366	€ -	€ -	€ 3,606	67%	15699			15699	67%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,855	€ 302	€ -	€ -	€ 2,157	0%	9392			9392	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 6		€ 1,456	€ 114	€ 1,575	-27%	25	5624	887	6536	-30%	Condensing Boiler
Oschner 19/Grand 61	€ 6	€ -	€ 1,485	€ 115	€ 1,606	-26%	25	5735	901	6661	-29%	Condensing Boiler
Oschner 14/Grand 31	€ 22	€ -	€ 1,387	€ 105	€ 1,514	-30%	96	5357	822	6275	-33%	Condensing Boiler
Oschner 9/Grand 25	€ 102	€ -	€ 1,409	€ 115	€ 1,627	-25%	446	5443	900	6789	-28%	Condensing Boiler
Grand 51	€ 6	€ -	€ 1,432	€ 117	€ 1,555	-28%	27	5534	912	6473	-31%	Condensing Boiler

Table 6.3.5.4

Summary of Findings - House Type F - Two Storey Single Glazed to Double Glazed (F 2SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,512	€366	€ -	€ -	€ 3,878	90%	16886			16886	90%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,738	€302	€ -	€ -	€ 2,040	0%	8882			8882	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ -		€ 1,341	€ 114	€ 1,455	-29%	0	5181	887	6068	-32%	Condensing Boiler
Oschner 19/Grand 61	€ -	€ -	€ 1,358	€ 115	€ 1,474	-28%	0	5248	901	6149	-31%	Condensing Boiler
Oschner 14/Grand 31	€ 10	€ -	€ 1,277	€ 105	€ 1,393	-32%	46	4933	822	5800	-35%	Condensing Boiler
Oschner 9/Grand 25	€ 70	€ -	€ 1,308	€ 115	€ 1,494	-27%	306	5054	900	6260	-30%	Condensing Boiler
Grand 51	€ 1	€ -	€ 1,337	€117	€ 1,455	-28.70%	5	5164	912	6081	0	Condensing Boiler

6.3.6 House Type G

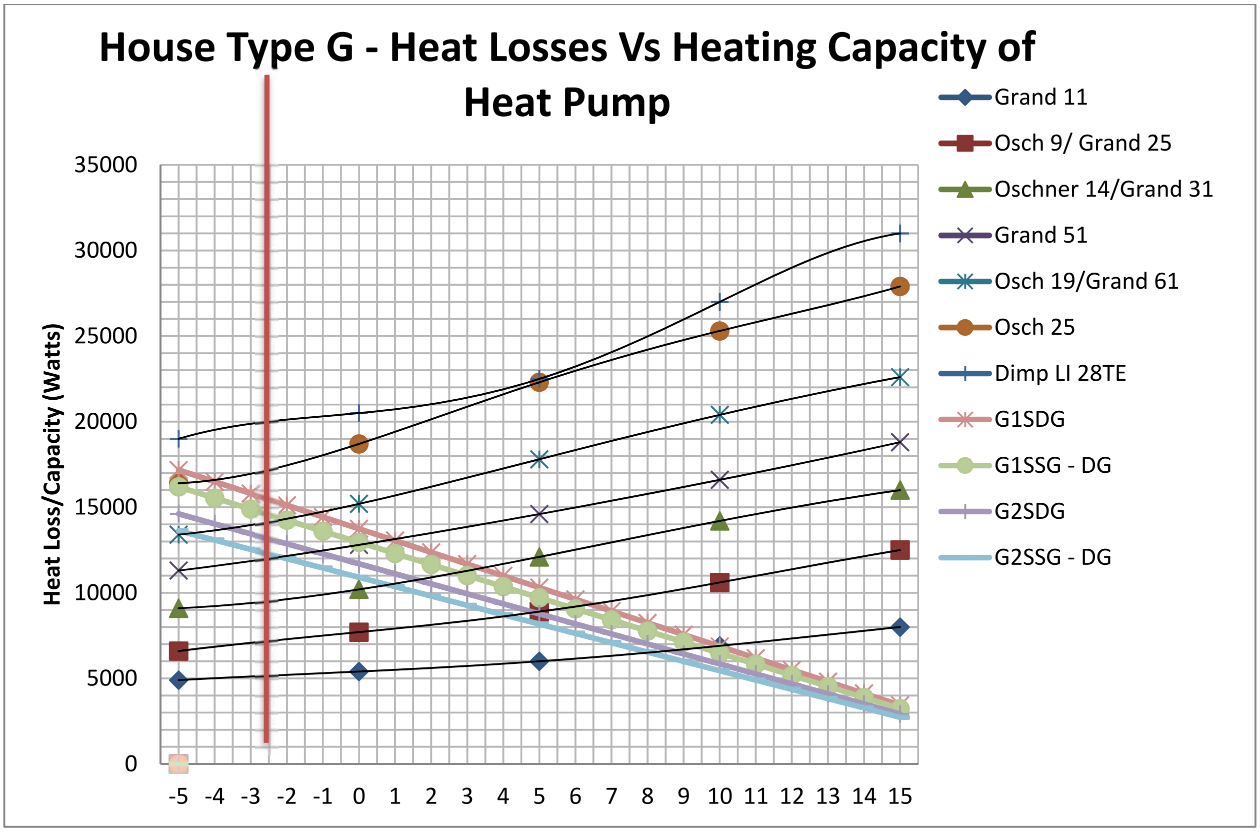


Figure 6.3.6.1

Table 6.3.6.1

Summary of Findings - House Type G - One Storey Double Glazed (G 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,990	€ 431	€ -	€ -	€ 3,421	38%	14895			14895	35%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,175	€ 302	€ -	€ -	€ 2,477	0%	11016			11016	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 191		€ 1,588	€ 134	€ 1,913	-23%	831	6137	1043	8010	-27%	Condensing Boiler
Oschner 19/Grand 61	€ 191	€ -	€ 1,660	€ 136	€ 1,987	-20%	831	6414	1060	8305	-25%	Condensing Boiler
Oschner 14/Grand 31	€ 202	€ -	€ 1,541	€ 124	€ 1,867	-25%	882	5953	967	7801	-29%	Condensing Boiler
Oschner 9/Grand 25	€ 319	€ -	€ 1,549	€ 136	€ 2,004	-19%	1387	5986	1059	8431	-23%	Condensing Boiler
Grand 51	€ 191	€ -	€ 1,527	€ 137	€ 1,856	-25%	831	5901	1073	7805	-29%	Condensing Boiler

Table 6.3.6.2

Summary of Findings - House Type G- One Storey Single Glazed to Double Glazed (G 1SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,278	€ 431	€ -	€ -	€ 3,709	58%	16148			16148	54%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,048	€ 302	€ -	€ -	€ 2,350	0%	10465			10465	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 94		€ 1,567	€ 134	€ 1,795	-24%	411	6052	1043	7507	-28%	Condensing Boiler
Oschner 19/Grand 61	€ 94	€ -	€ 1,624	€ 136	€ 1,854	-21%	411	6273	1060	7745	-26%	Condensing Boiler
Oschner 14/Grand 31	€ 109	€ -	€ 1,510	€ 124	€ 1,743	-26%	474	5834	967	7275	-30%	Condensing Boiler
Oschner 9/Grand 25	€ 214	€ -	€ 1,524	€ 136	€ 1,874	-20%	933	5888	1059	7880	-25%	Condensing Boiler
Grand 51	€ 94	€ -	€ 1,514	€ 137	€ 1,746	-26%	411	5848	1073	7332	-30%	Condensing Boiler

Table 6.3.6.3

Summary of Findings - House Type G - Two Storey Double Glazed (G 2SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,656	€ 431	€ -	€ -	€ 3,087	43%	13441			13441	40%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,852	€ 302	€ -	€ -	€ 2,154	0%	9610			9610	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 85		€ 1,417	€ 134	€ 1,636	-24%	372	5472	1043	6887	-28%	Condensing Boiler
Oschner 19/Grand 61	€ 85	€ -	€ 1,468	€ 136	€ 1,689	-22%	372	5672	1060	7104	-26%	Condensing Boiler
Oschner 14/Grand 31	€ 88	€ -	€ 1,376	€ 124	€ 1,588	-26%	384	5315	967	6666	-31%	Condensing Boiler
Oschner 9/Grand 25	€ 151	€ -	€ 1,421	€ 136	€ 1,708	-21%	659	5490	1059	7208	-25%	Condensing Boiler
Grand 51	€ 85	€ -	€ 1,369	€ 137	€ 1,591	-26%	372	5288	1073	6732	-30%	Condensing Boiler

Table 6.3.6.4

Summary of Findings - House Type G - Two Storey Single Glazed to Double Glazed (G 2SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,944	€ 431	€ -	€ -	€ 3,375	66%	14694			14694	62%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,725	€ 302	€ -	€ -	€ 2,027	0%	9059			9059	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 26		€ 1,355	€ 134	€ 1,515	-25%	115	5233	1043	6391	-29%	Condensing Boiler
Oschner 19/Grand 61	€ 26	€ -	€ 1,391	€ 136	€ 1,554	-23%	115	5375	1060	6551	-28%	Condensing Boiler
Oschner 14/Grand 31	€ 30	€ -	€ 1,308	€ 124	€ 1,462	-28%	133	5053	967	6152	-32%	Condensing Boiler
Oschner 9/Grand 25	€ 83	€ -	€ 1,356	€ 136	€ 1,574	-22%	362	5237	1059	6657	-27%	Condensing Boiler
Grand 51	€ 26	€ -	€ 1,320	€ 137	€ 1,484	-26.82%	115	5098	1073	6287	0	Condensing Boiler

6.3.7 House Type H

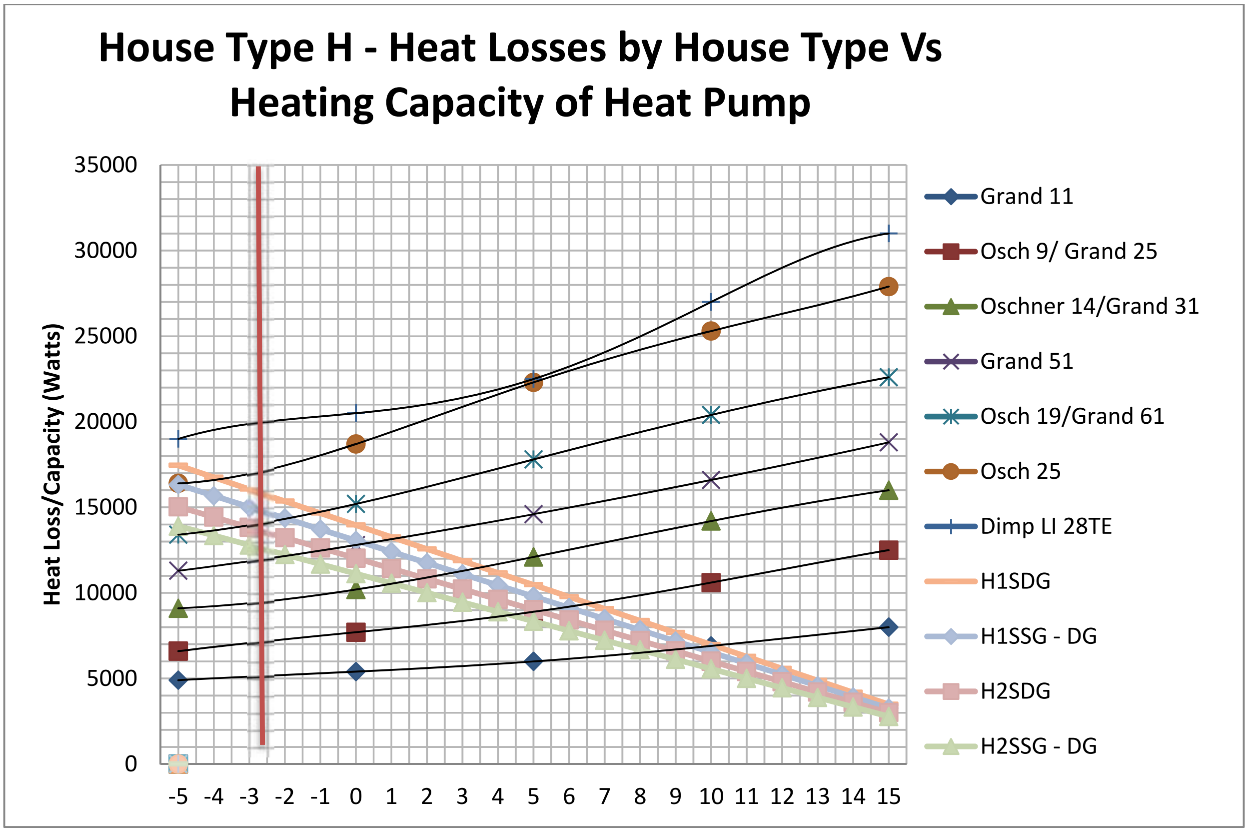


Figure 6.3.7.1

Table 6.3.7.1

Summary of Findings - House Type H - One Storey Double Glazed (H 1SDG)												
	Annual Running Costs						CO2 emissions					Comment / Secondary Heat Source
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	
Before Improvement Measures	€ 2,948	€ 431	€ -	€ -	€ 3,379	35%	14711			14711	32%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,210	€ 302	€ -	€ -	€ 2,512	0%	11168			11168	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 439		€ 1,406	€ 134	€ 1,978	-21%	1911	5431	1043	8385	-25%	Condensing Boiler
Oschner 19/Grand 61	€ 439	€ -	€ 1,499	€ 136	€ 2,074	-17%	1911	5791	1060	8763	-22%	Condensing Boiler
Oschner 14/Grand 31	€ 439	€ -	€ 1,386	€ 124	€ 1,949	-22%	1911	5353	967	8232	-26%	Condensing Boiler
Oschner 9/Grand 25	€ 502	€ -	€ 1,437	€ 136	€ 2,075	-17%	2186	5551	1059	8796	-21%	Condensing Boiler
Grand 51	€ 439	€ -	€ 1,342	€ 137	€ 1,919	-24%	1911	5185	1073	8170	-27%	Condensing Boiler

Table 6.3.7.2

Summary of Findings - House Type H- One Storey Single Glazed to Double Glazed (H 1SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,986	€ 431	€ -	€ -	€ 3,417	44%	14878			14878	41%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,067	€ 302	€ -	€ -	€ 2,369	0%	10548			10548	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 296		€ 1,415	€ 134	€ 1,844	-22%	1287	5467	1043	7798	-26%	Condensing Boiler
Oschner 19/Grand 61	€ 296	€ -	€ 1,496	€ 136	€ 1,928	-19%	1287	5781	1060	8128	-23%	Condensing Boiler
Oschner 14/Grand 31	€ 296	€ -	€ 1,391	€ 124	€ 1,810	-24%	1287	5373	967	7627	-28%	Condensing Boiler
Oschner 9/Grand 25	€ 357	€ -	€ 1,443	€ 136	€ 1,935	-18%	1553	5575	1059	8187	-22%	Condensing Boiler
Grand 51	€ 296	€ -	€ 1,354	€ 137	€ 1,787	-25%	1287	5229	1073	7590	-28%	Condensing Boiler

Table 6.3.7.3

Summary of Findings - House Type H - Two Storey Double Glazed (H 2SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,649	€ 431	€ -	€ -	€ 3,080	40%	13407			13407	36%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,903	€ 302	€ -	€ -	€ 2,205	0%	9831			9831	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 272		€ 1,303	€ 134	€ 1,708	-23%	1185	5032	1043	7260	-26%	Condensing Boiler
Oschner 19/Grand 61	€ 272	€ -	€ 1,377	€ 136	€ 1,785	-19%	1185	5321	1060	7566	-23%	Condensing Boiler
Oschner 14/Grand 31	€ 272	€ -	€ 1,280	€ 124	€ 1,676	-24%	1185	4945	967	7097	-28%	Condensing Boiler
Oschner 9/Grand 25	€ 301	€ -	€ 1,355	€ 136	€ 1,792	-19%	1312	5235	1059	7606	-23%	Condensing Boiler
Grand 51	€ 272	€ -	€ 1,246	€ 137	€ 1,655	-25%	1185	4813	1073	7071	-28%	Condensing Boiler

Table 6.3.7.4

Summary of Findings - House Type H - Two Storey Single Glazed to Double Glazed (H 2SSG/DG)											
	Annual Running Costs						CO2 emissions				
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total	
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,687	€ 431	€ -	€ -	€ 3,118	51%	13574			13574	47%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,760	€ 302	€ -	€ -	€ 2,062	0%	9211			9211	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 154		€ 1,286	€ 134	€ 1,574	-24%	672	4967	1043	6682	-27%	Condensing Boiler
Oschner 19/Grand 61	€ 154	€ -	€ 1,344	€ 136	€ 1,634	-21%	672	5191	1060	6924	-25%	Condensing Boiler
Oschner 14/Grand 31	€ 154	€ -	€ 1,256	€ 124	€ 1,535	-26%	672	4854	967	6493	-30%	Condensing Boiler
Oschner 9/Grand 25	€ 183	€ -	€ 1,330	€ 136	€ 1,648	-20%	795	5136	1059	6991	-24%	Condensing Boiler
Grand 51	€ 154	€ -	€ 1,236	€ 137	€ 1,528	-25.91%	672	4776	1073	6521	0	Condensing Boiler

6.3.8 House Type I

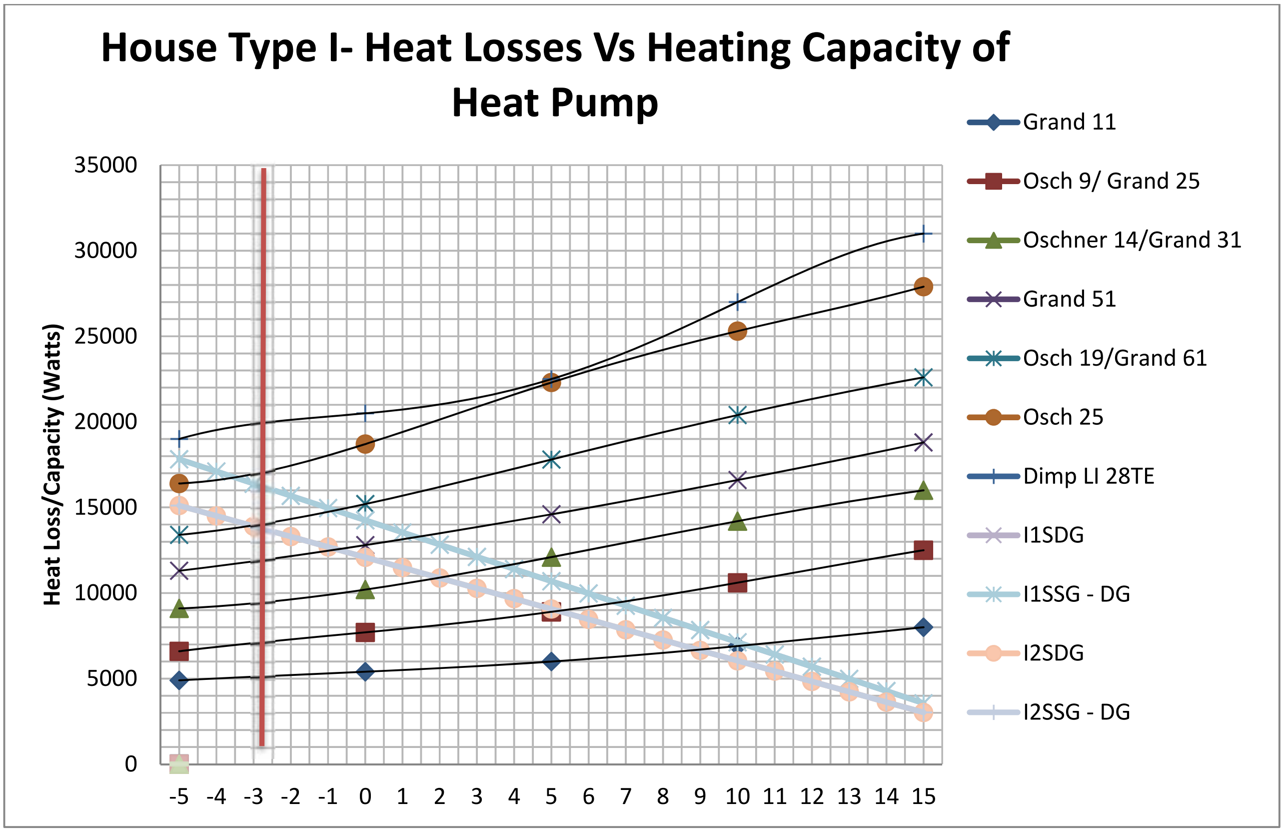


Figure 6.3.8.1

Table 6.3.8.1

Summary of Findings - House Type I - One Storey Double Glazed (I 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,021	€ 431	€ -	€ -	€ 3,452	35%	15028			15028	32%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,257	€ 302	€ -	€ -	€ 2,559	0%	11375			11375	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 323		€ 1,545	€ 134	€ 2,002	-22%	1406	5970	1043	8418	-26%	Condensing Boiler
Oschner 19/Grand 61	€ 323	€ -	€ 1,634	€ 136	€ 2,093	-18%	1406	6312	1060	8778	-23%	Condensing Boiler
Oschner 14/Grand 31	€ 327	€ -	€ 1,514	€ 124	€ 1,966	-23%	1425	5851	967	8242	-28%	Condensing Boiler
Oschner 9/Grand 25	€ 434	€ -	€ 1,532	€ 136	€ 2,101	-18%	1889	5918	1059	8866	-22%	Condensing Boiler
Grand 51	€ 323	€ -	€ 1,478	€ 137	€ 1,938	-24%	1406	5709	1073	8188	-28%	Condensing Boiler

Table 6.3.8.2

Summary of Findings - House Type I- One Storey Single Glazed to Double Glazed (I 1SSG/DG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 3,251	€ 431	€ -	€ -	€ 3,682	44%	16031			16031	41%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,257	€ 302	€ -	€ -	€ 2,559	0%	11375			11375	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 323		€ 1,545	€ 134	€ 2,002	-22%	1406	5970	1043	8418	-26%	Condensing Boiler
Oschner 19/Grand 61	€ 323	€ -	€ 1,634	€ 136	€ 2,093	-18%	1406	6312	1060	8778	-23%	Condensing Boiler
Oschner 14/Grand 31	€ 327	€ -	€ 1,514	€ 124	€ 1,966	-23%	1425	5851	967	8242	-28%	Condensing Boiler
Oschner 9/Grand 25	€ 434	€ -	€ 1,532	€ 136	€ 2,101	-18%	1889	5918	1059	8866	-22%	Condensing Boiler
Grand 51	€ 323	€ -	€ 1,478	€ 137	€ 1,938	-24%	1406	5709	1073	8188	-28%	Condensing Boiler

Table 6.3.8.3

Summary of Findings - House Type I - Two Storey Double Glazed (I 2SDG)

	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,679	€ 431	€ -	€ -	€ 3,110	40%	13541			13541	37%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,912	€ 302	€ -	€ -	€ 2,214	0%	9872			9872	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 168		€ 1,397	€ 134	€ 1,698	-23%	730	5395	1043	7169	-27%	Condensing Boiler
Oschner 19/Grand 61	€ 168	€ -	€ 1,460	€ 136	€ 1,763	-20%	730	5639	1060	7430	-25%	Condensing Boiler
Oschner 14/Grand 31	€ 168	€ -	€ 1,365	€ 124	€ 1,656	-25%	731	5272	967	6970	-29%	Condensing Boiler
Oschner 9/Grand 25	€ 224	€ -	€ 1,419	€ 136	€ 1,778	-20%	974	5481	1059	7513	-24%	Condensing Boiler
Grand 51	€ 168	€ -	€ 1,343	€ 137	€ 1,648	-26%	730	5188	1073	6991	-29%	Condensing Boiler

Table 6.3.8.4

Summary of Findings - House Type I - Two Storey Single Glazed to Double Glazed (I 2SSG/DG)

	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,910	€ 431	€ -	€ -	€ 3,341	51%	14544			14544	38%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,912	€ 302	€ -	€ -	€ 2,214	0%	10510			10510	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 168		€ 1,397	€ 134	€ 1,698	-23%	730	5395	1043	7169	-32%	Condensing Boiler
Oschner 19/Grand 61	€ 168	€ -	€ 1,460	€ 136	€ 1,763	-20%	730	5639	1060	7430	-29%	Condensing Boiler
Oschner 14/Grand 31	€ 168	€ -	€ 1,365	€ 124	€ 1,656	-25%	778	5272	967	7017	-33%	Condensing Boiler
Oschner 9/Grand 25	€ 224	€ -	€ 1,419	€ 136	€ 1,778	-20%	1037	5481	1059	7576	-28%	Condensing Boiler
Grand 51	€ 168	€ -	€ 1,343	€ 137	€ 1,648	-25.57%	777	5188	1073	7039	-33%	Condensing Boiler

6.3.9 House Type J

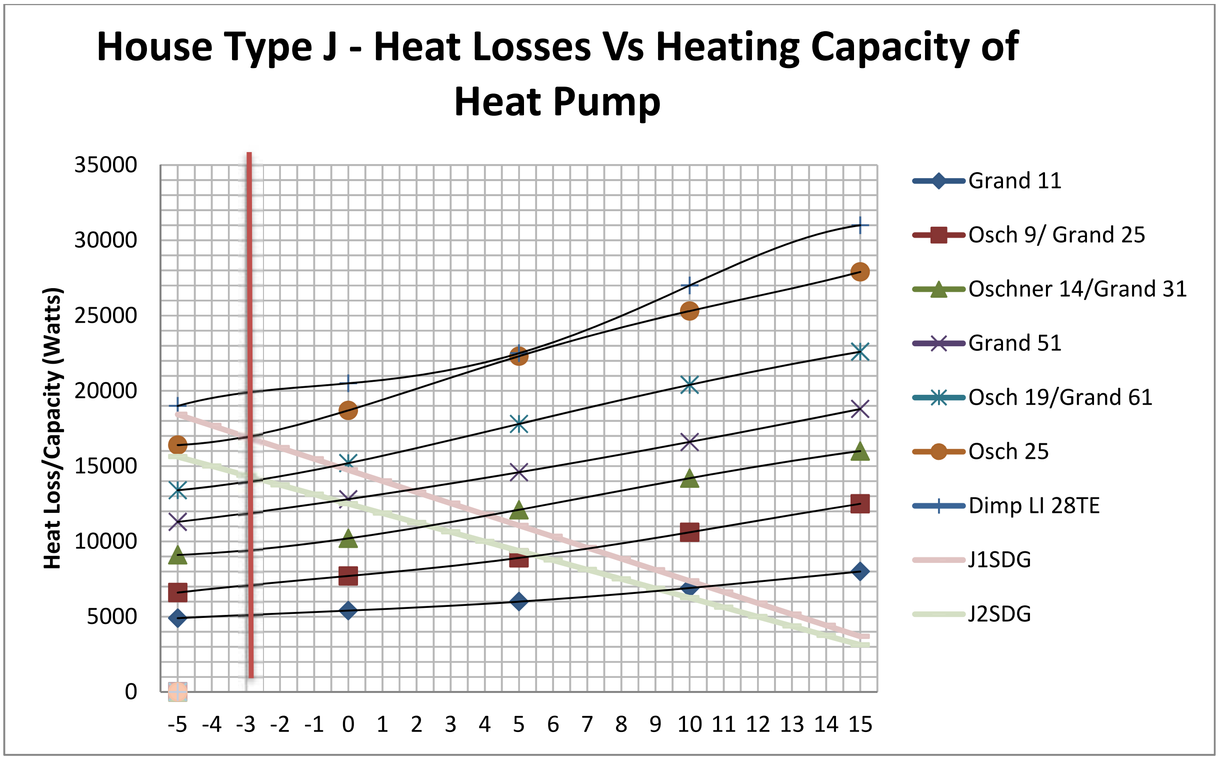


Figure 6.3.9.1

Table 6.3.9.1

Summary of Findings - House Type J - One Storey Double Glazed (J 1SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,917	€ 431	€ -	€ -	€ 3,348	27%	14577			14577	17%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 2,333	€ 302	€ -	€ -	€ 2,635	0%	12461			12461	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 1,063		€ 980	€ 134	€ 2,176	-17%	4627	3787	1043	9457	-24%	Condensing Boiler
Oschner 19/Grand 61	€ 1,063	€ -	€ 1,085	€ 136	€ 2,284	-13%	4627	4193	1060	9880	-21%	Condensing Boiler
Oschner 14/Grand 31	€ 1,063	€ -	€ 981	€ 124	€ 2,168	-18%	4925	3790	967	9682	-22%	Condensing Boiler
Oschner 9/Grand 25	€ 1,063	€ -	€ 1,054	€ 136	€ 2,252	-15%	4926	4072	1059	10057	-19%	Condensing Boiler
Grand 51	€ 1,063	€ -	€ 930	€ 137	€ 2,130	-19%	4925	3591	1073	9590	-23%	Condensing Boiler

Table 6.3.9.2

Summary of Findings - House Type J - Two Storey Double Glazed (J 2SDG)												
	Annual Running Costs						CO2 emissions					
	Boiler/Direct Htg		Heat Pump		Total		Boiler /Direct Htg	Heat Pump		Total		
Heat Pump/Boiler	Space Heating	DHW	Space Htg	DHW	Total	Adjust - ment	CO2 emissions (kg)	HP Space Htg CO2 Emissions (kg)	HP DHW CO2 Emissions (kg)	Total CO2 Emissions (kg)	Adjust - ment	Comment / Secondary Heat Source
Before Improvement Measures	€ 2,533	€ 431	€ -	€ -	€ 2,964	30%	12906			12906	19%	Standard Boiler (80% efficiency)
Post Improvement Measures	€ 1,979	€ 302	€ -	€ -	€ 2,281	0%	10818			10818	0%	Condensing Boiler (97% efficiency)
Oschner 25	€ 503		€ 1,167	€ 134	€ 1,803	-21%	2188	4509	1043	7741	-28%	Condensing Boiler
Oschner 19/Grand 61	€ 503	€ -	€ 1,259	€ 136	€ 1,897	-17%	2188	4863	1060	8111	-25%	Condensing Boiler
Oschner 14/Grand 31	€ 503	€ -	€ 1,158	€ 124	€ 1,784	-22%	2330	4473	967	7769	-28%	Condensing Boiler
Oschner 9/Grand 25	€ 510	€ -	€ 1,244	€ 136	€ 1,889	-17%	2362	4804	1059	8225	-24%	Condensing Boiler
Grand 51	€ 503	€ -	€ 1,110	€ 137	€ 1,750	-23%	2330	4289	1073	7692	-29%	Condensing Boiler

6.4 Analysis of Results

As expected the older the house and the poorer its insulation standard the greater the saving potential. Referencing figure 6.4.1; single glazed housing realised the greatest savings potential, this is because they can theoretically avail of lower flow and return temperatures, thus improving the COP of the heat pump, and hence achieving greater savings.

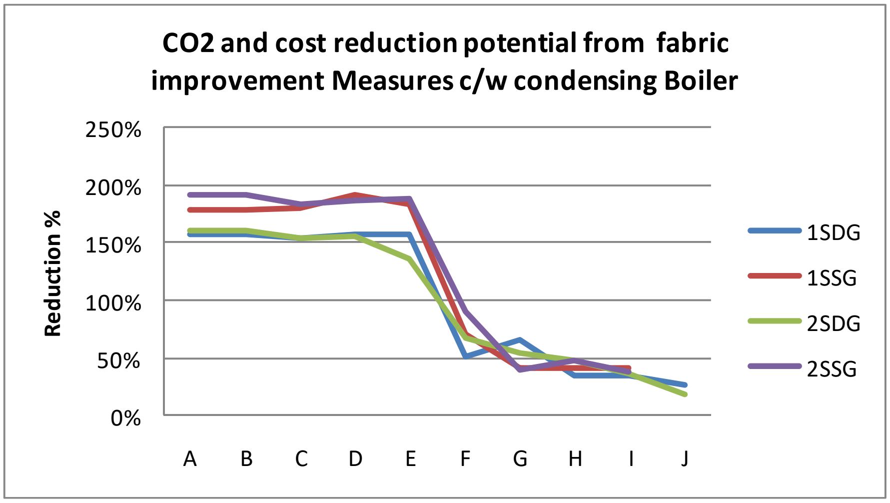


Figure 6.4.1

If we take a closer look at 1SDG type housing as a sample, reference Fig 7.0.2, we can compare the potential reduction the fabric improvement measures plus a high efficiency condensing boiler with the further saving potential with heat pump use. The results confirm that the NEEAP energy efficiency policy is correct when it states that the majority share of savings comes from energy efficiency measures and the government is correct to focus on the promotion of this area. The saving potential of house built prior to the introduction of the building regulations is staggering.

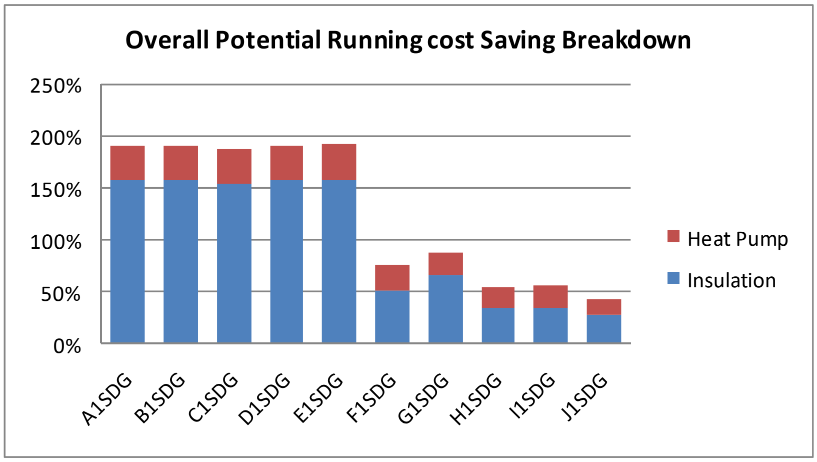


Figure 6.4.2

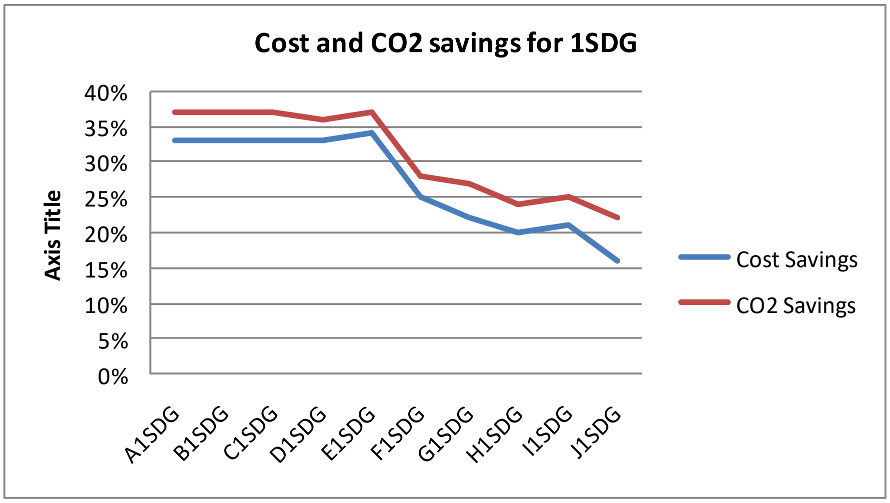


Figure 6.4.3

Let us now review the CO_2 and Cost saving potential shown in Fig 6.4.3. As a result of the literature review (Reginal 2009) it was expected to find that the economic case for heat pumps to less convincing than the carbon case. This study however, indicates that at current pricing levels that the *percentage* cost and CO_2 savings approximate one another by around 4%. In general the CO_2 saving potential is on average 3% greater than the cost saving potential for the older housing and 6.5% for newer housing.

Surprisingly, referencing table 6.3.1 to 6.3.9, the results indicate that the mode of operation whether monovalent or bivalent makes only a relatively small difference to the saving potential for that particular house type. It was expected that the heat pump mode of operation would have more of an impact than it has shown.

Bivalent heat pump operation produces greater cost savings and CO_2 savings than monovalent operation. Albeit the difference is not huge (-5%) but is surprising nonetheless because the boiler is expected to produce more CO_2/kWh, this can be explained by the fact that elevated heating flow and return temperatures are required when weather conditions are severe, the boiler is more efficient at delivering high temperature hot water that the heat pump is.

The Oschner 14/Grand 31 performs the best for house types A, B, C, D, E, F (190003 Houses) and the Grand 51 performs best for house types G, H, I, J (193,433 Houses).

The Grand 51 unit is a small bit bigger than the Oschner 14/Grand 31 unit.

An analysis of the balance point for house types A, B, C, D, E, F reveals that, for the Irish climate the optimum balance point occurs consistently at approximately 2.5°C, therefore below this temperature the boiler should fire.

Due to the homogenisation of the building envelope characteristics post fabric improvement measures and aside from property size, the only appreciable difference between house types A to F and G to J is the temperature of the heating flow and return. The model was set up such that if a heating flow temperature of above 60°C was required the boiler was employed in preference to the heat pump, this has resulted in the larger Grandezza 51 becoming the optimum unit for these dwellings as the boiler is employed for longer periods in these house types and this shift the optimum balance point to 0°C in house types G, H, I and J

Another surprising result is that the optimum balance point seems to correlate more with the heating flow and return temperatures that the heat loss characteristic of the dwelling!

Part 3 – Economic Analysis, Overall Analysis across Sector and Investigation Conclusions

7.0 Economic Analysis

7.0 Economic Analysis

To ensure the long term forecast of the heat pump units is accurate it is necessary to factor in the inflation rate of electricity and oil prices.

To establish the inflation rate associated with electricity tariffs an application for information was made to the Commission for Energy Regulation (CER 2010). On the information received it was calculated that the average inflation rate for the period 1998 to 2009 was 6.39%. See Table 6.2.1. The average all goods inflation rate for the Euro zone the period 1996-2009 is 1.9%[16] (Eurostat 2010), it is assumed this figure of 6.39% includes the average all goods inflation rate of 1.9%.

Table 7.0.1 Electricity Tariff Changes for the period 1998-2009

Year	Cost/kWh €	% Increase/ Decrease
1998	0.0795	0.00%
1999	0.0795	0.00%
2000	0.0795	0.00%
2001	0.0795	0.00%
2002	0.0883	9.97%
2003	0.1006	12.23%
2004	0.1055	4.64%
2005	0.1197	11.86%
2006	0.1285	6.85%
2007	0.1465	12.29%
2008	0.1559	6.03%
2009	0.1789	12.86%
Average		6.39%

Source: Commission for Energy Regulation (CER) on application

Eurostat (Eurostat 2010) publishes the cost of oil/1000 litres for the Euro zone for the period 2002-2008, see Table 6.2.2. The average inflation rate of oil is 6.42% it is assumed this figure of 6.39% includes the average all goods inflation rate of 1.9%.

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[16] Data published in February 2010 and is based on overall Harmonised index of consumer prices (HICP)

Table 7.0.2 Oil Price Inflation for the period 2002-2008

Year	Cost/1000 litres Diesel OIl €	Half Yearly % Increase / Decrease	Yearly % Increase / Decrease
2002	356.74		
2003	323.67	-10.22%	
	326.15	0.76%	-9.46%
2004	289.79	-12.55%	
	384.01	24.54%	11.99%
2005	416.24	7.74%	
	501.36	16.98%	24.72%
2006	522.85	4.11%	
	562.52	7.05%	11.16%
2007	484.83	-16.02%	
	536.9	9.70%	-6.33%
2008	622.85	13.80%	
Average		4.17%	6.42%

Source: Eurostat

Therefore the cost of oil was inflated at a rate of 6.42% and the cost of electricity inflated at a rate of 6.39% both figures are inclusive of the average good inflation rate.

The auxiliary boiler selected was a Grant Vortex oil fired condensing boiler which has a cost of €1,670 where direct electric heat is employed it is assumed that the cost of additional electric heaters amounts to €700[17].

With reference to prices as outlined in Table 6.0.1 the following Table 7.0.3 is a summary of the payback analysis, full details of which can be found in Appendix K, please not grants available from The Greener Homes Scheme have not been factored into the analysis.

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[17] Pricing supplied by Heat Merchants Limited

Table 7.0.6

SUMMARY OF PAYBACK ANALYSIS									
	Oschner 25	Oschner 25 (Price Adjusted)	Oschner 19	Grand 61	Grand 51	Oschner 14	Grand31	Grand 25	Oschner 9
A_{1SDG}	18	9	17	7	8	14	6	6	15
A_{1SSG}	18	9	17	7	8	14	5	6	15
A_{2SDG}			17	6	7	16	7	7	16
A_{2SSG}			18	7	7	16	7	7	17
B_{1SDG}	18	9	17	7	8	14	6	6	15
B_{1SSG}	18	9	17	7	8	14	5	6	15
B_{2SDG}			17	6	7	16	7	7	16
B_{2SSG}			18	7	7	16	7	7	17
C_{1SDG}	18	9	16	6	7	14	6	6	15
C_{1SSG}	16	9	16	6	7	14	6	6	15
C_{2SDG}	20	10	18	7	7	15	7	7	16
C_{2SSG}			19	8	7	15	7	7	16
D_{1SDG}	18	9	16	6	7	14	6	6	15
D_{1SSG}	18	9	17	7	7	14	6	6	15
D_{2SDG}	20	10	18	7	7	15	7	7	16
D_{2SSG}			19	8	7	16	7	7	16
E_{1SDG}	18	9	16	6	6	14	6	6	15
E_{1SSG}	18	9	17	7	7	14	6	6	15
E_{2SDG}	18	9	17	7	7	14	6	6	15
E_{2SSG}			19	8	7	15	7	7	16
F_{1SDG}	25	14	25	11	9	19	9	9	22
F_{1SSG}	25	14	25	11	9	19	9	9	21
F_{2SDG}	>25	14	25	11	10	19	9	9	22
F_{2SSG}	>25	14	24	11	7	18	9	9	21
G_{1SDG}	>25	15	>25	12	9	21	10	10	25
G_{1SSG}	>25	15	>25	12	10	21	10	10	25
G_{2SDG}	>25	16	>25	13	9	22	10	11	25
G_{2SSG}	>25	16	>25	13	7	21	10	10	25
H_{1SDG}	>25	16	>25	14	10	22	11	11	>25
H_{1SSG}	>25	16	>25	14	10	22	11	11	>25
H_{2SDG}	>25	16	>25	14	10	23	11	11	>25
H_{2SSG}	>25	16	>25	14	9	22	11	11	>25
I_{1SDG}	>25	15	>25	13	9	21	10	11	>25
I_{1SSG}	>25	15	>25	13	9	21	10	11	>25
I_{2SDG}	>25	16	>25	13	10	21	10	11	>25
I_{2SSG}	>25	16	>25	13	6	20	10	11	>25
J_{1SDG}	>25	18	>25	17	11	>25	13	13	>25
J_{2SDG}	>25	17	>25	15	11	23	12	12	>25
Average	**19**	**13**	**19**	**10**	**8**	**18**	**8**	**8**	**18**

The price point of the Oschner units is prohibitive even with the a grant from The Greener Homes Scheme, the resulting payback are very long and I suspect that it would be hard to convince a client to invest such a large capital sum in this technology especially in these hard economic times.

The DeLonghi/Climaventa - Grandezza Range is priced at a more realistic price point. Types 61/51/31/25 have similar paybacks, however due to inflation, the amount of monies to be saved over the longer term is much better with a larger unit.

7.1 Long-term Analysis

As the scale of savings approximate each other for the various heat pumps and due to time constraints, it is considered necessary to further analyse one heat pump over the longer term.

It is a tossup between the Grandezza 51 unit and the 31 unit. There are a greater number of houses benefiting from the Grandezza 51 unit so it is decided to focus on this unit as a test case to estimate the possible CO_2 and cost savings for the amount of houses in that particular age band. Summary Table s for monies saved after 10 year and 15 years can be found in Appendix L, and full calculations on the attached CD.

7.2 Summary of Investigation Results

Table 7.2.1 Summary of Investigation Results by House Type

		Cost Saving			CO2 Saving			Ratio of CO2 to Cost Savings (kgCO2/€)		
House	**%**	**Fabric**	**Heat Pump**	**Total**	**Fabric**	**Heat Pump**	**Total**	**Fabric**	**Heat Pump**	**Total**
A	17%	€ 183,448,317	€ 38,982,805	€ 222,431,122	816,533,595	162,561,547	979,095,142	4.5	4.2	4.4
B	13%	€ 141,556,955	€ 30,075,676	€ 171,632,631	630,085,031	126,960,982	757,046,013	4.5	4.2	4.4
C	12%	€ 133,133,712	€ 26,760,756	€ 159,894,468	571,085,324	136,714,135	707,799,459	4.3	5.1	4.4
D	12%	€ 127,454,963	€ 25,939,456	€ 153,394,419	556,185,432	128,117,377	684,302,809	4.4	4.9	4.5
E	19%	€ 206,284,592	€ 44,228,549	€ 250,513,141	898,170,647	223,760,584	1,121,931,231	4.4	5.1	4.5
F	5%	€ 44,767,693	€ 17,096,748	€ 61,864,441	194,872,473	92,993,050	287,865,523	4.4	5.4	4.7
G	8%	€ 63,206,975	€ 36,645,677	€ 99,852,652	261,251,882	187,932,460	449,184,342	4.1	5.1	4.5
H	5%	€ 40,843,450	€ 26,073,266	€ 66,916,716	167,165,483	135,395,835	302,561,318	4.1	5.2	4.5
I	6%	€ 45,300,897	€ 32,139,852	€ 77,440,749	172,722,420	135,988,663	308,711,083	3.8	4.2	4.0
J	3%	€ 24,111,040	€ 18,114,690	€ 42,225,730	72,895,847	105,386,705	178,282,552	3.0	5.8	4.2
		€ 1,010,108,594	**€ 296,057,475**	**€ 1,306,166,069**	**4,340,968,134**	**1,435,811,338**	**5,776,779,472**	**4.1**	**4.9**	**4.4**
		71%	29%	100%	67%	33%	100%			

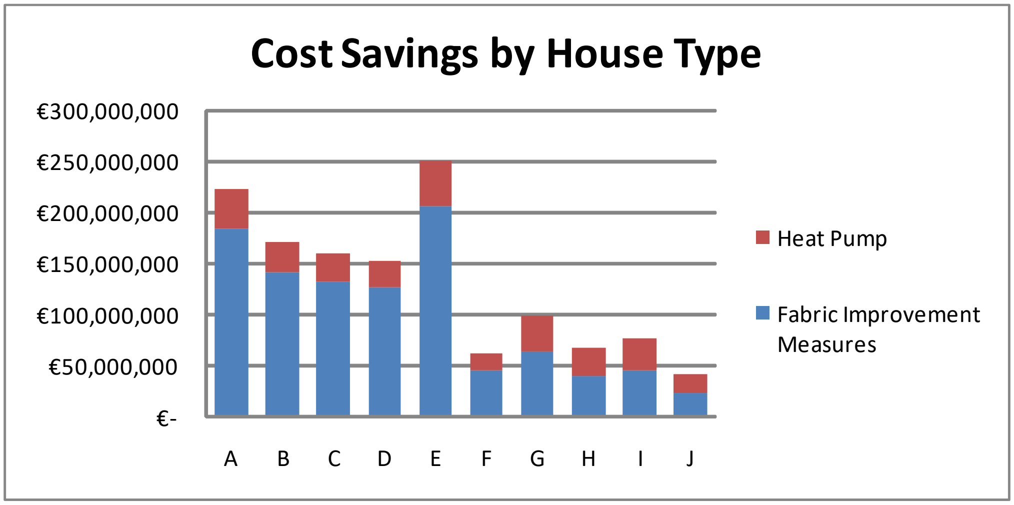

Figure 7.2.1

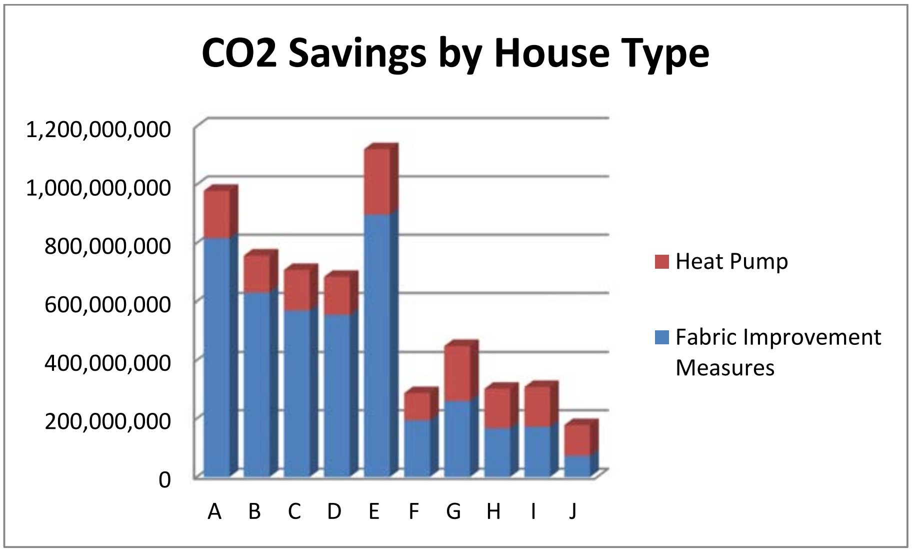

Figure 7.2.1

The savings shown in table 7.2.1 and Figure 7.2.1 & 7.2.2 are overestimated (due to extended occupancy profiles and assumed comfort levels) but are nevertheless indicative of the scale of reductions achievable through energy efficiency measures and heat pump operation

If we apply the indicative figures resulting to actual spend on energy in the residential sector in 2006, we get the following results:

The total spend on energy in the residential sector in 2006 2.5 billion (SEI 2008) and the average spend on energy per permanently occupied dwelling in 2006 was €1,767.

Roughly 80% of the energy bills are spent on heating and hot water and detached housing accounts for 43% of the sector. If we conservatively assume that, due to its larger size that this sector accounts for 50% of the current 2.5 billion spend the total spend on heating and hot water in the residential sector is;

2.5 billion x 0.8 x .5 = 1 billion is the estimated spend on energy for this house type.

Fabric improvement measures result in an average saving on the current energy bill of 61% for house types A to E and an average of 30% for house types F to J, the split among the volume of housing between these two age bands is 50/50 hence an average reduction of 45% is assumed.

If now estimate that the customers current energy bill can be reduced by 45% and if we assume that 12%[18] of the saving goes towards increasing comfort levels and alleviating fuel poverty, an estimated cost savings of:

1 billion x (0.45- 0.12) = 330 million

A further saving potential of €99 million (30%) from heat pump installations. Thus a total saving of €429 million is possible.

Table 7.2.1 shows the ratio of CO_2 emissions savings to cost savings; it is estimated that for every euro saved arising from fabric improvement measures a saving of 4.1 kg/CO_2/€ results and similarly for every euro saved through heat pump operation a saving of 4.9 kg/CO_2/€ results. Therefore the resultant savings in CO_2 emission possible are as follows;

Fabric Improvement Measures
= €330 million x 4.1 = 1.35 billion kg's of CO_2 = 1.35 million tonnes of CO_2

Heat Pump Operation
= €99 million x 4.9= 0.49 billion kg's CO2 = 0.49 million tonnes of CO_2

Therefore the resultant CO_2 emission savings possible are 1.84 million tonnes of CO_2

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[18] Ireland fuel poverty ratio is 12% Whyley, C., Callender C., (1997). Fuel Poverty in Europe: Evidence from the European Household Panel Survey. London, Policy Studies Institute.

8.0 Conclusions

8.0 Conclusions

8.1 Fabric Improvement Measures

- ✓ The case for fabric improvement measures is categorical; fabric improvement measures can reduce cost and CO_2 emissions from their current levels by up to 65% for older housing and by even 40% in newer housing. Thus this study is in agreement with the Government's focus on energy efficiency policy measures as outlined in NEAPP.

- ✓ Insulation measures will either greatly reduce fuel costs or alleviate fuel poverty by increasing the energy efficiency and thus cost effectiveness of the home whilst freeing up disposable income which is reinvested in the economy.

- ✓ The amounts of CO_2 which can be potentially saved outweigh the amount of money saved by a ratio of 4.1kg/CO_2/€. An approximate saving of €330 million euro is possible with a resultant saving of 1.35 million tonnes of CO_2 (1000kg/CO_2) arising from the retrofitting of insulation and the replacement of single glazed windows.

- ✓ The greatest savings (73%) are achieved by addressing the housing stock constructed prior to the 1979 building regulations House Type A to E

- ✓ As fabric improvement measures are employed within the existing stock and the thermal properties of the housing becomes more homogonised, house size, window and door area became the most influential factors for heat losses and the energy efficiency of the building envelope

8.2 Heat Pump

- ✓ The results have shown that heat pumps can be successfully employed as a direct replacement for a condensing boiler in systems serving radiators without replacing the existing radiators. The installation of a heat pump resulted in an average saving of 30% in both cost and CO2 emissions.

- ✓ Heat pumps can be successfully deployed in a house of any age provided they are sized accurately.

- ✓ Bivalent operation of the heat pump results in greater CO_2 and cost savings than monovalent operation at current performance and pricing levels; this is because the boiler is still better at handling the heating load when the outdoor temperature are low. However, the economic and carbon case for heat pumps operating in either monovalent or bivalent operation in the Irish climate is conclusive with an average seasonal COP of 4 resulting for the majority units

- ✓ A heat pump realises greater savings when low flow and return temperatures are used, However heat pump can still be successfully employed in heating systems requiring high heating water flow and return temperatures if a boiler is employed at low outdoor temperatures

- ✓ The amount of CO_2 which can be potentially saved through the employment of a heat pump outweighs the amount of money saved by a ratio of 4.9kg/CO_2/€. A approximate saving of €99 million is possible with a resultant saving of 0.49 million tonnes of CO_2 (1000kg/CO_2)

- ✓ Fuel inflation rates have a significant impact on payback analysis, the average payback period for heat pumps is 8 years for the lower price point (Grandezza) units and 16 years for the higher priced (Oschner) units

- ✓ Heat pump installations are made less attractive in Ireland than in other European countries, as Ireland, in 2009, had the highest electricity prices in Europe (Kirby 2010) A regulatory framework of making our electricity supply cheaper to the users of greener heat would help with the promotion of heat pumps.

Large scale deployment of domestic heat pumps will relocate the CO_2 emissions from current domestic fossil fuel burning systems to central electricity power plants. With the Irish government's proposal of employing greater amount of wind and ocean energy, heat pumps can be seen as devices supplying domestic heat without adding to the Ireland’s GHG emissions if they are run on renewable generated electricity.

Manufacturers need to engage is establishing more reliable performance prediction tools to avoid the over or under sizing of heat pumps for Ireland for which no past knowledge exists. To facilitate this there is a requirement for test standards to be revised to account for humidity levels, in this way a model can be built to predict the performance of the heat pump under certain climatic conditions. A greater amount of information is also required about the defrost method employed in the unit.

Laws and policies mentioned earlier are also expected to provide some impetus to the growth of the Ireland’s domestic heat pump market. Although it is difficult to predict the effect of these policies on one particular component of the renewable heat market, the effect is going to be felt across the board on all such renewable heat technologies. This may encourage competition among various different renewable heat technologies and in such an environment, less cost effective technologies may lose their market share. In this regard, heat pumps have an advantage in their ability to supply space heating, cooling and domestic hot water (unlike solar panels for instance).

8.2 Final Comment on Policy Measures

If the cost and CO_2 measures are to be realised it is important that the public at large engage with the policy measures the government has put in place, but the hard truth is that in recessionary times, money is an issue, both in terms of the public purse and the Irish people in general. The Insulation Retrofit scheme requires a minimum spend of €500 and it is necessary to have a Building Energy Rating carried out before and after works are in place to qualify for the monies. Consequently if a home owner decided to fit roof insulation at a cost of €250 they shall not qualify for the grant. In a survey carried out recently on 1000 Irish adults by a leading market research institute in Ireland called Amárach Research; it found that 58 % of homeowners responsible for energy bills said they didn't have enough money saved to upgrade their home, whilst 29 % said they didn't know which upgrade measures their homes needed. 43 % had made energy efficiency improvements and were keen to do more, 28 % had considered but not carried out improvements, whilst 16 % hadn't considered an energy upgrade before (Colley 2010).

"The results indicate that Irish people are ready to invest in energy efficiency if the requirement for upfront finance is removed," (Colley 2010)

Obstacles of this nature must be overcome if any significant volume of energy work is to be realized and there may be a more realistic route to addressing these problems – an approach developed in the US called 'Pay as You Save' (PAYS).

This approach was developed by Harlan Lachman and Paul A. Cillo of Vermont's Energy Efficiency Institute over the last decade, PAYS places little or no requirement for state subsidy in the form of grants or any other fiscal measure, and eliminates all disincentives to anyone investing in efficiency technologies, whether they're the owner or tenant of the home in question.

In short, PAYS offers people the opportunity of energy upgrading the building they occupy, without requiring them to provide upfront finance and without placing debt obligation to them. A PAYS tariff is instead assigned to the building through a utility bill. Customers who sign up for the PAYS tariff see and immediate financial benefit, as the repayment tariff is set up to cost less that the amount of energy that the customer has avoided using. For instance, if a customer uses PAYS to reduce their annual energy bills by an estimated €1000, the PAYS tariff would cost €750 – a net saving of €250.

Under PAYS, the repayments for the energy work on an energy bill would always be lower than the cost reduction caused by the energy efficiency savings achieved. To achieve this, Lachman and Cillo developed what they call the ¾ - ¾ rule. Firstly the amount of the monthly repayment term for PAYS products cannot exceed three quarters of the estimated saving, which means that the customer will get immediate financial savings – even if their savings estimates are off by as much as 25%. Secondly, the payment terms for PAYS products cannot be longer that three quarters of the measure's estimated life – thereby ensuring that customer's doesn't keep paying for technologies that they no longer use.

The payment obligation for the PAYS products is attached to the property through the electricity meter rather than a specific owner or occupant. A PAYS tariff is attached to the dwelling until all costs associated with the installing measures have been repaid, including missed payments, repairs, interest and programme fees and so on. If the occupancy of the property changes hands, the new occupant who receives the savings from the installed measure assumes the obligation to pay the PAYS tariff on their energy bills and if there is a gap between occupancies, the repayment period is extended accordingly.

Insulation measures as well as heat pumps could be included within a PAYS tariff; customers could even use such a tariff to make incremental improvements over time. For instance, initially the tariff could include a repayment for CFLs over, say one year, along with cavity and attic insulation over, say, three to five years. Perhaps after feeling the benefit of the insulation over a couple of years, the customer might like to add a heat pump to the tariff over five to eight years or so. Ten years down the line they may wish to use a PAYS tariff to help make their house carbon neutral. PAYS therefore offers the prospect of creating a continuous demand for innovative technologies to meet customers' needs in a changing energy (and climate) landscape.

There are precedents for this type of scheme. In the aftermath of the 1979 oil crisis, ESB and Moy Insulation teamed up to offer attic insulation to customers, requiring no upfront capital investment, but instead adding the cost to the energy bills of the participating customers. Roughly 30,000 attics were insulated on this basis, and the scheme was commercially successful. Similarly, the rural electrification of Ireland led to ESB opening shops over time and offering hire purchase on a broad range of appliances. Often this was a last resort for credit for many people, as their likelihood of defaulting was cut by their need for continuing energy supply.

The Energy Efficiency Institute developed PAYS in the late 1990's. Programmes based on PAYS have been successfully implemented by six utilities in Kansas, Hawaii and New Hampshire. Hundreds of customers at New Hampshire Electric Cooperative paid full cost for compact fluorescent light bulbs and several customers weatherised their homes and businesses, including the installation of improved heating, ventilation and air handling equipment. Municipal customers at the Public Service of New Hampshire implemented hundreds of efficiency projects, especially lighting and street lighting retrofits. More than 200 customers in Hawaii Electric Company's subsidiaries installed solar water heating systems, including many who had previously rejected offers. Midwest Energy has had 150 customers use its PAYS tariff to install insulation, new windows, and efficient heating systems (Colley 2010).

More recently, PAYS is being considered in Japan and the UK. Both the Labour government and the Conservative party `have recently backed PAYS as a proposed financing mechanism for low carbon refurbishment in the household sector, with the UK Department of Energy and Climate Change's recently announced Low Carbon Transition Plan including a commitment to the piloting of PAYS. Central to the UK version is the idea of spreading the cost of refurbishment for a property over a substantial period of time, and across different owners. A UK Green Building Council task group[19]has just published a proposal on overcoming the barriers to practical implementation of PAYS on its website.

Interestingly, the Department of Communications, Energy and Natural Resources has just gone out to consultation on a programme that could encourage the energy supply sector to adapt their business models to incorporate PAYS. The department is proposing that the programme, to be called the Energy Demand Reduction Target (EDRT) (DCENR 2010), may involve passing a law forcing the energy supply sector to substantially reduce the amount of energy consumed in Ireland, with a particular focus on stimulating end-use efficiency.[20]

Ireland's government should use the EDRT to set a mandatory energy and carbon reduction target for the energy sector to achieve, whilst encouraging energy suppliers to come up with solutions which prioritise end use efficiency. The government could even help their decision by facilitating cost-effective finance for energy efficiency work through issuing green bonds[21], for instance.

As far back as 2006 the International Energy Agency (IEA) estimated that, on average, $1 spent on more efficient electrical equipment, appliances, and buildings avoids more than $2 of investment in electricity supply (IEA 2006) Up till now, the Irish energy utilities haven't found a way of profiting from this equation. PAYS would change that, enabling the utilities to secure a guaranteed income into the medium to long-term, simply by enabling their customers to use less energy and the occupant would benefit by having a more comfortable, healthy carbon efficient building which can hold onto heat.

8.3 Areas for future study

- Another national survey on housing quality should be carried out as the information currently available is outdated. In addition to the survey question originally asked, the study should establish typical occupancy profiles for domestic units along with habits of heating use. Thus allowing for energy efficiency measures to be accurately quantified with respect to prevailing outdoor weather conditions. The study should

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[19] The UK PAYS report recommends that participating homeowners be billed through local authorities rather than energy companies. This may be more achievable in the UK, where homeowners are used to being billed by local authorities. Whilst this shouldn't be ruled out in Ireland, it may prove less attractive than using energy companies both from a promotion and billing point of view. Psychologically, it may be much more attractive for homeowners to repay for upgrade measures and pay for energy in one bill. The report can be downloaded from http://tinyurl.com/ukpays

[20] See **http://tinyurl.com/energyreduction** to access the EDRT consultation document. Submissions must be lodged by 30 September

[21] The government could set up a green fund, perhaps under the auspices of the National Treasury Management Agency, and fund it by issuing green government bonds. Those green bonds would offer a low but secured rate of return, and all monies invested in these bonds would be ring-fenced for green projects in Ireland, such as PAYS projects. This money would be used by the utilities to pay the upfront costs for approved energy upgrade work for projects using the PAYS principles, therefore offering occupants a low, secure interest rate and making the prospect of committing to repaying this over a long period of time attractive.

also quantify the amount of glazing and its orientation to allow for dynamic simulation of the building conditions.

- Further study needs to be carried out into the adverse affect of the defrost cycle on the unit COP in the Irish climate
- The model established in this investigation needs expanded to incorporate the effect of a buffer tank as this will increase the efficiency of the unit, also it would be interesting to establish the amount of further savings that could be realised with the use of under floor heating with its correspondingly low flow and return temperatures.
- An assessment of the effect that a widespread roll out of heat pumps on the balance of plant (BOP) on our national grid should also be carried out. This study should include for energy storage and more complex control strategies for the grid.
- A study should be carried out to establish the degradation of the boiler efficiency under such part load conditions as would occur under part load conditions. There is a requirement for the development of small oil boilers (≈5kW) that would be required for this scenario, also more study needs to establish the most efficient control mechanisms and optimum balance points.
- More reliable statistical weather files need to be established for different areas in rural Ireland

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8.0 Bibliography

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9.0 Appendices

9.0 Appendices

Appendix A – Rural Urban Housing by Fuel Type

Table A1 Quantity of Rural Houses by year and presence of Central Heating

Year built * Central heating Crosstabulation

			Central heating			
			Not stated	Has central heating	No central heating	Total
Year built	Not stated	Count	7704	6074	1329	15107
		% within Year built	51.0%	40.2%	8.8%	100.0%
		% within Central heating	73.6%	3.3%	8.3%	7.1%
		% of Total	3.6%	2.9%	.6%	7.1%
	Before 1919	Count	270	15173	3006	18449
		% within Year built	1.5%	82.2%	16.3%	100.0%
		% within Central heating	2.6%	8.2%	18.9%	8.7%
		% of Total	.1%	7.2%	1.4%	8.7%
	1919-1940	Count	231	11090	1634	12955
		% within Year built	1.8%	85.6%	12.6%	100.0%
		% within Central heating	2.2%	6.0%	10.3%	6.1%
		% of Total	.1%	5.2%	.8%	6.1%
	1941-1960	Count	265	16296	1608	18169
		% within Year built	1.5%	89.7%	8.9%	100.0%
		% within Central heating	2.5%	8.8%	10.1%	8.6%
		% of Total	.1%	7.7%	.8%	8.6%
	1961-1970	Count	203	13796	1031	15030
		% within Year built	1.4%	91.8%	6.9%	100.0%
		% within Central heating	1.9%	7.4%	6.5%	7.1%
		% of Total	.1%	6.5%	.5%	7.1%
	1971-1980	Count	423	29323	1854	31600
		% within Year built	1.3%	92.8%	5.9%	100.0%
		% within Central heating	4.0%	15.8%	11.6%	14.9%
		% of Total	.2%	13.8%	.9%	14.9%
	1981-1990	Count	320	24595	1714	26629
		% within Year built	1.2%	92.4%	6.4%	100.0%
		% within Central heating	3.1%	13.3%	10.8%	12.6%
		% of Total	.2%	11.6%	.8%	12.6%
	1991-1995	Count	196	13686	944	14826
		% within Year built	1.3%	92.3%	6.4%	100.0%
		% within Central heating	1.9%	7.4%	5.9%	7.0%
		% of Total	.1%	6.5%	.4%	7.0%
	1996-2000	Count	302	23110	1099	24511
		% within Year built	1.2%	94.3%	4.5%	100.0%
		% within Central heating	2.9%	12.5%	6.9%	11.6%
		% of Total	.1%	10.9%	.5%	11.6%
	2001 or later	Count	553	32466	1711	34730
		% within Year built	1.6%	93.5%	4.9%	100.0%
		% within Central heating	5.3%	17.5%	10.7%	16.4%
		% of Total	.3%	15.3%	.8%	16.4%
Total		Count	10467	185609	15930	212006
		% within Year built	4.9%	87.5%	7.5%	100.0%
		% within Central heating	100.0%	100.0%	100.0%	100.0%
		% of Total	4.9%	87.5%	7.5%	100.0%

Table A2 Quantity of Houses with central heating by Year of Construction

	Total No of Rural Detached House Constructed in that period	% with central heating	Amount of Detached Houses with Central Heating	% of Total Detached Houses in that period	Housing Type not Stated x 87.5%	Distribution of Non Stated Housing Type over construction periods	Total Amt of Detached Houses with Central Heating constructed in a certain period corrected to account for 'Not Stated' data
before 1919	74136	82.2	60940	17	5176	862	61802
1919 to 1940	40418	85.6	34598	9	5176	470	35068
1941-1960	36,488	89.7	32730	8	5176	424	33154
1961-1970	25118	91.8	23058	6	5176	292	23350
1971-1980	65554	92.8	60834	15	5176	762	61596
1981 -1990	60593	92.4	55988	14	5176	705	56693
1991-1995	26533	92.3	24490	6	5176	309	24798
1996-2000	46844	94.3	44174	11	5176	545	44719
2001-2006	69436	93.5	64923	16	5176	807	65730
Sub Total	445120			**100.00**		**5176**	**406910**
Not Stated	5915	87.5	5176				
Total	**451035**						

Source: CSO/INSHQ

Table A3 –Rural Housing

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Record general type of dwelling * Central heating run on-OIL	14566	77.5%	4226	22.5%	18792	100.0%
Record general type of dwelling * Central heating run on-MAINS GAS	216	1.1%	18576	98.9%	18792	100.0%
Record general type of dwelling * Central heating run on-LPG/BOTTLED GAS	270	1.4%	18522	98.6%	18792	100.0%
Record general type of dwelling * Central heating-SOLID FUEL OPN FIRE ONLY	1896	10.1%	16896	89.9%	18792	100.0%
Record general type of dwelling * Central heating-SOLID FUEL COOKER/STOVE	4249	22.6%	14543	77.4%	18792	100.0%
Record general type of dwelling * Central heating-ELECTRICIY	750	4.0%	18042	96.0%	18792	100.0%
Record general type of dwelling * Central heating-SOLAR/HEAT PUMP	9	.0%	18783	100.0%	18792	100.0%
Record general type of dwelling * Central heating-DONT KNOW	9	.0%	18783	100.0%	18792	100.0%

Source: INSHQ 2001-2002

Table A4

Record general type of dwelling * Central heating run on-OIL Crosstabulation

			Central heating run on-OIL		
			Oil	None	Total
Record general type of dwelling	Detached house/bungalow	Count	11270	1816	13086
		% within Record general type of dwelling	86.1%	13.9%	100.0%
		% within Central heating run on-OIL	92.0%	78.4%	89.8%
		% of Total	77.4%	12.5%	89.8%
	Semi-detached house/bungalow	Count	636	249	885
		% within Record general type of dwelling	71.9%	28.1%	100.0%
		% within Central heating run on-OIL	5.2%	10.7%	6.1%
		% of Total	4.4%	1.7%	6.1%
	Terraced house (incl. end of tce)	Count	304	185	489
		% within Record general type of dwelling	62.2%	37.8%	100.0%
		% within Central heating run on-OIL	2.5%	8.0%	3.4%
		% of Total	2.1%	1.3%	3.4%
	Purpose built flat/apartment etc	Count	11	5	16
		% within Record general type of dwelling	68.8%	31.3%	100.0%
		% within Central heating run on-OIL	.1%	.2%	.1%
		% of Total	.1%	.0%	.1%
	Flat/apartment in converted house etc. (	Count	19	3	22
		% within Record general type of dwelling	86.4%	13.6%	100.0%
		% within Central heating run on-OIL	.2%	.1%	.2%
		% of Total	.1%	.0%	.2%
	Caravan/Mobile Home	Count	9	59	68
		% within Record general type of dwelling	13.2%	86.8%	100.0%
		% within Central heating run on-OIL	.1%	2.5%	.5%
		% of Total	.1%	.4%	.5%
Total		Count	12249	2317	14566
		% within Record general type of dwelling	84.1%	15.9%	100.0%
		% within Central heating run on-OIL	100.0%	100.0%	100.0%
		% of Total	84.1%	15.9%	100.0%

Source: INSHQ 2001-2002

Table A5 – INSHQ Dataset - Rural Housing

Record general type of dwelling * Central heating run on-MAINS GAS Crosstabulation

			Central heating run on-MAINS GAS	
			Mains Gas	Total
Record general type of dwelling	Detached house/bungalow	Count	105	105
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	48.6%	48.6%
		% of Total	48.6%	48.6%
	Semi-detached house/bungalow	Count	76	76
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	35.2%	35.2%
		% of Total	35.2%	35.2%
	Terraced house (incl. end of tce)	Count	28	28
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	13.0%	13.0%
		% of Total	13.0%	13.0%
	Purpose built flat/apartment etc	Count	4	4
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	1.9%	1.9%
		% of Total	1.9%	1.9%
	Flat/apartment in converted house etc. (	Count	3	3
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	1.4%	1.4%
		% of Total	1.4%	1.4%
Total		Count	216	216
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table A6 – INSHQ Dataset - Rural Housing

Record general type of dwelling * Central heating run on-LPG/BOTTLED GAS Crosstabulation

			Central heating run on-LPG/BOTTLED GAS	
			Bottled Gas	Total
Record general type of dwelling	Detached house/bungalow	Count	246	246
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	91.1%	91.1%
		% of Total	91.1%	91.1%
	Semi-detached house/bungalow	Count	9	9
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	3.3%	3.3%
		% of Total	3.3%	3.3%
	Terraced house (incl. end of tce)	Count	8	8
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	3.0%	3.0%
		% of Total	3.0%	3.0%
	Purpose built flat/apartment etc	Count	2	2
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	.7%	.7%
		% of Total	.7%	.7%
	Flat/apartment in converted house etc. (	Count	2	2
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	.7%	.7%
		% of Total	.7%	.7%
	Caravan/Mobile Home	Count	3	3
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	1.1%	1.1%
		% of Total	1.1%	1.1%
Total		Count	270	270
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table A7 – INSHQ Dataset - Rural Housing

Record general type of dwelling * Central heating-SOLID FUEL OPN FIRE ONLY Crosstabulation

			Central heating-SOLID FUEL OPN FIRE ONLY	Total
			Open fire	
Record general type of dwelling	Detached house/bungalow	Count	1641	1641
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	86.6%	86.6%
		% of Total	86.6%	86.6%
	Semi-detached house/bungalow	Count	160	160
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	8.4%	8.4%
		% of Total	8.4%	8.4%
	Terraced house (incl. end of tce)	Count	94	94
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	5.0%	5.0%
		% of Total	5.0%	5.0%
	Purpose built flat/apartment etc	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	.1%	.1%
		% of Total	.1%	.1%
Total		Count	1896	1896
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table A8 – INSHQ Dataset - Rural Housing

Record general type of dwelling * Central heating-SOLID FUEL COOKER/STOVE Crosstabulation

			Central heating-SOLID FUEL COOKER/STOVE	
			Solid fuel stove	Total
Record general type of dwelling	Detached house/bungalow	Count	3954	3954
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	93.1%	93.1%
		% of Total	93.1%	93.1%
	Semi-detached house/bungalow	Count	208	208
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	4.9%	4.9%
		% of Total	4.9%	4.9%
	Terraced house (incl. end of tce)	Count	79	79
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	1.9%	1.9%
		% of Total	1.9%	1.9%
	Purpose built flat/apartment etc	Count	4	4
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	.1%	.1%
		% of Total	.1%	.1%
	Flat/apartment in converted house etc. (	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	.0%	.0%
		% of Total	.0%	.0%
	Caravan/Mobile Home	Count	3	3
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	.1%	.1%
		% of Total	.1%	.1%
Total		Count	4249	4249
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table A9 – INSHQ Dataset - Rural Housing

Record general type of dwelling * Central heating-ELECTRICIY Crosstabulation

			Central heating-ELECTRICIY	
			6	Total
Record general type of dwelling	Detached house/bungalow	Count	640	640
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	85.3%	85.3%
		% of Total	85.3%	85.3%
	Semi-detached house/bungalow	Count	58	58
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	7.7%	7.7%
		% of Total	7.7%	7.7%
	Terraced house (incl. end of tce)	Count	33	33
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	4.4%	4.4%
		% of Total	4.4%	4.4%
	Purpose built flat/apartment etc	Count	12	12
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	1.6%	1.6%
		% of Total	1.6%	1.6%
	Flat/apartment in converted house etc. (	Count	6	6
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	.8%	.8%
		% of Total	.8%	.8%
	Caravan/Mobile Home	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	.1%	.1%
		% of Total	.1%	.1%
Total		Count	750	750
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table A10 – INSHQ Dataset - Rural Housing

Source: INSHQ 2001-2002

Record general type of dwelling * Central heating-SOLAR/HEAT PUMP Crosstabulation

			Central heating-SOLAR/HEAT PUMP	
			Solar/Heat pump	Total
Record general type of dwelling	Detached house/bungalow	Count	9	9
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLAR/HEAT PUMP	100.0%	100.0%
		% of Total	100.0%	100.0%
Total		Count	9	9
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLAR/HEAT PUMP	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table A11

Record general type of dwelling * Central heating-DONT KNOW Crosstabulation

			Central heating-DONT KNOW	
			Don't know	Total
Record general type of dwelling	Detached house/bungalow	Count	9	9
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	100.0%	100.0%
		% of Total	100.0%	100.0%
Total		Count	9	9
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Appendix B- Urban Housing and Heating Fuel Type

Urban Housing Scenario. Of the 174,953 urban located detached dwellings in Ireland's, 95% or 166,600 (Table 32B CSO 2006) households have central heating, if we apply the INSHQ analysis to the heated housing stock we can surmise the following; See Table A2 and Fig A1

Table B1 Urban House Type and Fuel Type

	Urban (Population Density > 1500)											
	Detached Housing		Semi-		Terraced		Purpose built		Flat/Apartme		Caravan/	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Oil	3354	62	3673	45	1876	32	32	7	56	36	5	24
Gas	1060	19	3070	38	2395	41	224	52	35	23	12	57
LPG/Bottled Gas	84	2	48	1	30	1	5	1	1	1	0	0
Solid Fuel Open Fire Only	422	8	698	9	831	14	15	3	5	3	1	5
Solid FuelCooker/Stove	297	5	337	4	323	6	5	1	2	1	3	14
Electricity	238	4	273	3	333	6	147	34	53	34	0	0
Solar/Heat Pump	1	0	1	0	3	0	0	0	0	0	0	0
Don't know	2	0	3	0	1	0	4	1	2	1	0	0
Total	**5458**	**101**	**8103**	**100**	**5792**	**100**	**432**	**100**	**154**	**100**	**21**	**100**

Source: INSHQ 2001-2002

Table B2 Distribution of Heating Fuel Type in Urban Ireland's

Distribution of Heating Fuel Type in Urban Ireland			
Oil	62	166,600	103292
Gas	19	166,600	31654
LPG/Bottled Gas	2	166,600	3332
Solid Fuel Open Fire Only	8	166,600	13328
Solid FuelCooker/Stove	5	166,600	8330
Electricity	4	166,600	6664
Solar/Heat Pump	0	166,600	42
Don't know	0	166,600	100

Source: INSHQ 2001-2002/CSO 2006

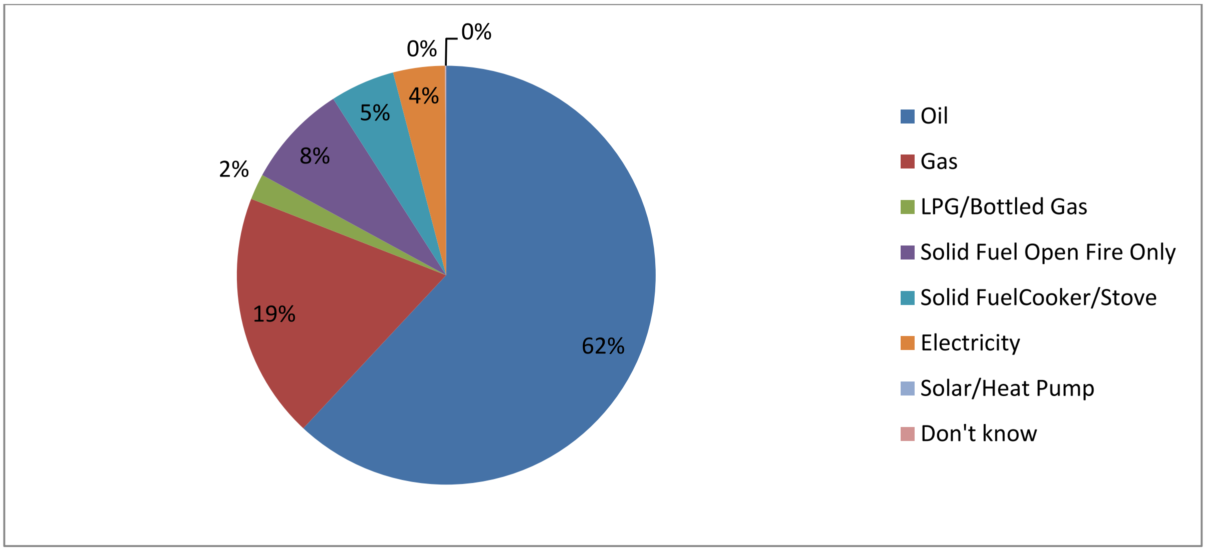


Figure B1 Distribution of Heating Fuel Type in Urban Ireland's

Source: INSHQ 2001-2002

Table B3 - Urban House Type and Fuel Type

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Record general type of dwelling * Central heating run on-OIL	11141	53.6%	9626	46.4%	20767	100.0%
Record general type of dwelling * Central heating run on-MAINS GAS	6796	32.7%	13971	67.3%	20767	100.0%
Record general type of dwelling * Central heating run on-LPG/BOTTLED GAS	168	.8%	20599	99.2%	20767	100.0%
Record general type of dwelling * Central heating-SOLID FUEL OPN FIRE ONLY	1972	9.5%	18795	90.5%	20767	100.0%
Record general type of dwelling * Central heating-SOLID FUEL COOKER/STOVE	964	4.6%	19803	95.4%	20767	100.0%
Record general type of dwelling * Central heating-ELECTRICIY	1044	5.0%	19723	95.0%	20767	100.0%
Record general type of dwelling * Central heating-SOLAR/HEAT PUMP	5	.0%	20762	100.0%	20767	100.0%
Record general type of dwelling * Central heating-DONT KNOW	12	.1%	20755	99.9%	20767	100.0%

Source: INSHQ 2001-2002

Table B4

Record general type of dwelling * Central heating run on-OIL Crosstabulation

			Central heating run on-OIL		Total
			Oil	None	
Record general type of dwelling	Detached house/bungalow	Count	3364	134	3498
		% within Record general type of dwelling	96.2%	3.8%	100.0%
		% within Central heating run on-OIL	37.4%	6.3%	31.4%
		% of Total	30.2%	1.2%	31.4%
	Semi-detached house/bungalow	Count	3673	451	4124
		% within Record general type of dwelling	89.1%	10.9%	100.0%
		% within Central heating run on-OIL	40.8%	21.1%	37.0%
		% of Total	33.0%	4.0%	37.0%
	Terraced house (incl. end of tce)	Count	1876	1390	3266
		% within Record general type of dwelling	57.4%	42.6%	100.0%
		% within Central heating run on-OIL	20.8%	65.1%	29.3%
		% of Total	16.8%	12.5%	29.3%
	Purpose built flat/apartment etc	Count	32	53	85
		% within Record general type of dwelling	37.6%	62.4%	100.0%
		% within Central heating run on-OIL	.4%	2.5%	.8%
		% of Total	.3%	.5%	.8%
	Flat/apartment in converted house etc. (	Count	56	89	145
		% within Record general type of dwelling	38.6%	61.4%	100.0%
		% within Central heating run on-OIL	.6%	4.2%	1.3%
		% of Total	.5%	.8%	1.3%
	Caravan/Mobile Home	Count	5	18	23
		% within Record general type of dwelling	21.7%	78.3%	100.0%
		% within Central heating run on-OIL	.1%	.8%	.2%
		% of Total	.0%	.2%	.2%
Total		Count	9006	2135	11141
		% within Record general type of dwelling	80.8%	19.2%	100.0%
		% within Central heating run on-OIL	100.0%	100.0%	100.0%
		% of Total	80.8%	19.2%	100.0%

Source: INSHQ 2001-2002

Table B5

Record general type of dwelling * Central heating run on-MAINS GAS Crosstabulation

			Central heating run on-MAINS GAS	
			Mains Gas	Total
Record general type of dwelling	Detached house/bungalow	Count	1060	1060
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	15.6%	15.6%
		% of Total	15.6%	15.6%
	Semi-detached house/bungalow	Count	3070	3070
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	45.2%	45.2%
		% of Total	45.2%	45.2%
	Terraced house (incl. end of tce)	Count	2395	2395
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	35.2%	35.2%
		% of Total	35.2%	35.2%
	Purpose built flat/apartment etc	Count	224	224
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	3.3%	3.3%
		% of Total	3.3%	3.3%
	Flat/apartment in converted house etc. (	Count	35	35
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	.5%	.5%
		% of Total	.5%	.5%
	Caravan/Mobile Home	Count	12	12
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	.2%	.2%
		% of Total	.2%	.2%
Total		Count	6796	6796
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-MAINS GAS	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table B5

Record general type of dwelling * Central heating run on-LPG/BOTTLED GAS Crosstabulation

			Central heating run on-LPG/BOTTLED GAS	
			Bottled Gas	Total
Record general type of dwelling	Detached house/bungalow	Count	84	84
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	50.0%	50.0%
		% of Total	50.0%	50.0%
	Semi-detached house/bungalow	Count	48	48
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	28.6%	28.6%
		% of Total	28.6%	28.6%
	Terraced house (incl. end of tce)	Count	30	30
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	17.9%	17.9%
		% of Total	17.9%	17.9%
	Purpose built flat/apartment etc	Count	5	5
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	3.0%	3.0%
		% of Total	3.0%	3.0%
	Flat/apartment in converted house etc. (	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	.6%	.6%
		% of Total	.6%	.6%
Total		Count	168	168
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating run on-LPG/BOTTLED GAS	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table B6

Record general type of dwelling * Central heating-SOLID FUEL OPN FIRE ONLY Crosstabulation

			Central heating-SOLID FUEL OPN FIRE ONLY	
			Open fire	Total
Record general type of dwelling	Detached house/bungalow	Count	422	422
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	21.4%	21.4%
		% of Total	21.4%	21.4%
	Semi-detached house/bungalow	Count	698	698
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	35.4%	35.4%
		% of Total	35.4%	35.4%
	Terraced house (incl. end of tce)	Count	831	831
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	42.1%	42.1%
		% of Total	42.1%	42.1%
	Purpose built flat/apartment etc	Count	15	15
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	.8%	.8%
		% of Total	.8%	.8%
	Flat/apartment in converted house etc. (	Count	5	5
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	.3%	.3%
		% of Total	.3%	.3%
	Caravan/Mobile Home	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	.1%	.1%
		% of Total	.1%	.1%
Total		Count	1972	1972
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL OPN FIRE ONLY	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table B7

Record general type of dwelling * Central heating-SOLID FUEL COOKER/STOVE Crosstabulation

			Central heating-SOLID FUEL COOKER/STOVE	
			Solid fuel stove	Total
Record general type of dwelling	Detached house/bungalow	Count	297	297
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	30.8%	30.8%
		% of Total	30.8%	30.8%
	Semi-detached house/bungalow	Count	337	337
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	35.0%	35.0%
		% of Total	35.0%	35.0%
	Terraced house (incl. end of tce)	Count	323	323
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	33.5%	33.5%
		% of Total	33.5%	33.5%
	Purpose built flat/apartment etc	Count	5	5
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	.5%	.5%
		% of Total	.5%	.5%
	Flat/apartment in converted house etc. (	Count	2	2
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	.2%	.2%
		% of Total	.2%	.2%
Total		Count	964	964
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLID FUEL COOKER/STOVE	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table B8

Record general type of dwelling * Central heating-ELECTRICIY Crosstabulation

			Central heating-ELECTRICIY	Total
			6	
Record general type of dwelling	Detached house/bungalow	Count	238	238
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	22.8%	22.8%
		% of Total	22.8%	22.8%
	Semi-detached house/bungalow	Count	273	273
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	26.1%	26.1%
		% of Total	26.1%	26.1%
	Terraced house (incl. end of tce)	Count	333	333
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	31.9%	31.9%
		% of Total	31.9%	31.9%
	Purpose built flat/apartment etc	Count	147	147
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	14.1%	14.1%
		% of Total	14.1%	14.1%
	Flat/apartment in converted house etc. (	Count	53	53
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	5.1%	5.1%
		% of Total	5.1%	5.1%
Total		Count	1044	1044
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-ELECTRICIY	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table B9

Record general type of dwelling * Central heating-SOLAR/HEAT PUMP Crosstabulation

			Central heating-SOLAR/HEAT PUMP	
			Solar/Heat pump	Total
Record general type of dwelling	Detached house/bungalow	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLAR/HEAT PUMP	20.0%	20.0%
		% of Total	20.0%	20.0%
	Semi-detached house/bungalow	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLAR/HEAT PUMP	20.0%	20.0%
		% of Total	20.0%	20.0%
	Terraced house (incl. end of tce)	Count	3	3
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLAR/HEAT PUMP	60.0%	60.0%
		% of Total	60.0%	60.0%
Total		Count	5	5
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-SOLAR/HEAT PUMP	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Table B10

Record general type of dwelling * Central heating-DONT KNOW Crosstabulation

			Central heating-DONT KNOW	
			Don't know	Total
Record general type of dwelling	Detached house/bungalow	Count	2	2
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	16.7%	16.7%
		% of Total	16.7%	16.7%
	Semi-detached house/bungalow	Count	3	3
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	25.0%	25.0%
		% of Total	25.0%	25.0%
	Terraced house (incl. end of tce)	Count	1	1
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	8.3%	8.3%
		% of Total	8.3%	8.3%
	Purpose built flat/apartment etc	Count	4	4
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	33.3%	33.3%
		% of Total	33.3%	33.3%
	Flat/apartment in converted house etc. (	Count	2	2
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	16.7%	16.7%
		% of Total	16.7%	16.7%
Total		Count	12	12
		% within Record general type of dwelling	100.0%	100.0%
		% within Central heating-DONT KNOW	100.0%	100.0%
		% of Total	100.0%	100.0%

Source: INSHQ 2001-2002

Appendix C – Typical Floor Areas by Dwelling Type Source NSHQ

Table C1

Record general type of dwelling * Size in Sq.Mtr. - grouped Crosstabulation

			Size in Sq.Mtr. - grouped					
			93 or under	94-112	113-137	138-185	over 185	Total
Record general type of dwelling	Detached house/bungalow	Count	762	947	1261	1707	1850	6527
		% within Record general type of dwelling	11.7%	14.5%	19.3%	26.2%	28.3%	100.0%
		% within Size in Sq.Mtr. - grouped	37.8%	55.8%	69.7%	79.2%	85.9%	66.4%
		% of Total	7.8%	9.6%	12.8%	17.4%	18.8%	66.4%
	Semi-detached house/bungalow	Count	419	562	461	369	201	2012
		% within Record general type of dwelling	20.8%	27.9%	22.9%	18.3%	10.0%	100.0%
		% within Size in Sq.Mtr. - grouped	20.8%	33.1%	25.5%	17.1%	9.3%	20.5%
		% of Total	4.3%	5.7%	4.7%	3.8%	2.0%	20.5%
	Terraced house (incl. end of tce)	Count	691	180	85	76	92	1124
		% within Record general type of dwelling	61.5%	16.0%	7.6%	6.8%	8.2%	100.0%
		% within Size in Sq.Mtr. - grouped	34.3%	10.6%	4.7%	3.5%	4.3%	11.4%
		% of Total	7.0%	1.8%	.9%	.8%	.9%	11.4%
	Purpose built flat/apartment etc	Count	81	3	1	2	3	90
		% within Record general type of dwelling	90.0%	3.3%	1.1%	2.2%	3.3%	100.0%
		% within Size in Sq.Mtr. - grouped	4.0%	.2%	.1%	.1%	.1%	.9%
		% of Total	.8%	.0%	.0%	.0%	.0%	.9%
	Flat/apartment in converted house etc. (	Count	28	3	1	0	7	39
		% within Record general type of dwelling	71.8%	7.7%	2.6%	.0%	17.9%	100.0%
		% within Size in Sq.Mtr. - grouped	1.4%	.2%	.1%	.0%	.3%	.4%
		% of Total	.3%	.0%	.0%	.0%	.1%	.4%
	Caravan/Mobile Home	Count	35	1	0	1	0	37
		% within Record general type of dwelling	94.6%	2.7%	.0%	2.7%	.0%	100.0%
		% within Size in Sq.Mtr. - grouped	1.7%	.1%	.0%	.0%	.0%	.4%
		% of Total	.4%	.0%	.0%	.0%	.0%	.4%
Total		Count	2016	1696	1809	2155	2153	9829
		% within Record general type of dwelling	20.5%	17.3%	18.4%	21.9%	21.9%	100.0%
		% within Size in Sq.Mtr. - grouped	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	20.5%	17.3%	18.4%	21.9%	21.9%	100.0%

Source: INSHQ 2001-2002

Table C2a – Record Type of Dwelling and presence of a staircase (Rural Filter Off)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Have staircase in accommodation * Record general type of dwelling * Year Built	39911	98.6%	575	1.4%	40486	100.0%

Source: INSHQ 2001-2002

Table C2b – Record Type of Dwelling, by Year and presence of a staircase (Rural Filter off)

Have staircase in accommodation * Record general type of dwelling * Year Built Crosstabulation

				Record general type of dwelling						
Year Built				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Flat/apartment in converted house etc. (	Caravan/Mobile Home	Total
Pre-1940	Have staircase in accommodation	yes	Count	3729	861	2085	30	114	3	6822
			% within Have staircase in accommodation	54.7%	12.6%	30.6%	.4%	1.7%	.0%	100.0%
			% within Record general type of dwelling	60.8%	78.8%	87.6%	46.2%	55.1%	23.1%	68.9%
			% of Total	37.7%	8.7%	21.1%	.3%	1.2%	.0%	68.9%
		no	Count	2409	232	296	35	93	10	3075
			% within Have staircase in accommodation	78.3%	7.5%	9.6%	1.1%	3.0%	.3%	100.0%
			% within Record general type of dwelling	39.2%	21.2%	12.4%	53.8%	44.9%	76.9%	31.1%
			% of Total	24.3%	2.3%	3.0%	.4%	.9%	.1%	31.1%
	Total		Count	6138	1093	2381	65	207	13	9897
			% within Have staircase in accommodation	62.0%	11.0%	24.1%	.7%	2.1%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	62.0%	11.0%	24.1%	.7%	2.1%	.1%	100.0%
1941-1970	Have staircase in accommodation	yes	Count	1434	2401	2383	46	16	5	6285
			% within Have staircase in accommodation	22.8%	38.2%	37.9%	.7%	.3%	.1%	100.0%
			% within Record general type of dwelling	35.3%	89.0%	94.6%	32.9%	53.3%	55.6%	66.4%
			% of Total	15.2%	25.4%	25.2%	.5%	.2%	.1%	66.4%
		no	Count	2631	298	135	94	14	4	3176
			% within Have staircase in accommodation	82.8%	9.4%	4.3%	3.0%	.4%	.1%	100.0%
			% within Record general type of dwelling	64.7%	11.0%	5.4%	67.1%	46.7%	44.4%	33.6%
			% of Total	27.8%	3.1%	1.4%	1.0%	.1%	.0%	33.6%
	Total		Count	4065	2699	2518	140	30	9	9461
			% within Have staircase in accommodation	43.0%	28.5%	26.6%	1.5%	.3%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	43.0%	28.5%	26.6%	1.5%	.3%	.1%	100.0%
1971-1980	Have staircase in accommodation	yes	Count	1640	2358	1551	14	2	3	5568
			% within Have staircase in accommodation	29.5%	42.3%	27.9%	.3%	.0%	.1%	100.0%
			% within Record general type of dwelling	33.4%	90.2%	95.4%	22.6%	15.4%	15.0%	60.2%
			% of Total	17.7%	25.5%	16.8%	.2%	.0%	.0%	60.2%
		no	Count	3270	255	75	48	11	17	3676
			% within Have staircase in accommodation	89.0%	6.9%	2.0%	1.3%	.3%	.5%	100.0%
			% within Record general type of dwelling	66.6%	9.8%	4.6%	77.4%	84.6%	85.0%	39.8%
			% of Total	35.4%	2.8%	.8%	.5%	.1%	.2%	39.8%
	Total		Count	4910	2613	1626	62	13	20	9244
			% within Have staircase in accommodation	53.1%	28.3%	17.6%	.7%	.1%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	53.1%	28.3%	17.6%	.7%	.1%	.2%	100.0%
1980-1996	Have staircase in accommodation	yes	Count	2326	2080	913	65	8	5	5397
			% within Have staircase in accommodation	43.1%	38.5%	16.9%	1.2%	.1%	.1%	100.0%
			% within Record general type of dwelling	44.3%	88.0%	90.1%	34.9%	32.0%	11.1%	60.8%
			% of Total	26.2%	23.4%	10.3%	.7%	.1%	.1%	60.8%
		no	Count	2920	283	100	121	17	40	3481
			% within Have staircase in accommodation	83.9%	8.1%	2.9%	3.5%	.5%	1.1%	100.0%
			% within Record general type of dwelling	55.7%	12.0%	9.9%	65.1%	68.0%	88.9%	39.2%
			% of Total	32.9%	3.2%	1.1%	1.4%	.2%	.5%	39.2%
	Total		Count	5246	2363	1013	186	25	45	8878
			% within Have staircase in accommodation	59.1%	26.6%	11.4%	2.1%	.3%	.5%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	59.1%	26.6%	11.4%	2.1%	.3%	.5%	100.0%
After 1996	Have staircase in accommodation	yes	Count	854	598	144	34	4	1	1635
			% within Have staircase in accommodation	52.2%	36.6%	8.8%	2.1%	.2%	.1%	100.0%
			% within Record general type of dwelling	57.7%	90.1%	89.4%	37.8%	33.3%	4.0%	67.3%
			% of Total	35.1%	24.6%	5.9%	1.4%	.2%	.0%	67.3%
		no	Count	625	66	17	56	8	24	796
			% within Have staircase in accommodation	78.5%	8.3%	2.1%	7.0%	1.0%	3.0%	100.0%
			% within Record general type of dwelling	42.3%	9.9%	10.6%	62.2%	66.7%	96.0%	32.7%
			% of Total	25.7%	2.7%	.7%	2.3%	.3%	1.0%	32.7%
	Total		Count	1479	664	161	90	12	25	2431
			% within Have staircase in accommodation	60.8%	27.3%	6.6%	3.7%	.5%	1.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	60.8%	27.3%	6.6%	3.7%	.5%	1.0%	100.0%

Source INHSQ 2001-2002

Figure C1 – Random Snapshot Rural Ireland

Figure C2 – Random Snapshot Rural Ireland

Figure C3 – Random Snapshot Rural Ireland

Figure C3 – Random Snapshot Rural Ireland

Appendix D – House Type by Year of Contstruction and Window Type

Table D1

Sort of windows-TIMBER FRAME * Record general type of dwelling * Year Built Crosstabulation

Year Built				Record general type of dwelling						Total
				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Flat/apartment in converted house etc. (	Caravan/Mobile Home	
Pre-1940	Sort of windows-TIMBER FRAME	Timber frame	Count	3405	465	1123	23	113	2	5131
			% within Sort of windows-TIMBER FRAME	66.4%	9.1%	21.9%	.4%	2.2%	.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	66.4%	9.1%	21.9%	.4%	2.2%	.0%	100.0%
	Total		Count	3405	465	1123	23	113	2	5131
			% within Sort of windows-TIMBER FRAME	66.4%	9.1%	21.9%	.4%	2.2%	.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	66.4%	9.1%	21.9%	.4%	2.2%	.0%	100.0%
1941-1970	Sort of windows-TIMBER FRAME	Timber frame	Count	1715	589	703	21	13	1	3042
			% within Sort of windows-TIMBER FRAME	56.4%	19.4%	23.1%	.7%	.4%	.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	56.4%	19.4%	23.1%	.7%	.4%	.0%	100.0%
	Total		Count	1715	589	703	21	13	1	3042
			% within Sort of windows-TIMBER FRAME	56.4%	19.4%	23.1%	.7%	.4%	.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	56.4%	19.4%	23.1%	.7%	.4%	.0%	100.0%
1971-1980	Sort of windows-TIMBER FRAME	Timber frame	Count	2466	635	472	27	6	8	3614
			% within Sort of windows-TIMBER FRAME	68.2%	17.6%	13.1%	.7%	.2%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	68.2%	17.6%	13.1%	.7%	.2%	.2%	100.0%
	Total		Count	2466	635	472	27	6	8	3614
			% within Sort of windows-TIMBER FRAME	68.2%	17.6%	13.1%	.7%	.2%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	68.2%	17.6%	13.1%	.7%	.2%	.2%	100.0%
1980-1996	Sort of windows-TIMBER FRAME	Timber frame	Count	2067	999	481	63	5	8	3623
			% within Sort of windows-TIMBER FRAME	57.1%	27.6%	13.3%	1.7%	.1%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	57.1%	27.6%	13.3%	1.7%	.1%	.2%	100.0%
	Total		Count	2067	999	481	63	5	8	3623
			% within Sort of windows-TIMBER FRAME	57.1%	27.6%	13.3%	1.7%	.1%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	57.1%	27.6%	13.3%	1.7%	.1%	.2%	100.0%
After 1996	Sort of windows-TIMBER FRAME	Timber frame	Count	141	91	40	16	3	3	294
			% within Sort of windows-TIMBER FRAME	48.0%	31.0%	13.6%	5.4%	1.0%	1.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	48.0%	31.0%	13.6%	5.4%	1.0%	1.0%	100.0%
	Total		Count	141	91	40	16	3	3	294
			% within Sort of windows-TIMBER FRAME	48.0%	31.0%	13.6%	5.4%	1.0%	1.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	48.0%	31.0%	13.6%	5.4%	1.0%	1.0%	100.0%

Source INHSQ 2001-2002

Table D2

Sort of windows-PVC * Record general type of dwelling * Year Built Crosstabulation

				Record general type of dwelling						
Year Built				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Flat/apartment in converted house etc. (	Caravan/Mobile Home	Total
Pre-1940	Sort of windows-PVC	PVC	Count	2854	556	1099	34	77	2	4622
			% within Sort of windows-PVC	61.7%	12.0%	23.8%	.7%	1.7%	.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	61.7%	12.0%	23.8%	.7%	1.7%	.0%	100.0%
	Total		Count	2854	556	1099	34	77	2	4622
			% within Sort of windows-PVC	61.7%	12.0%	23.8%	.7%	1.7%	.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	61.7%	12.0%	23.8%	.7%	1.7%	.0%	100.0%
1941-1970	Sort of windows-PVC	PVC	Count	2255	1533	1239	81	13	4	5125
			% within Sort of windows-PVC	44.0%	29.9%	24.2%	1.6%	.3%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	44.0%	29.9%	24.2%	1.6%	.3%	.1%	100.0%
	Total		Count	2255	1533	1239	81	13	4	5125
			% within Sort of windows-PVC	44.0%	29.9%	24.2%	1.6%	.3%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	44.0%	29.9%	24.2%	1.6%	.3%	.1%	100.0%
1971-1980	Sort of windows-PVC	PVC	Count	2631	1636	948	25	5	3	5248
			% within Sort of windows-PVC	50.1%	31.2%	18.1%	.5%	.1%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	50.1%	31.2%	18.1%	.5%	.1%	.1%	100.0%
	Total		Count	2631	1636	948	25	5	3	5248
			% within Sort of windows-PVC	50.1%	31.2%	18.1%	.5%	.1%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	50.1%	31.2%	18.1%	.5%	.1%	.1%	100.0%
1980-1996	Sort of windows-PVC	PVC	Count	3001	1293	461	105	19	8	4887
			% within Sort of windows-PVC	61.4%	26.5%	9.4%	2.1%	.4%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	61.4%	26.5%	9.4%	2.1%	.4%	.2%	100.0%
	Total		Count	3001	1293	461	105	19	8	4887
			% within Sort of windows-PVC	61.4%	26.5%	9.4%	2.1%	.4%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	61.4%	26.5%	9.4%	2.1%	.4%	.2%	100.0%
After 1996	Sort of windows-PVC	PVC	Count	1323	556	113	68	7	12	2079
			% within Sort of windows-PVC	63.6%	26.7%	5.4%	3.3%	.3%	.6%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	63.6%	26.7%	5.4%	3.3%	.3%	.6%	100.0%
	Total		Count	1323	556	113	68	7	12	2079
			% within Sort of windows-PVC	63.6%	26.7%	5.4%	3.3%	.3%	.6%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	63.6%	26.7%	5.4%	3.3%	.3%	.6%	100.0%

Source INHSQ 2001-2002

Table D3

Sort of windows-STEEL * Record general type of dwelling * Year Built Crosstabulation

				Record general type of dwelling						
Year Built				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Flat/apartment in converted house etc. (	Caravan/Mobile Home	Total
Pre-1940	Sort of windows-STEEL	Steel	Count	66	13	17	1	3	4	104
			% within Sort of windows-STEEL	63.5%	12.5%	16.3%	1.0%	2.9%	3.8%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	63.5%	12.5%	16.3%	1.0%	2.9%	3.8%	100.0%
	Total		Count	66	13	17	1	3	4	104
			% within Sort of windows-STEEL	63.5%	12.5%	16.3%	1.0%	2.9%	3.8%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	63.5%	12.5%	16.3%	1.0%	2.9%	3.8%	100.0%
1941-1970	Sort of windows-STEEL	Steel	Count	77	81	56	11	2	2	229
			% within Sort of windows-STEEL	33.6%	35.4%	24.5%	4.8%	.9%	.9%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	33.6%	35.4%	24.5%	4.8%	.9%	.9%	100.0%
	Total		Count	77	81	56	11	2	2	229
			% within Sort of windows-STEEL	33.6%	35.4%	24.5%	4.8%	.9%	.9%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	33.6%	35.4%	24.5%	4.8%	.9%	.9%	100.0%
1971-1980	Sort of windows-STEEL	Steel	Count	9	9	20	1		1	40
			% within Sort of windows-STEEL	22.5%	22.5%	50.0%	2.5%		2.5%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%
			% of Total	22.5%	22.5%	50.0%	2.5%		2.5%	100.0%
	Total		Count	9	9	20	1		1	40
			% within Sort of windows-STEEL	22.5%	22.5%	50.0%	2.5%		2.5%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%
			% of Total	22.5%	22.5%	50.0%	2.5%		2.5%	100.0%
1980-1996	Sort of windows-STEEL	Steel	Count	9	4	1	2		5	21
			% within Sort of windows-STEEL	42.9%	19.0%	4.8%	9.5%		23.8%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%
			% of Total	42.9%	19.0%	4.8%	9.5%		23.8%	100.0%
	Total		Count	9	4	1	2		5	21
			% within Sort of windows-STEEL	42.9%	19.0%	4.8%	9.5%		23.8%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%
			% of Total	42.9%	19.0%	4.8%	9.5%		23.8%	100.0%
After 1996	Sort of windows-STEEL	Steel	Count			1			1	2
			% within Sort of windows-STEEL			50.0%			50.0%	100.0%
			% within Record general type of dwelling			100.0%			100.0%	100.0%
			% of Total			50.0%			50.0%	100.0%
	Total		Count			1			1	2
			% within Sort of windows-STEEL			50.0%			50.0%	100.0%
			% within Record general type of dwelling			100.0%			100.0%	100.0%
			% of Total			50.0%			50.0%	100.0%

Source INHSQ 2001-2002

Table D4

Sort of windows-ALUMINIUM * Record general type of dwelling * Year Built Crosstabulation

				Record general type of dwelling						
Year Built				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Flat/apartment in converted house etc. (	Caravan/Mobile Home	Total
Pre-1940	Sort of windows-ALUMINIUM	Aluminium	Count	706	201	439	7	27	6	1386
			% within Sort of windows-ALUMINIUM	50.9%	14.5%	31.7%	.5%	1.9%	.4%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	50.9%	14.5%	31.7%	.5%	1.9%	.4%	100.0%
	Total		Count	706	201	439	7	27	6	1386
			% within Sort of windows-ALUMINIUM	50.9%	14.5%	31.7%	.5%	1.9%	.4%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	50.9%	14.5%	31.7%	.5%	1.9%	.4%	100.0%
1941-1970	Sort of windows-ALUMINIUM	Aluminium	Count	600	758	731	28	3	3	2123
			% within Sort of windows-ALUMINIUM	28.3%	35.7%	34.4%	1.3%	.1%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	28.3%	35.7%	34.4%	1.3%	.1%	.1%	100.0%
	Total		Count	600	758	731	28	3	3	2123
			% within Sort of windows-ALUMINIUM	28.3%	35.7%	34.4%	1.3%	.1%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	28.3%	35.7%	34.4%	1.3%	.1%	.1%	100.0%
1971-1980	Sort of windows-ALUMINIUM	Aluminium	Count	468	571	297	12	2	8	1358
			% within Sort of windows-ALUMINIUM	34.5%	42.0%	21.9%	.9%	.1%	.6%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	34.5%	42.0%	21.9%	.9%	.1%	.6%	100.0%
	Total		Count	468	571	297	12	2	8	1358
			% within Sort of windows-ALUMINIUM	34.5%	42.0%	21.9%	.9%	.1%	.6%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	34.5%	42.0%	21.9%	.9%	.1%	.6%	100.0%
1980-1996	Sort of windows-ALUMINIUM	Aluminium	Count	461	181	124	18	2	26	812
			% within Sort of windows-ALUMINIUM	56.8%	22.3%	15.3%	2.2%	.2%	3.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	56.8%	22.3%	15.3%	2.2%	.2%	3.2%	100.0%
	Total		Count	461	181	124	18	2	26	812
			% within Sort of windows-ALUMINIUM	56.8%	22.3%	15.3%	2.2%	.2%	3.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	56.8%	22.3%	15.3%	2.2%	.2%	3.2%	100.0%
After 1996	Sort of windows-ALUMINIUM	Aluminium	Count	24	20	7	6	2	9	68
			% within Sort of windows-ALUMINIUM	35.3%	29.4%	10.3%	8.8%	2.9%	13.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	35.3%	29.4%	10.3%	8.8%	2.9%	13.2%	100.0%
	Total		Count	24	20	7	6	2	9	68
			% within Sort of windows-ALUMINIUM	35.3%	29.4%	10.3%	8.8%	2.9%	13.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	35.3%	29.4%	10.3%	8.8%	2.9%	13.2%	100.0%

Source INHSQ 2001-2002

Table D5

Sort of windows-OTHER * Record general type of dwelling * Year Built Crosstabulation

				Record general type of dwelling					
Year Built				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Caravan/Mobile Home	Total
Pre-1940	Sort of windows-OTHER	Other	Count	7	2	6			15
			% within Sort of windows-OTHER	46.7%	13.3%	40.0%			100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%			100.0%
			% of Total	46.7%	13.3%	40.0%			100.0%
	Total		Count	7	2	6			15
			% within Sort of windows-OTHER	46.7%	13.3%	40.0%			100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%			100.0%
			% of Total	46.7%	13.3%	40.0%			100.0%
1941-1970	Sort of windows-OTHER	Other	Count	1	7	8			16
			% within Sort of windows-OTHER	6.3%	43.8%	50.0%			100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%			100.0%
			% of Total	6.3%	43.8%	50.0%			100.0%
	Total		Count	1	7	8			16
			% within Sort of windows-OTHER	6.3%	43.8%	50.0%			100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%			100.0%
			% of Total	6.3%	43.8%	50.0%			100.0%
1971-1980	Sort of windows-OTHER	Other	Count	6	6	4			16
			% within Sort of windows-OTHER	37.5%	37.5%	25.0%			100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%			100.0%
			% of Total	37.5%	37.5%	25.0%			100.0%
	Total		Count	6	6	4			16
			% within Sort of windows-OTHER	37.5%	37.5%	25.0%			100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%			100.0%
			% of Total	37.5%	37.5%	25.0%			100.0%
1980-1996	Sort of windows-OTHER	Other	Count	7	2	3	1	2	15
			% within Sort of windows-OTHER	46.7%	13.3%	20.0%	6.7%	13.3%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	46.7%	13.3%	20.0%	6.7%	13.3%	100.0%
	Total		Count	7	2	3	1	2	15
			% within Sort of windows-OTHER	46.7%	13.3%	20.0%	6.7%	13.3%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	46.7%	13.3%	20.0%	6.7%	13.3%	100.0%
After 1996	Sort of windows-OTHER	Other	Count	4	1				5
			% within Sort of windows-OTHER	80.0%	20.0%				100.0%
			% within Record general type of dwelling	100.0%	100.0%				100.0%
			% of Total	80.0%	20.0%				100.0%
	Total		Count	4	1				5
			% within Sort of windows-OTHER	80.0%	20.0%				100.0%
			% within Record general type of dwelling	100.0%	100.0%				100.0%
			% of Total	80.0%	20.0%				100.0%

Source INHSQ 2001-2002

Table D6- Presence of Double Glazing

Have in home-DOUBLE GLAZING * Record general type of dwelling * Year Built Crosstabulation

				Record general type of dwelling						
Year Built				Detached house/bungalow	Semi-detached house/bungalow	Terraced house (incl. end of tce)	Purpose built flat/apartment etc	Flat/apartment in converted house etc. (	Caravan/Mobile Home	Total
Pre-1940	Have in home-DOUBLE GLAZING	yes	Count	3156	662	1297	35	79	3	5232
			% within Have in home-DOUBLE GLAZING	60.3%	12.7%	24.8%	.7%	1.5%	.1%	100.0%
			% within Record general type of dwelling	51.6%	60.7%	54.6%	55.6%	38.9%	25.0%	53.0%
			% of Total	32.0%	6.7%	13.1%	.4%	.8%	.0%	53.0%
		no	Count	2966	428	1079	28	124	9	4634
			% within Have in home-DOUBLE GLAZING	64.0%	9.2%	23.3%	.6%	2.7%	.2%	100.0%
			% within Record general type of dwelling	48.4%	39.3%	45.4%	44.4%	61.1%	75.0%	47.0%
			% of Total	30.1%	4.3%	10.9%	.3%	1.3%	.1%	47.0%
	Total		Count	6122	1090	2376	63	203	12	9866
			% within Have in home-DOUBLE GLAZING	62.1%	11.0%	24.1%	.6%	2.1%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	62.1%	11.0%	24.1%	.6%	2.1%	.1%	100.0%
1941-1970	Have in home-DOUBLE GLAZING	yes	Count	2646	1959	1485	88	15	6	6199
			% within Have in home-DOUBLE GLAZING	42.7%	31.6%	24.0%	1.4%	.2%	.1%	100.0%
			% within Record general type of dwelling	65.2%	72.9%	59.0%	63.3%	50.0%	66.7%	65.7%
			% of Total	28.0%	20.8%	15.7%	.9%	.2%	.1%	65.7%
		no	Count	1410	729	1030	51	15	3	3238
			% within Have in home-DOUBLE GLAZING	43.5%	22.5%	31.8%	1.6%	.5%	.1%	100.0%
			% within Record general type of dwelling	34.8%	27.1%	41.0%	36.7%	50.0%	33.3%	34.3%
			% of Total	14.9%	7.7%	10.9%	.5%	.2%	.0%	34.3%
	Total		Count	4056	2688	2515	139	30	9	9437
			% within Have in home-DOUBLE GLAZING	43.0%	28.5%	26.7%	1.5%	.3%	.1%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	43.0%	28.5%	26.7%	1.5%	.3%	.1%	100.0%
1971-1980	Have in home-DOUBLE GLAZING	yes	Count	3184	2004	1033	27	7	5	6260
			% within Have in home-DOUBLE GLAZING	50.9%	32.0%	16.5%	.4%	.1%	.1%	100.0%
			% within Record general type of dwelling	65.0%	76.9%	63.6%	42.9%	53.8%	25.0%	67.8%
			% of Total	34.5%	21.7%	11.2%	.3%	.1%	.1%	67.8%
		no	Count	1718	602	591	36	6	15	2968
			% within Have in home-DOUBLE GLAZING	57.9%	20.3%	19.9%	1.2%	.2%	.5%	100.0%
			% within Record general type of dwelling	35.0%	23.1%	36.4%	57.1%	46.2%	75.0%	32.2%
			% of Total	18.6%	6.5%	6.4%	.4%	.1%	.2%	32.2%
	Total		Count	4902	2606	1624	63	13	20	9228
			% within Have in home-DOUBLE GLAZING	53.1%	28.2%	17.6%	.7%	.1%	.2%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	53.1%	28.2%	17.6%	.7%	.1%	.2%	100.0%
1980-1996	Have in home-DOUBLE GLAZING	yes	Count	3829	1718	607	147	20	8	6329
			% within Have in home-DOUBLE GLAZING	60.5%	27.1%	9.6%	2.3%	.3%	.1%	100.0%
			% within Record general type of dwelling	73.1%	72.7%	59.9%	79.0%	80.0%	18.6%	71.4%
			% of Total	43.2%	19.4%	6.8%	1.7%	.2%	.1%	71.4%
		no	Count	1409	646	406	39	5	35	2540
			% within Have in home-DOUBLE GLAZING	55.5%	25.4%	16.0%	1.5%	.2%	1.4%	100.0%
			% within Record general type of dwelling	26.9%	27.3%	40.1%	21.0%	20.0%	81.4%	28.6%
			% of Total	15.9%	7.3%	4.6%	.4%	.1%	.4%	28.6%
	Total		Count	5238	2364	1013	186	25	43	8869
			% within Have in home-DOUBLE GLAZING	59.1%	26.7%	11.4%	2.1%	.3%	.5%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	59.1%	26.7%	11.4%	2.1%	.3%	.5%	100.0%
After 1996	Have in home-DOUBLE GLAZING	yes	Count	1442	647	136	76	10	6	2317
			% within Have in home-DOUBLE GLAZING	62.2%	27.9%	5.9%	3.3%	.4%	.3%	100.0%
			% within Record general type of dwelling	97.4%	97.3%	85.0%	85.4%	83.3%	24.0%	95.3%
			% of Total	59.3%	26.6%	5.6%	3.1%	.4%	.2%	95.3%
		no	Count	38	18	24	13	2	19	114
			% within Have in home-DOUBLE GLAZING	33.3%	15.8%	21.1%	11.4%	1.8%	16.7%	100.0%
			% within Record general type of dwelling	2.6%	2.7%	15.0%	14.6%	16.7%	76.0%	4.7%
			% of Total	1.6%	.7%	1.0%	.5%	.1%	.8%	4.7%
	Total		Count	1480	665	160	89	12	25	2431
			% within Have in home-DOUBLE GLAZING	60.9%	27.4%	6.6%	3.7%	.5%	1.0%	100.0%
			% within Record general type of dwelling	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	60.9%	27.4%	6.6%	3.7%	.5%	1.0%	100.0%

Source INHSQ 2001-2002

Appendix E - Presence of Cavity Wall

The data from the INSHQ was corrected in accordance with the DEAP Age Bands, and the quantities of houses within that category were established See Table 4.3.2.1, Figure 4.3.2.1 and Figure 4.3.2.2

Table E1 Cavity wall by dwelling age

	Cavity Wall			Cavity Wall Insulation			Cavity Wall with Cavity Wall Insulation		
	Yes	No	Don't know	Yes	No	Don't know	Yes	No	Don't know
Pre 1940	20	63	8	47	19	4	9	12	0
1941-1970	56	27	12	52	31	6	29	8	1
1971-1980	84	5	7	67	24	5	56	1	0
1980-1996	90	3	5	89	5	3	80	0	0
After 96	93	2	3	95	2	2	88	0	0
	62.7	24.5	7.4	71.7	16.3	4.2			

Table E2 Cavity wall by DEAP age Band and by dwelling quantities

DEAP Age Band	Period	INSHQ Data corrected for DEAP Age Band							Detached Housing within Category			
		No Cavity Wall %	Cavity Wall %	Don't Know %	Rebalancing 'Don't Knows'		Presence of Cavity Insulation %	Cavity Wall with No Insulation %	Amount of Dwelling in Category	Housing Quantity by Wall Type		
					No Cavity Wall %	Cavity Wall (Insulated and Non-Insulated)				No Cavity Wall	Cavity Wall No Insulation	Cavity Wall With Insulation
A	Before 1900	63	20	8	76	24	9	15	44784	33993	6761	4031
B	1900-1929	63	20	8	76	24	9	15	34552	26226	5216	3110
C	1930-1949	47	36	10	56	44	18	26	32453	18333	8279	5842
D	1950-1966	27	56	12	33	67	29	38	32245	10489	12404	9351
E	1967-1977	14	74	9	16	84	46	38	52457	8345	19877	24235
F	1978-1982	5	88	6	5	95	70	24	29817	1603	7223	20991
G	1983-1993	3	90	5	3	97	80	17	60233	1943	10104	48187
H	1994-1999	2	92	4	2	98	84	14	45694	972	6339	38383
I	2000-2004	0	100	0	0	100	100	0	52764	0	0	52764
J	2005-2006	0	100	0	0	100	100		21910	0	0	21910

Appendix I – Presence of Cavity Wall

The following tables E3a&b and E4 a & b are all source from the INSHQ

Table E3 a&b

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Do you have cavity walls * Year Built * Record general type of dwelling	39552	97.7%	934	2.3%	40486	100.0%

Do you have cavity walls * Year Built * Record general type of dwelling Crosstabulation

				Year Built					
Record general type of dwelling				Pre-1940	1941-1970	1971-1980	1980-1996	After 1996	Total
Detached house/bungalow	Do you have cavity walls	Some of the accomodation	Count	610	253	166	130	18	1177
			% within Do you have cavity walls	51.8%	21.5%	14.1%	11.0%	1.5%	100.0%
			% within Year Built	10.0%	6.3%	3.4%	2.5%	1.2%	5.4%
			% of Total	2.8%	1.2%	.8%	.6%	.1%	5.4%
		All of the accommodation	Count	1193	2238	4125	4676	1373	13605
			% within Do you have cavity walls	8.8%	16.4%	30.3%	34.4%	10.1%	100.0%
			% within Year Built	19.7%	55.5%	84.4%	89.5%	93.2%	62.7%
			% of Total	5.5%	10.3%	19.0%	21.6%	6.3%	62.7%
		No	Count	3811	1068	251	140	35	5305
			% within Do you have cavity walls	71.8%	20.1%	4.7%	2.6%	.7%	100.0%
			% within Year Built	62.8%	26.5%	5.1%	2.7%	2.4%	24.5%
			% of Total	17.6%	4.9%	1.2%	.6%	.2%	24.5%
		Dont know	Count	456	471	343	280	47	1597
			% within Do you have cavity walls	28.6%	29.5%	21.5%	17.5%	2.9%	100.0%
			% within Year Built	7.5%	11.7%	7.0%	5.4%	3.2%	7.4%
			% of Total	2.1%	2.2%	1.6%	1.3%	.2%	7.4%
	Total		Count	6070	4030	4885	5226	1473	21684
			% within Do you have cavity walls	28.0%	18.6%	22.5%	24.1%	6.8%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	28.0%	18.6%	22.5%	24.1%	6.8%	100.0%
Semi-detached house/bungalow	Do you have cavity walls	Some of the accomodation	Count	83	117	103	94	14	411
			% within Do you have cavity walls	20.2%	28.5%	25.1%	22.9%	3.4%	100.0%
			% within Year Built	7.7%	4.4%	4.0%	4.0%	2.1%	4.4%
			% of Total	.9%	1.3%	1.1%	1.0%	.1%	4.4%
		All of the accommodation	Count	230	1355	1543	1682	544	5354
			% within Do you have cavity walls	4.3%	25.3%	28.8%	31.4%	10.2%	100.0%
			% within Year Built	21.2%	50.6%	59.9%	71.8%	82.4%	57.3%
			% of Total	2.5%	14.5%	16.5%	18.0%	5.8%	57.3%
		No	Count	571	589	284	91	17	1552
			% within Do you have cavity walls	36.8%	38.0%	18.3%	5.9%	1.1%	100.0%
			% within Year Built	52.7%	22.0%	11.0%	3.9%	2.6%	16.6%
			% of Total	6.1%	6.3%	3.0%	1.0%	.2%	16.6%
		Dont know	Count	199	616	648	474	85	2022
			% within Do you have cavity walls	9.8%	30.5%	32.0%	23.4%	4.2%	100.0%
			% within Year Built	18.4%	23.0%	25.1%	20.2%	12.9%	21.7%
			% of Total	2.1%	6.6%	6.9%	5.1%	.9%	21.7%
	Total		Count	1083	2677	2578	2341	660	9339
			% within Do you have cavity walls	11.6%	28.7%	27.6%	25.1%	7.1%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	11.6%	28.7%	27.6%	25.1%	7.1%	100.0%
Terraced house (incl. end of tce)	Do you have cavity walls	Some of the accomodation	Count	101	99	68	36	1	305
			% within Do you have cavity walls	33.1%	32.5%	22.3%	11.8%	.3%	100.0%
			% within Year Built	4.3%	4.0%	4.2%	3.6%	.6%	4.0%
			% of Total	1.3%	1.3%	.9%	.5%	.0%	4.0%
		All of the accommodation	Count	264	903	978	599	109	2853
			% within Do you have cavity walls	9.3%	31.7%	34.3%	21.0%	3.8%	100.0%
			% within Year Built	11.3%	36.1%	60.8%	59.4%	68.6%	37.5%
			% of Total	3.5%	11.9%	12.8%	7.9%	1.4%	37.5%
		No	Count	1458	793	145	71	9	2476
			% within Do you have cavity walls	58.9%	32.0%	5.9%	2.9%	.4%	100.0%
			% within Year Built	62.4%	31.7%	9.0%	7.0%	5.7%	32.5%
			% of Total	19.2%	10.4%	1.9%	.9%	.1%	32.5%
		Dont know	Count	515	703	418	302	40	1978
			% within Do you have cavity walls	26.0%	35.5%	21.1%	15.3%	2.0%	100.0%
			% within Year Built	22.0%	28.1%	26.0%	30.0%	25.2%	26.0%
			% of Total	6.8%	9.2%	5.5%	4.0%	.5%	26.0%
	Total		Count	2338	2498	1609	1008	159	7612
			% within Do you have cavity walls	30.7%	32.8%	21.1%	13.2%	2.1%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	30.7%	32.8%	21.1%	13.2%	2.1%	100.0%
Purpose built flat/apartment etc	Do you have cavity walls	Some of the accomodation	Count	1	0	4	3	0	8
			% within Do you have cavity walls	12.5%	.0%	50.0%	37.5%	.0%	100.0%
			% within Year Built	1.7%	.0%	6.3%	1.7%	.0%	1.5%
			% of Total	.2%	.0%	.8%	.6%	.0%	1.5%
		All of the accommodation	Count	11	19	13	90	50	183
			% within Do you have cavity walls	6.0%	10.4%	7.1%	49.2%	27.3%	100.0%
			% within Year Built	18.6%	13.8%	20.6%	50.0%	57.5%	34.7%
			% of Total	2.1%	3.6%	2.5%	17.1%	9.5%	34.7%
		No	Count	22	65	14	15	5	121
			% within Do you have cavity walls	18.2%	53.7%	11.6%	12.4%	4.1%	100.0%
			% within Year Built	37.3%	47.1%	22.2%	8.3%	5.7%	23.0%
			% of Total	4.2%	12.3%	2.7%	2.8%	.9%	23.0%
		Dont know	Count	25	54	32	72	32	215
			% within Do you have cavity walls	11.6%	25.1%	14.9%	33.5%	14.9%	100.0%
			% within Year Built	42.4%	39.1%	50.8%	40.0%	36.8%	40.8%
			% of Total	4.7%	10.2%	6.1%	13.7%	6.1%	40.8%
	Total		Count	59	138	63	180	87	527
			% within Do you have cavity walls	11.2%	26.2%	12.0%	34.2%	16.5%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	11.2%	26.2%	12.0%	34.2%	16.5%	100.0%
Flat/apartment in converted house etc. (	Do you have cavity walls	Some of the accomodation	Count	3	0	0	0	0	3
			% within Do you have cavity walls	100.0%	.0%	.0%	.0%	.0%	100.0%
			% within Year Built	1.5%	.0%	.0%	.0%	.0%	1.1%
			% of Total	1.1%	.0%	.0%	.0%	.0%	1.1%
		All of the accommodation	Count	18	5	4	13	8	48
			% within Do you have cavity walls	37.5%	10.4%	8.3%	27.1%	16.7%	100.0%
			% within Year Built	9.0%	16.7%	30.8%	54.2%	66.7%	17.1%
			% of Total	6.4%	1.8%	1.4%	4.6%	2.9%	17.1%
		No	Count	98	7	2	0	0	107
			% within Do you have cavity walls	91.6%	6.5%	1.9%	.0%	.0%	100.0%
			% within Year Built	48.8%	23.3%	15.4%	.0%	.0%	38.2%
			% of Total	35.0%	2.5%	.7%	.0%	.0%	38.2%
		Dont know	Count	82	18	7	11	4	122
			% within Do you have cavity walls	67.2%	14.8%	5.7%	9.0%	3.3%	100.0%
			% within Year Built	40.8%	60.0%	53.8%	45.8%	33.3%	43.6%
			% of Total	29.3%	6.4%	2.5%	3.9%	1.4%	43.6%
	Total		Count	201	30	13	24	12	280
			% within Do you have	71.8%	10.7%	4.6%	8.6%	4.3%	100.0%

Table E4 a&b

Case Processing Summary

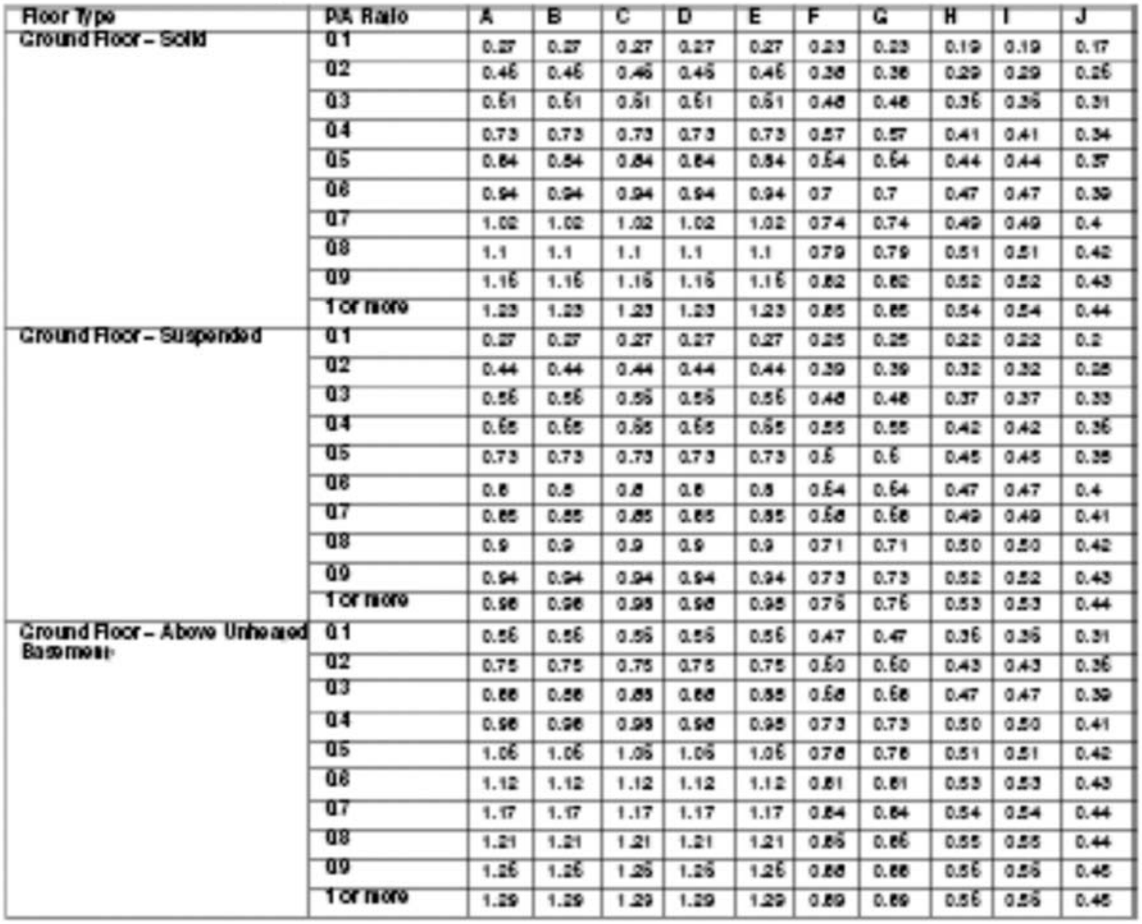
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Do you have cavity wall insulation * Year Built * Record general type of dwelling	23374	57.7%	17112	42.3%	40486	100.0%

Do you have cavity wall insulation * Year Built * Record general type of dwelling Crosstabulation

				Year Built					
Record general type of dwelling				Pre-1940	1941-1970	1971-1980	1980-1996	After 1996	Total
Detached house/bungalow	Do you have cavity wall insulation	Some of the accomodation	Count	519	256	188	147	20	1130
			% within Do you have cavity wall insulation	45.9%	22.7%	16.6%	13.0%	1.8%	100.0%
			% within Year Built	29.6%	10.5%	4.5%	3.1%	1.5%	7.8%
			% of Total	3.6%	1.8%	1.3%	1.0%	.1%	7.8%
		All of the accommodation	Count	827	1266	2791	4160	1284	10328
			% within Do you have cavity wall insulation	8.0%	12.3%	27.0%	40.3%	12.4%	100.0%
			% within Year Built	47.2%	52.1%	66.7%	88.9%	94.6%	71.7%
			% of Total	5.7%	8.8%	19.4%	28.9%	8.9%	71.7%
		No	Count	335	755	991	233	31	2345
			% within Do you have cavity wall insulation	14.3%	32.2%	42.3%	9.9%	1.3%	100.0%
			% within Year Built	19.1%	31.1%	23.7%	5.0%	2.3%	16.3%
			% of Total	2.3%	5.2%	6.9%	1.6%	.2%	16.3%
		Dont know	Count	72	154	216	138	22	602
			% within Do you have cavity wall insulation	12.0%	25.6%	35.9%	22.9%	3.7%	100.0%
			% within Year Built	4.1%	6.3%	5.2%	2.9%	1.6%	4.2%
			% of Total	.5%	1.1%	1.5%	1.0%	.2%	4.2%
	Total		Count	1753	2431	4186	4678	1357	14405
			% within Do you have cavity wall insulation	12.2%	16.9%	29.1%	32.5%	9.4%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	12.2%	16.9%	29.1%	32.5%	9.4%	100.0%
Semi-detached house/bungalow	Do you have cavity wall insulation	Some of the accomodation	Count	77	100	92	100	12	381
			% within Do you have cavity wall insulation	20.2%	26.2%	24.1%	26.2%	3.1%	100.0%
			% within Year Built	25.1%	7.0%	5.7%	5.7%	2.2%	6.8%
			% of Total	1.4%	1.8%	1.6%	1.8%	.2%	6.8%
		All of the accommodation	Count	119	505	808	1332	476	3240
			% within Do you have cavity wall insulation	3.7%	15.6%	24.9%	41.1%	14.7%	100.0%
			% within Year Built	38.8%	35.3%	50.4%	76.6%	88.1%	57.7%
			% of Total	2.1%	9.0%	14.4%	23.7%	8.5%	57.7%
		No	Count	82	630	459	106	18	1295
			% within Do you have cavity wall insulation	6.3%	48.6%	35.4%	8.2%	1.4%	100.0%
			% within Year Built	26.7%	44.1%	28.7%	6.1%	3.3%	23.0%
			% of Total	1.5%	11.2%	8.2%	1.9%	.3%	23.0%
		Dont know	Count	29	195	243	202	34	703
			% within Do you have cavity wall insulation	4.1%	27.7%	34.6%	28.7%	4.8%	100.0%
			% within Year Built	9.4%	13.6%	15.2%	11.6%	6.3%	12.5%
			% of Total	.5%	3.5%	4.3%	3.6%	.6%	12.5%
	Total		Count	307	1430	1602	1740	540	5619
			% within Do you have cavity wall insulation	5.5%	25.4%	28.5%	31.0%	9.6%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	5.5%	25.4%	28.5%	31.0%	9.6%	100.0%
Terraced house (incl. end of tce)	Do you have cavity wall insulation	Some of the accomodation	Count	84	73	47	32	1	237
			% within Do you have cavity wall insulation	35.4%	30.8%	19.8%	13.5%	.4%	100.0%
			% within Year Built	23.1%	7.5%	4.6%	5.2%	.9%	7.7%
			% of Total	2.7%	2.4%	1.5%	1.0%	.0%	7.7%
		All of the accommodation	Count	153	340	449	439	88	1469
			% within Do you have cavity wall insulation	10.4%	23.1%	30.6%	29.9%	6.0%	100.0%
			% within Year Built	42.1%	34.7%	43.5%	71.0%	83.0%	47.4%
			% of Total	4.9%	11.0%	14.5%	14.2%	2.8%	47.4%
		No	Count	73	421	317	52	5	868
			% within Do you have cavity wall insulation	8.4%	48.5%	36.5%	6.0%	.6%	100.0%
			% within Year Built	20.1%	43.0%	30.7%	8.4%	4.7%	28.0%
			% of Total	2.4%	13.6%	10.2%	1.7%	.2%	28.0%
		Dont know	Count	53	145	218	95	12	523
			% within Do you have cavity wall insulation	10.1%	27.7%	41.7%	18.2%	2.3%	100.0%
			% within Year Built	14.6%	14.8%	21.1%	15.4%	11.3%	16.9%
			% of Total	1.7%	4.7%	7.0%	3.1%	.4%	16.9%
	Total		Count	363	979	1031	618	106	3097
			% within Do you have cavity wall insulation	11.7%	31.6%	33.3%	20.0%	3.4%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	11.7%	31.6%	33.3%	20.0%	3.4%	100.0%
Purpose built flat/apartment etc	Do you have cavity wall insulation	Some of the accomodation	Count	1	0	2	2	0	5
			% within Do you have cavity wall insulation	20.0%	.0%	40.0%	40.0%	.0%	100.0%
			% within Year Built	11.1%	.0%	12.5%	2.2%	.0%	2.7%
			% of Total	.5%	.0%	1.1%	1.1%	.0%	2.7%
		All of the accommodation	Count	2	11	9	78	41	141
			% within Do you have cavity wall insulation	1.4%	7.8%	6.4%	55.3%	29.1%	100.0%
			% within Year Built	22.2%	55.0%	56.3%	83.9%	87.2%	76.2%
			% of Total	1.1%	5.9%	4.9%	42.2%	22.2%	76.2%
		No	Count	1	6	0	2	3	12
			% within Do you have cavity wall insulation	8.3%	50.0%	.0%	16.7%	25.0%	100.0%
			% within Year Built	11.1%	30.0%	.0%	2.2%	6.4%	6.5%
			% of Total	.5%	3.2%	.0%	1.1%	1.6%	6.5%
		Dont know	Count	5	3	5	11	3	27
			% within Do you have cavity wall insulation	18.5%	11.1%	18.5%	40.7%	11.1%	100.0%
			% within Year Built	55.6%	15.0%	31.3%	11.8%	6.4%	14.6%
			% of Total	2.7%	1.6%	2.7%	5.9%	1.6%	14.6%
	Total		Count	9	20	16	93	47	185
			% within Do you have cavity wall insulation	4.9%	10.8%	8.6%	50.3%	25.4%	100.0%
			% within Year Built	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	4.9%	10.8%	8.6%	50.3%	25.4%	100.0%
Flat/apartment in converted house etc. (	Do you have cavity wall insulation	Some of the accomodation	Count	2	0	0	0	0	2
			% within Do you have cavity wall insulation	100.0%	.0%	.0%	.0%	.0%	100.0%
			% within Year Built	11.1%	.0%	.0%	.0%	.0%	4.3%
			% of Total	4.3%	.0%	.0%	.0%	.0%	4.3%
		All of the accommodation	Count	8	2	2	7	7	26
			% within Do you have cavity wall insulation	30.8%	7.7%	7.7%	26.9%	26.9%	100.0%
			% within Year Built	44.4%	40.0%	66.7%	53.8%	87.5%	55.3%
			% of Total	17.0%	4.3%	4.3%	14.9%	14.9%	55.3%
		No	Count	2	2	1	1	0	6
			% within Do you have cavity wall insulation	33.3%	33.3%	16.7%	16.7%	.0%	100.0%
			% within Year Built	11.1%	40.0%	33.3%	7.7%	.0%	12.8%
			% of Total	4.3%	4.3%	2.1%	2.1%	.0%	12.8%
		Dont know	Count	6	1	0	5	1	13

Appendix F – Floor U-values

Table F1 - DEAP Default Ground Floor Values by P/A Ratio and Age Band



Floor Type	P/A Ratio	A	B	C	D	E	F	G	H	I	J
Ground Floor – Solid	0.1	0.27	0.27	0.27	0.27	0.27	0.23	0.23	0.19	0.19	0.17
	0.2	0.46	0.46	0.46	0.46	0.46	0.38	0.38	0.29	0.29	0.26
	0.3	0.61	0.61	0.61	0.61	0.61	0.48	0.48	0.36	0.36	0.31
	0.4	0.73	0.73	0.73	0.73	0.73	0.57	0.57	0.41	0.41	0.34
	0.5	0.84	0.84	0.84	0.84	0.84	0.64	0.64	0.44	0.44	0.37
	0.6	0.94	0.94	0.94	0.94	0.94	0.7	0.7	0.47	0.47	0.39
	0.7	1.02	1.02	1.02	1.02	1.02	0.74	0.74	0.49	0.49	0.4
	0.8	1.1	1.1	1.1	1.1	1.1	0.79	0.79	0.51	0.51	0.42
	0.9	1.16	1.16	1.16	1.16	1.16	0.82	0.82	0.52	0.52	0.43
	1 or more	1.23	1.23	1.23	1.23	1.23	0.85	0.85	0.54	0.54	0.44
Ground Floor – Suspended	0.1	0.27	0.27	0.27	0.27	0.27	0.25	0.25	0.22	0.22	0.2
	0.2	0.44	0.44	0.44	0.44	0.44	0.39	0.39	0.32	0.32	0.28
	0.3	0.56	0.56	0.56	0.56	0.56	0.48	0.48	0.37	0.37	0.33
	0.4	0.65	0.65	0.65	0.65	0.65	0.55	0.55	0.42	0.42	0.36
	0.5	0.73	0.73	0.73	0.73	0.73	0.6	0.6	0.45	0.45	0.38
	0.6	0.8	0.8	0.8	0.8	0.8	0.64	0.64	0.47	0.47	0.4
	0.7	0.85	0.85	0.85	0.85	0.85	0.68	0.68	0.49	0.49	0.41
	0.8	0.9	0.9	0.9	0.9	0.9	0.71	0.71	0.50	0.50	0.42
	0.9	0.94	0.94	0.94	0.94	0.94	0.73	0.73	0.52	0.52	0.43
	1 or more	0.98	0.98	0.98	0.98	0.98	0.76	0.76	0.53	0.53	0.44
Ground Floor – Above Unheated Basement	0.1	0.56	0.56	0.56	0.56	0.56	0.47	0.47	0.36	0.36	0.31
	0.2	0.75	0.75	0.75	0.75	0.75	0.60	0.60	0.43	0.43	0.36
	0.3	0.88	0.88	0.88	0.88	0.88	0.68	0.68	0.47	0.47	0.39
	0.4	0.98	0.98	0.98	0.98	0.98	0.73	0.73	0.50	0.50	0.41
	0.5	1.06	1.06	1.06	1.06	1.06	0.78	0.78	0.51	0.51	0.42
	0.6	1.12	1.12	1.12	1.12	1.12	0.81	0.81	0.53	0.53	0.43
	0.7	1.17	1.17	1.17	1.17	1.17	0.84	0.84	0.54	0.54	0.44
	0.8	1.21	1.21	1.21	1.21	1.21	0.86	0.86	0.55	0.55	0.44
	0.9	1.26	1.26	1.26	1.26	1.26	0.88	0.88	0.56	0.56	0.45
	1 or more	1.29	1.29	1.29	1.29	1.29	0.89	0.89	0.56	0.56	0.45

Source: DEAP (Table S8)

Appendix G – No of External Doors

Source Data INHSQ 2001-2002

With the file split the valid results amounted to 844 (Table G1), considered insufficient, analysis carried out with rural filter off (Table G2 a & b)

Table G1

Case Processing Summary[a]

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Record general type of dwelling * How many external doors on accomodation * Year Built	844	91.0%	83	9.0%	927	100.0%

a. R=2 (FILTER) = .

Table G2 a & b

Case Processing Summary

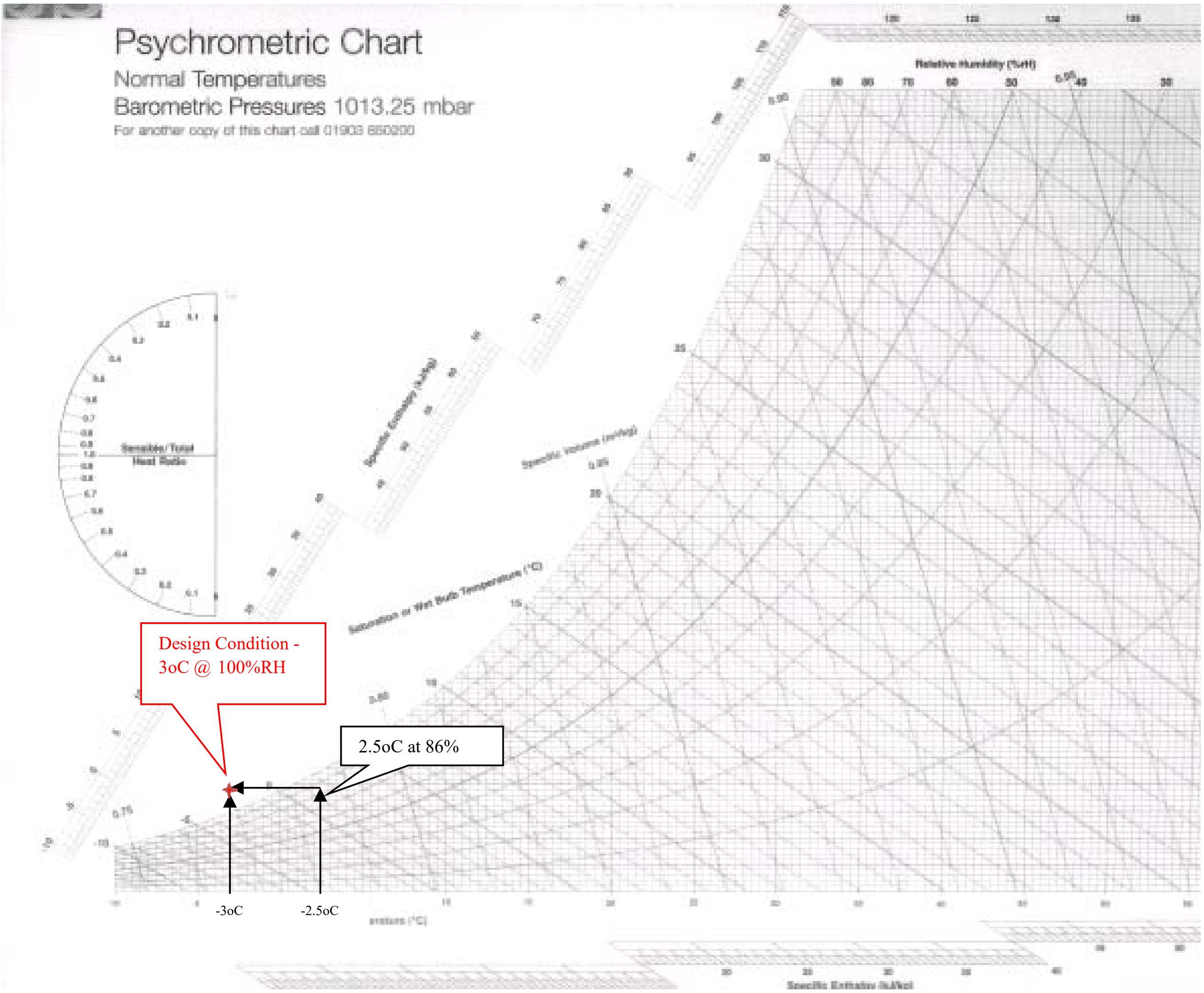
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
How many external doors on accomodation * Record general type of dwelling * Year Built	39201	96.8%	1285	3.2%	40486	100.0%

Record general type of dwelling * How many external doors on accomodation * Year Built Crosstabulation

				How many external doors on accomodation																																
Year Built				0	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	18	20	21	22	23	24	25	31	32	33	35	40	41	42	44	50	Total
Pre-1940	Record general type of dwelling	Detached house/bungalow	Count	1	608	4334	786	175	49	16	7	1		1	4	3	1		1	0	0	13	16	0			3	0	0	1	0		0	1	1	6022
			% within Record general type of dwelling	.0%	10.1%	72.0%	13.1%	2.9%	.8%	.3%	.1%	.0%		.0%	.1%	.0%	.0%		.0%	.0%	.0%	.2%	.3%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
			% within How many external doors on accomodation	2.3%	74.9%	60.7%	65.4%	58.9%	59.0%	80.0%	77.8%	100.0%		100.0%	80.0%	60.0%	100.0%		100.0%	.0%	.0%	72.2%	43.2%	.0%			75.0%	.0%	.0%	100.0%	.0%		.0%	50.0%	100.0%	62.1%
			% of Total	.0%	6.3%	44.7%	8.1%	1.8%	.5%	.2%	.1%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.1%	.2%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	62.1%
		Semi-detached house/bungalow	Count	0	31	756	190	52	18	3	1	0		0	0	1	0		0	0	0	3	8	2			1	0	1	0	0		0	1	0	1068
			% within Record general type of dwelling	.0%	2.9%	70.8%	17.8%	4.9%	1.7%	.3%	.1%	.0%		.0%	.0%	.1%	.0%		.0%	.0%	.0%	.3%	.7%	.2%			.1%	.0%	.1%	.0%	.0%		.0%	.1%	.0%	100.0%
			% within How many external doors on accomodation	.0%	3.8%	10.6%	15.8%	17.5%	21.7%	15.0%	11.1%	.0%		.0%	.0%	20.0%	.0%		.0%	.0%	.0%	16.7%	21.6%	100.0%			25.0%	.0%	100.0%	.0%	.0%		.0%	50.0%	.0%	11.0%
			% of Total	.0%	.3%	7.8%	2.0%	.5%	.2%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.1%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	11.0%
		Terraced house (incl. end of tce)	Count	9	56	1960	215	63	14	1	1	0		0	1	0	0		0	1	1	2	12	0			0	3	0	0	1		1	0	0	2341
			% within Record general type of dwelling	.4%	2.4%	83.7%	9.2%	2.7%	.6%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.1%	.5%	.0%			.0%	.1%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
			% within How many external doors on accomodation	20.5%	6.9%	27.4%	17.9%	21.2%	16.9%	5.0%	11.1%	.0%		.0%	20.0%	.0%	.0%		.0%	100.0%	100.0%	11.1%	32.4%	.0%			.0%	100.0%	.0%	.0%	100.0%		100.0%	.0%	.0%	24.1%
			% of Total	.1%	.6%	20.2%	2.2%	.6%	.1%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.1%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	24.1%
		Purpose built flat/apartment etc	Count	1	35	24	0	0	0	0	0	0		0	0	0	0		0	0	0	0	0	0			0	0	0	0	0		0	0	0	60
			% within Record general type of dwelling	1.7%	58.3%	40.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
			% within How many external doors on accomodation	2.3%	4.3%	.3%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.6%
			% of Total	.0%	.4%	.2%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.6%
		Flat/apartment in converted house etc. (	Count	33	77	65	10	6	2	0	0	0		0	0	1	0		0	0	0	0	1	0			0	0	0	0	0		0	0	0	195
			% within Record general type of dwelling	16.9%	39.5%	33.3%	5.1%	3.1%	1.0%	.0%	.0%	.0%		.0%	.0%	.5%	.0%		.0%	.0%	.0%	.0%	.5%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
			% within How many external doors on accomodation	75.0%	9.5%	.9%	.8%	2.0%	2.4%	.0%	.0%	.0%		.0%	.0%	20.0%	.0%		.0%	.0%	.0%	.0%	2.7%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	2.0%
			% of Total	.3%	.8%	.7%	.1%	.1%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	2.0%
		Caravan/Mobile Home	Count	0	5	6	0	1	0	0	0	0		0	0	0	0		0	0	0	0	0	0			0	0	0	0	0		0	0	0	12
			% within Record general type of dwelling	.0%	41.7%	50.0%	.0%	8.3%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
			% within How many external doors on accomodation	.0%	.6%	.1%	.0%	.3%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.1%
			% of Total	.0%	.1%	.1%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%		.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	.1%
	Total		Count	44	812	7145	1201	297	83	20	9	1		1	5	5	1		1	1	1	18	37	2			4	3	1	1	1		1	2	1	9698
			% within Record general type of dwelling	.5%	8.4%	73.7%	12.4%	3.1%	.9%	.2%	.1%	.0%		.0%	.1%	.1%	.0%		.0%	.0%	.0%	.2%	.4%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
			% within How many external doors on accomodation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%
			% of Total	.5%	8.4%	73.7%	12.4%	3.1%	.9%	.2%	.1%	.0%		.0%	.1%	.1%	.0%		.0%	.0%	.0%	.2%	.4%	.0%			.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%	100.0%
1941-1970	Record general type of dwelling	Detached house/bungalow	Count	1	118	3056	605	137	32	10	1	1			4	2					0	8	13	0		1	3	0				0				3992
			% within Record general type of dwelling	.0%	3.0%	76.6%	15.2%	3.4%	.8%	.3%	.0%	.0%			.1%	.1%					.0%	.2%	.3%	.0%		.0%	.1%	.0%				.0%				100.0%
			% within How many external doors on accomodation	25.0%	47.2%	41.7%	45.1%	52.1%	74.4%	76.9%	50.0%	100.0%			100.0%	66.7%					.0%	53.3%	39.4%	.0%		100.0%	75.0%	.0%				.0%				42.9%
			% of Total	.0%	1.3%	32.8%	6.5%	1.5%	.3%	.1%	.0%	.0%			.0%	.0%					.0%	.1%	.1%	.0%		.0%	.0%	.0%				.0%				42.9%
		Semi-detached house/bungalow	Count	1	23	1900	590	113	10	3	0	0			0	0					1	4	11	1		0	1	2				2				2662
			% within Record general type of dwelling	.0%	.9%	71.4%	22.2%	4.2%	.4%	.1%	.0%	.0%			.0%	.0%					.0%	.2%	.4%	.0%		.0%	.0%	.1%				.1%				100.0%
			% within How many external doors on accomodation	25.0%	9.2%	25.9%	44.0%	43.0%	23.3%	23.1%	.0%	.0%			.0%	.0%					100.0%	26.7%	33.3%	100.0%		.0%	25.0%	100.0%				100.0%				28.6%
			% of Total	.0%	.2%	20.4%	6.3%	1.2%	.1%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.1%	.0%		.0%	.0%	.0%				.0%				28.6%
		Terraced house (incl. end of tce)	Count	0	18	2288	142	13	1	0	1	0			0	1					0	3	9	0		0	0	0				0				2476
			% within Record general type of dwelling	.0%	.7%	92.4%	5.7%	.5%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.1%	.4%	.0%		.0%	.0%	.0%				.0%				100.0%
			% within How many external doors on accomodation	.0%	7.2%	31.2%	10.6%	4.9%	2.3%	.0%	50.0%	.0%			.0%	33.3%					.0%	20.0%	27.3%	.0%		.0%	.0%	.0%				.0%				26.6%
			% of Total	.0%	.2%	24.6%	1.5%	.1%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.1%	.0%		.0%	.0%	.0%				.0%				26.6%
		Purpose built flat/apartment etc	Count	1	73	61	1	0	0	0	0	0			0	0					0	0	0	0		0	0	0				0				136
			% within Record general type of dwelling	.7%	53.7%	44.9%	.7%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				100.0%
			% within How many external doors on accomodation	25.0%	29.2%	.8%	.1%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				1.5%
			% of Total	.0%	.8%	.7%	.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				1.5%
		Flat/apartment in converted house etc. (	Count	1	15	13	1	0	0	0	0	0			0	0					0	0	0	0		0	0	0				0				30
			% within Record general type of dwelling	3.3%	50.0%	43.3%	3.3%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				100.0%
			% within How many external doors on accomodation	25.0%	6.0%	.2%	.1%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				.3%
			% of Total	.0%	.2%	.1%	.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				.3%
		Caravan/Mobile Home	Count	0	3	5	1	0	0	0	0	0			0	0					0	0	0	0		0	0	0				0				9
			% within Record general type of dwelling	.0%	33.3%	55.6%	11.1%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				100.0%
			% within How many external doors on accomodation	.0%	1.2%	.1%	.1%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				.1%
			% of Total	.0%	.0%	.1%	.0%	.0%	.0%	.0%	.0%	.0%			.0%	.0%					.0%	.0%	.0%	.0%		.0%	.0%	.0%				.0%				.1%
	Total		Count	4	250	7323	1340	263	43	13	2	1			4	3					1	15	33	1		1	4	2				2				9305
			% within Record general type of dwelling	.0%	2.7%	78.7%	14.4%	2.8%	.5%	.1%	.0%	.0%			.0%	.0%					.0%	.2%	.4%	.0%		.0%	.0%	.0%				.0%				100.0%
			% within How many external doors on accomodation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%	100.0%					100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%				100.0%				100.0%
			% of Total	.0%	2.7%	78.7%	14.4%	2.8%	.5%	.1%	.0%	.0%			.0%	.0%					.0%	.2%	.4%	.0%		.0%	.0%	.0%				.0%				100.0%
1971-1980	Record general type of dwelling	Detached house/bungalow	Count	1	48	3554	939	198	42	5	3	1		1	4	0			1		0	13	16				2								1	4829
			% within Record general type of dwelling	.0%	1.0%	73.6%	19.4%	4.1%	.9%	.1%	.1%	.0%		.0%	.1%	.0%			.0%		.0%	.3%	.3%				.0%								.0%	100.0%
			% within How many external doors on accomodation	7.7%	43.2%	50.0%	63.9%	74.2%	89.4%	71.4%	100.0%	100.0%		100.0%	66.7%	.0%			100.0%		.0%	65.0%	53.3%				100.0%								100.0%	53.1%
			% of Total	.0%	.5%	39.1%	10.3%	2.2%	.5%	.1%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.1%	.2%				.0%								.0%	53.1%
		Semi-detached house/bungalow	Count	3	16	2003	481	60	5	1	0	0		0	0	0			0		1	3	9				0								0	2582
			% within Record general type of dwelling	.1%	.6%	77.6%	18.6%	2.3%	.2%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.1%	.3%				.0%								.0%	100.0%
			% within How many external doors on accomodation	23.1%	14.4%	28.2%	32.7%	22.5%	10.6%	14.3%	.0%	.0%		.0%	.0%	.0%			.0%		100.0%	15.0%	30.0%				.0%								.0%	28.4%
			% of Total	.0%	.2%	22.0%	5.3%	.7%	.1%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.1%				.0%								.0%	28.4%
		Terraced house (incl. end of tce)	Count	0	4	1516	47	8	0	0	0	0		0	2	2			0		0	4	5				0								0	1588
			% within Record general type of dwelling	.0%	.3%	95.5%	3.0%	.5%	.0%	.0%	.0%	.0%		.0%	.1%	.1%			.0%		.0%	.3%	.3%				.0%								.0%	100.0%
			% within How many external doors on accomodation	.0%	3.6%	21.3%	3.2%	3.0%	.0%	.0%	.0%	.0%		.0%	33.3%	100.0%			.0%		.0%	20.0%	16.7%				.0%								.0%	17.5%
			% of Total	.0%	.0%	16.7%	.5%	.1%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.1%				.0%								.0%	17.5%
		Purpose built flat/apartment etc	Count	8	26	25	1	0	0	0	0	0		0	0	0			0		0	0	0				0								0	60
			% within Record general type of dwelling	13.3%	43.3%	41.7%	1.7%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	100.0%
			% within How many external doors on accomodation	61.5%	23.4%	.4%	.1%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	.7%
			% of Total	.1%	.3%	.3%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	.7%
		Flat/apartment in converted house etc. (	Count	1	9	3	0	0	0	0	0	0		0	0	0			0		0	0	0				0								0	13
			% within Record general type of dwelling	7.7%	69.2%	23.1%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	100.0%
			% within How many external doors on accomodation	7.7%	8.1%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	.1%
			% of Total	.0%	.1%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	.1%
		Caravan/Mobile Home	Count	0	8	9	1	1	0	1	0	0		0	0	0			0		0	0	0				0								0	20
			% within Record general type of dwelling	.0%	40.0%	45.0%	5.0%	5.0%	.0%	5.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	100.0%
			% within How many external doors on accomodation	.0%	7.2%	.1%	.1%	.4%	.0%	14.3%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	.2%
			% of Total	.0%	.1%	.1%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%			.0%		.0%	.0%	.0%				.0%								.0%	.2%
	Total		Count	13	111	7110	1469	267	47	7	3	1		1	6	2			1		1	20	30				2								1	9092
			% within Record general type of dwelling	.1%	1.2%	78.2%	16.2%	2.9%	.5%	.1%	.0%	.0%		.0%	.1%	.0%			.0%		.0%	.2%	.3%				.0%								.0%	100.0%
			% within How many external doors on accomodation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%			100.0%		100.0%	100.0%	100.0%				100.0%								100.0%	100.0%
			% of Total	.1%	1.2%	78.2%	16.2%	2.9%	.5%	.1%	.0%	.0%		.0%	.1%	.0%			.0%		.0%	.2%	.3%				.0%								.0%	100.0%
1980-1996	Record general type of dwelling	Detached house/bungalow	Count	3	37	3412	1309	289	42	10	4	1	0		0	0				1		11	22		1		5	5				1	1			5154
			% within Record general type of dwelling	.1%	.7%	66.2%	25.4%	5.6%	.8%	.2%	.1%	.0%	.0%		.0%	.0%				.0%		.2%	.4%		.0%		.1%	.1%				.0%	.0%			100.0%
			% within How many external doors on accomodation	12.5%	17.8%	54.9%	72.0%	90.3%	100.0%	100.0%	100.0%	100.0%	.0%		.0%	.0%				100.0%		68.8%	66.7%		100.0%		100.0%	71.4%				100.0%	100.0%			59.2%
			% of Total	.0%	.4%	39.2%	15.0%	3.3%	.5%	.1%	.0%	.0%	.0%		.0%	.0%				.0%		.1%	.3%		.0%		.1%	.1%				.0%	.0%			59.2%
		Semi-detached house/bungalow	Count	0	22	1798	466	25	0	0	0	0	1		0	0				0		5	7		0		0	2				0	0			2326
			% within Record general type of dwelling	.0%	.9%	77.3%	20.0%	1.1%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.2%	.3%		.0%		.0%	.1%				.0%	.0%			100.0%
			% within How many external doors on accomodation	.0%	10.6%	28.9%	25.6%	7.8%	.0%	.0%	.0%	.0%	100.0%		.0%	.0%				.0%		31.3%	21.2%		.0%		.0%	28.6%				.0%	.0%			26.7%
			% of Total	.0%	.3%	20.6%	5.3%	.3%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.1%	.1%		.0%		.0%	.0%				.0%	.0%			26.7%
		Terraced house (incl. end of tce)	Count	0	24	919	37	5	0	0	0	0	0		0	0				0		0	2		0		0	0				0	0			987
			% within Record general type of dwelling	.0%	2.4%	93.1%	3.7%	.5%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.2%		.0%		.0%	.0%				.0%	.0%			100.0%
			% within How many external doors on accomodation	.0%	11.5%	14.8%	2.0%	1.6%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	6.1%		.0%		.0%	.0%				.0%	.0%			11.3%
			% of Total	.0%	.3%	10.5%	.4%	.1%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			11.3%
		Purpose built flat/apartment etc	Count	19	91	60	3	1	0	0	0	0	0		1	2				0		0	2		0		0	0				0	0			179
			% within Record general type of dwelling	10.6%	50.8%	33.5%	1.7%	.6%	.0%	.0%	.0%	.0%	.0%		.6%	1.1%				.0%		.0%	1.1%		.0%		.0%	.0%				.0%	.0%			100.0%
			% within How many external doors on accomodation	79.2%	43.8%	1.0%	.2%	.3%	.0%	.0%	.0%	.0%	.0%		100.0%	100.0%				.0%		.0%	6.1%		.0%		.0%	.0%				.0%	.0%			2.1%
			% of Total	.2%	1.0%	.7%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			2.1%
		Flat/apartment in converted house etc. (	Count	2	16	6	0	0	0	0	0	0	0		0	0				0		0	0		0		0	0				0	0			24
			% within Record general type of dwelling	8.3%	66.7%	25.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			100.0%
			% within How many external doors on accomodation	8.3%	7.7%	.1%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			.3%
			% of Total	.0%	.2%	.1%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			.3%
		Caravan/Mobile Home	Count	0	18	23	2	0	0	0	0	0	0		0	0				0		0	0		0		0	0				0	0			43
			% within Record general type of dwelling	.0%	41.9%	53.5%	4.7%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			100.0%
			% within How many external doors on accomodation	.0%	8.7%	.4%	.1%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			.5%
			% of Total	.0%	.2%	.3%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%				.0%		.0%	.0%		.0%		.0%	.0%				.0%	.0%			.5%
	Total		Count	24	208	6218	1817	320	42	10	4	1	1		1	2				1		16	33		1		5	7				1	1			8713
			% within Record general type of dwelling	.3%	2.4%	71.4%	20.9%	3.7%	.5%	.1%	.0%	.0%	.0%		.0%	.0%				.0%		.2%	.4%		.0%		.1%	.1%				.0%	.0%			100.0%
			% within How many external doors on accomodation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%				100.0%		100.0%	100.0%		100.0%		100.0%	100.0%				100.0%	100.0%			100.0%
			% of Total	.3%	2.4%	71.4%	20.9%	3.7%	.5%	.1%	.0%	.0%	.0%		.0%	.0%				.0%		.2%	.4%		.0%		.1%	.1%				.0%	.0%			100.0%
After 1996	Record general type of dwelling	Detached house/bungalow	Count	0	9	662	626	125	22	3	3	2		1	1	0		1					3					1				0				1459
			% within Record general type of dwelling	.0%	.6%	45.4%	42.9%	8.6%	1.5%	.2%	.2%	.1%		.1%	.1%	.0%		.1%					.2%					.1%				.0%				100.0%
			% within How many external doors on accomodation	.0%	10.5%	52.8%	72.4%	90.6%	95.7%	100.0%	100.0%	100.0%		100.0%	100.0%	.0%		100.0%					37.5%					100.0%				.0%				61.0%
			% of Total	.0%	.4%	27.7%	26.2%	5.2%	.9%	.1%	.1%	.1%		.0%	.0%	.0%		.0%					.1%					.0%				.0%				61.0%
		Semi-detached house/bungalow	Count	0	5	411	225	11	1	0	0	0		0	0	0		0					4					0				1				658
			% within Record general type of dwelling	.0%	.8%	62.5%	34.2%	1.7%	.2%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.6%					.0%				.2%				100.0%
			% within How many external doors on accomodation	.0%	5.8%	32.8%	26.0%	8.0%	4.3%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					50.0%					.0%				100.0%				27.5%
			% of Total	.0%	.2%	17.2%	9.4%	.5%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.2%					.0%				.0%				27.5%
		Terraced house (incl. end of tce)	Count	1	4	135	10	2	0	0	0	0		0	0	0		0					0					0				0				152
			% within Record general type of dwelling	.7%	2.6%	88.8%	6.6%	1.3%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				100.0%
			% within How many external doors on accomodation	20.0%	4.7%	10.8%	1.2%	1.4%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				6.4%
			% of Total	.0%	.2%	5.6%	.4%	.1%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				6.4%
		Purpose built flat/apartment etc	Count	3	49	30	4	0	0	0	0	0		0	0	1		0					0					0				0				87
			% within Record general type of dwelling	3.4%	56.3%	34.5%	4.6%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	1.1%		.0%					.0%					.0%				.0%				100.0%
			% within How many external doors on accomodation	60.0%	57.0%	2.4%	.5%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	100.0%		.0%					.0%					.0%				.0%				3.6%
			% of Total	.1%	2.0%	1.3%	.2%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				3.6%
		Flat/apartment in converted house etc. (	Count	1	6	4	0	0	0	0	0	0		0	0	0		0					1					0				0				12
			% within Record general type of dwelling	8.3%	50.0%	33.3%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					8.3%					.0%				.0%				100.0%
			% within How many external doors on accomodation	20.0%	7.0%	.3%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					12.5%					.0%				.0%				.5%
			% of Total	.0%	.3%	.2%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				.5%
		Caravan/Mobile Home	Count	0	13	12	0	0	0	0	0	0		0	0	0		0					0					0				0				25
			% within Record general type of dwelling	.0%	52.0%	48.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				100.0%
			% within How many external doors on accomodation	.0%	15.1%	1.0%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				1.0%
			% of Total	.0%	.5%	.5%	.0%	.0%	.0%	.0%	.0%	.0%		.0%	.0%	.0%		.0%					.0%					.0%				.0%				1.0%
	Total		Count	5	86	1254	865	138	23	3	3	2		1	1	1		1					8					1				1				2393
			% within Record general type of dwelling	.2%	3.6%	52.4%	36.1%	5.8%	1.0%	.1%	.1%	.1%		.0%	.0%	.0%		.0%					.3%					.0%				.0%				100.0%
			% within How many external doors on accomodation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%		100.0%					100.0%					100.0%				100.0%				100.0%
			% of Total	.2%	3.6%	52.4%	36.1%	5.8%	1.0%	.1%	.1%	.1%		.0%	.0%	.0%		.0%					.3%					.0%				.0%				100.0%

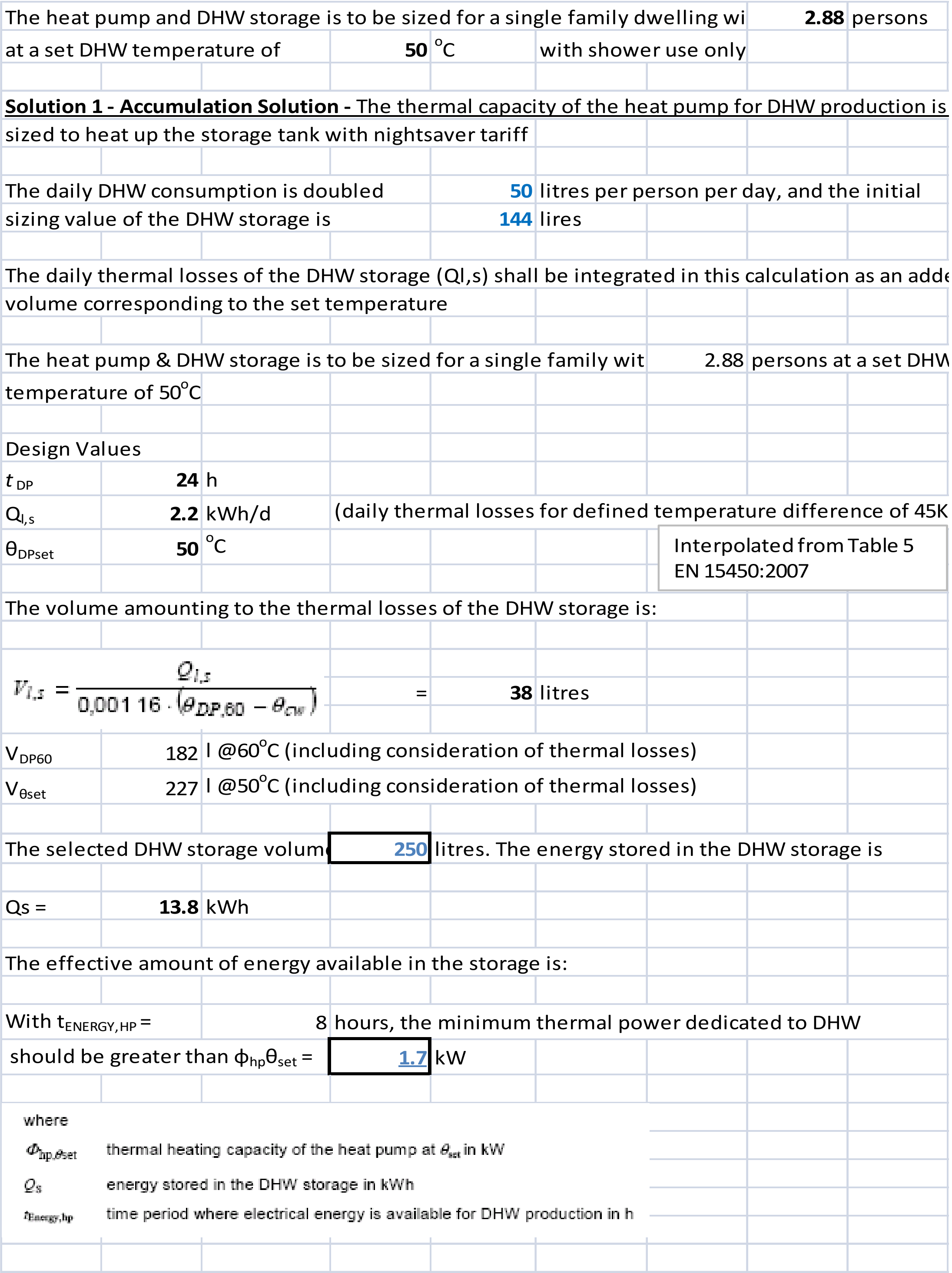
Source: INSHQ 2001-2002

Appendix H – External Temperature Calculation



Appendix I – DHW Calculation

Table I1 – Solution 1 – Accumulation Solution - House Type A, B, C, D and E



The heat pump and DHW storage is to be sized for a single family dwelling wi **2.88** persons

at a set DHW temperature of **50** °C with shower use only

Solution 1 - Accumulation Solution - The thermal capacity of the heat pump for DHW production is sized to heat up the storage tank with nightsaver tariff

The daily DHW consumption is doubled **50** litres per person per day, and the initial sizing value of the DHW storage is **144** lires

The daily thermal losses of the DHW storage (Ql,s) shall be integrated in this calculation as an adde volume corresponding to the set temperature

The heat pump & DHW storage is to be sized for a single family wit 2.88 persons at a set DHW temperature of 50°C

Design Values

t_{DP} **24** h

$Q_{l,s}$ **2.2** kWh/d (daily thermal losses for defined temperature difference of 45K

θ_{DPset} **50** °C

Interpolated from Table 5 EN 15450:2007

The volume amounting to the thermal losses of the DHW storage is:

$$V_{l,s} = \frac{Q_{l,s}}{0{,}001\,16 \cdot (\theta_{DP,60} - \theta_{CW})}$$ = **38** litres

V_{DP60} 182 l @60°C (including consideration of thermal losses)

$V_{\theta set}$ 227 l @50°C (including consideration of thermal losses)

The selected DHW storage volum **250** litres. The energy stored in the DHW storage is

Qs = **13.8** kWh

The effective amount of energy available in the storage is:

With $t_{ENERGY,HP}$ = 8 hours, the minimum thermal power dedicated to DHW

should be greater than $\phi_{hp}\theta_{set}$ = 1.7 kW

where

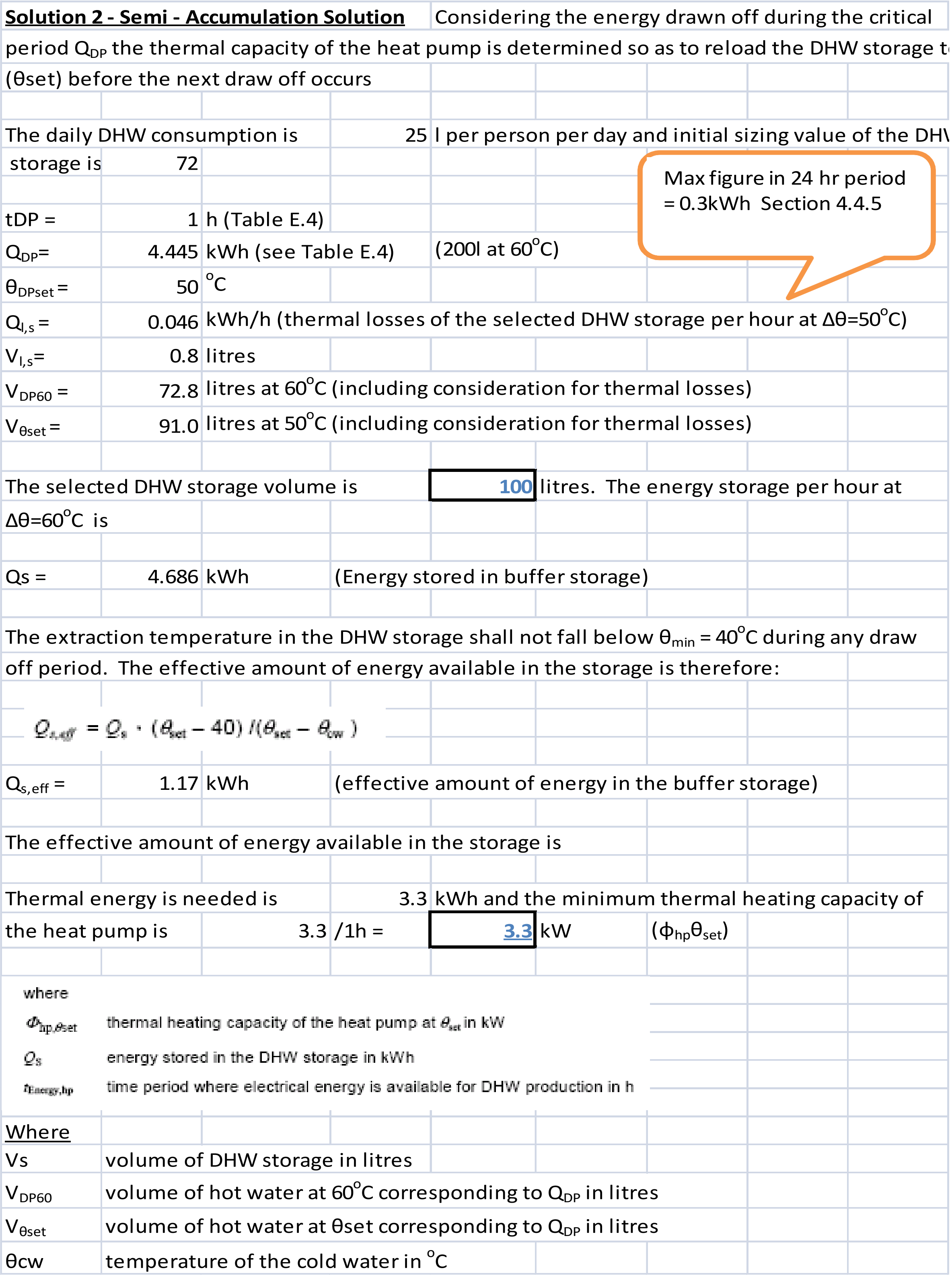
$\Phi_{hp,\theta set}$ thermal heating capacity of the heat pump at θ_{set} in kW

Q_s energy stored in the DHW storage in kWh

$t_{Energy,hp}$ time period where electrical energy is available for DHW production in h

Source: EN15450:2007 (E)

Table I2 – Solution 2 – Semi-Accumulation Solution - House Type A, B, C, D and E



Solution 2 - Semi - Accumulation Solution Considering the energy drawn off during the critical period Q_{DP} the thermal capacity of the heat pump is determined so as to reload the DHW storage t
(θset) before the next draw off occurs

The daily DHW consumption is 25 l per person per day and initial sizing value of the DH
storage is 72

Max figure in 24 hr period = 0.3kWh Section 4.4.5

tDP = 1 h (Table E.4)

Q_{DP}= 4.445 kWh (see Table E.4) (200l at 60°C)

θ_{DPset} = 50 °C

$Q_{l,s}$ = 0.046 kWh/h (thermal losses of the selected DHW storage per hour at Δθ=50°C)

$V_{l,s}$= 0.8 litres

V_{DP60} = 72.8 litres at 60°C (including consideration for thermal losses)

$V_{\theta set}$ = 91.0 litres at 50°C (including consideration for thermal losses)

The selected DHW storage volume is 100 litres. The energy storage per hour at Δθ=60°C is

Qs = 4.686 kWh (Energy stored in buffer storage)

The extraction temperature in the DHW storage shall not fall below θ_{min} = 40°C during any draw off period. The effective amount of energy available in the storage is therefore:

$$Q_{s,eff} = Q_s \cdot (\theta_{set} - 40) / (\theta_{set} - \theta_{cw})$$

$Q_{s,eff}$ = 1.17 kWh (effective amount of energy in the buffer storage)

The effective amount of energy available in the storage is

Thermal energy is needed is 3.3 kWh and the minimum thermal heating capacity of the heat pump is 3.3 /1h = 3.3 kW ($\phi_{hp}\theta_{set}$)

where

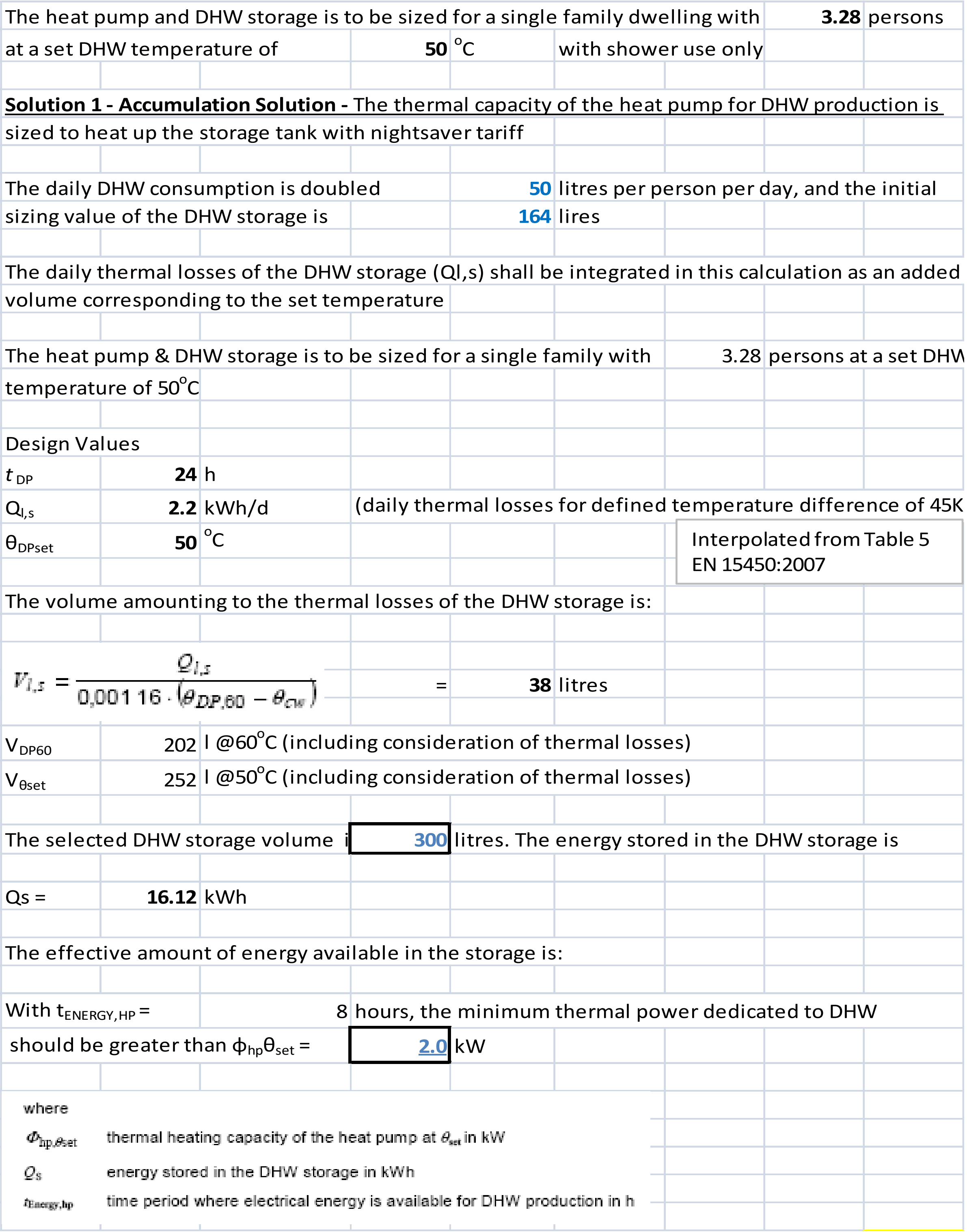
$\Phi_{hp,\theta set}$	thermal heating capacity of the heat pump at θ_{set} in kW
Q_s	energy stored in the DHW storage in kWh
$t_{Energy,hp}$	time period where electrical energy is available for DHW production in h

Where

Vs	volume of DHW storage in litres
V_{DP60}	volume of hot water at 60°C corresponding to Q_{DP} in litres
$V_{\theta set}$	volume of hot water at θset corresponding to Q_{DP} in litres
θcw	temperature of the cold water in °C

Source: EN15450:2007 (E)

Table I3 – Solution 1 – Accumulation Solution - House Types F, I, J



The heat pump and DHW storage is to be sized for a single family dwelling with **3.28** persons
at a set DHW temperature of **50** °C with shower use only

<u>Solution 1 - Accumulation Solution -</u> <u>The thermal capacity of the heat pump for DHW production is</u>
sized to heat up the storage tank with nightsaver tariff

The daily DHW consumption is doubled **50** litres per person per day, and the initial
sizing value of the DHW storage is **164** lires

The daily thermal losses of the DHW storage (Ql,s) shall be integrated in this calculation as an added
volume corresponding to the set temperature

The heat pump & DHW storage is to be sized for a single family with 3.28 persons at a set DHW
temperature of 50°C

Design Values

t_{DP} **24** h

$Q_{l,s}$ **2.2** kWh/d (daily thermal losses for defined temperature difference of 45K

θ_{DPset} **50** °C

Interpolated from Table 5
EN 15450:2007

The volume amounting to the thermal losses of the DHW storage is:

$$V_{l,s} = \frac{Q_{l,s}}{0{,}001\,16 \cdot (\theta_{DP,60} - \theta_{cw})}$$ = **38** litres

V_{DP60} 202 l @60°C (including consideration of thermal losses)

$V_{\theta set}$ 252 l @50°C (including consideration of thermal losses)

The selected DHW storage volume i **300** litres. The energy stored in the DHW storage is

Qs = **16.12** kWh

The effective amount of energy available in the storage is:

With $t_{ENERGY,HP}$ = 8 hours, the minimum thermal power dedicated to DHW

should be greater than $\phi_{hp}\theta_{set}$ = <u>2.0</u> kW

where

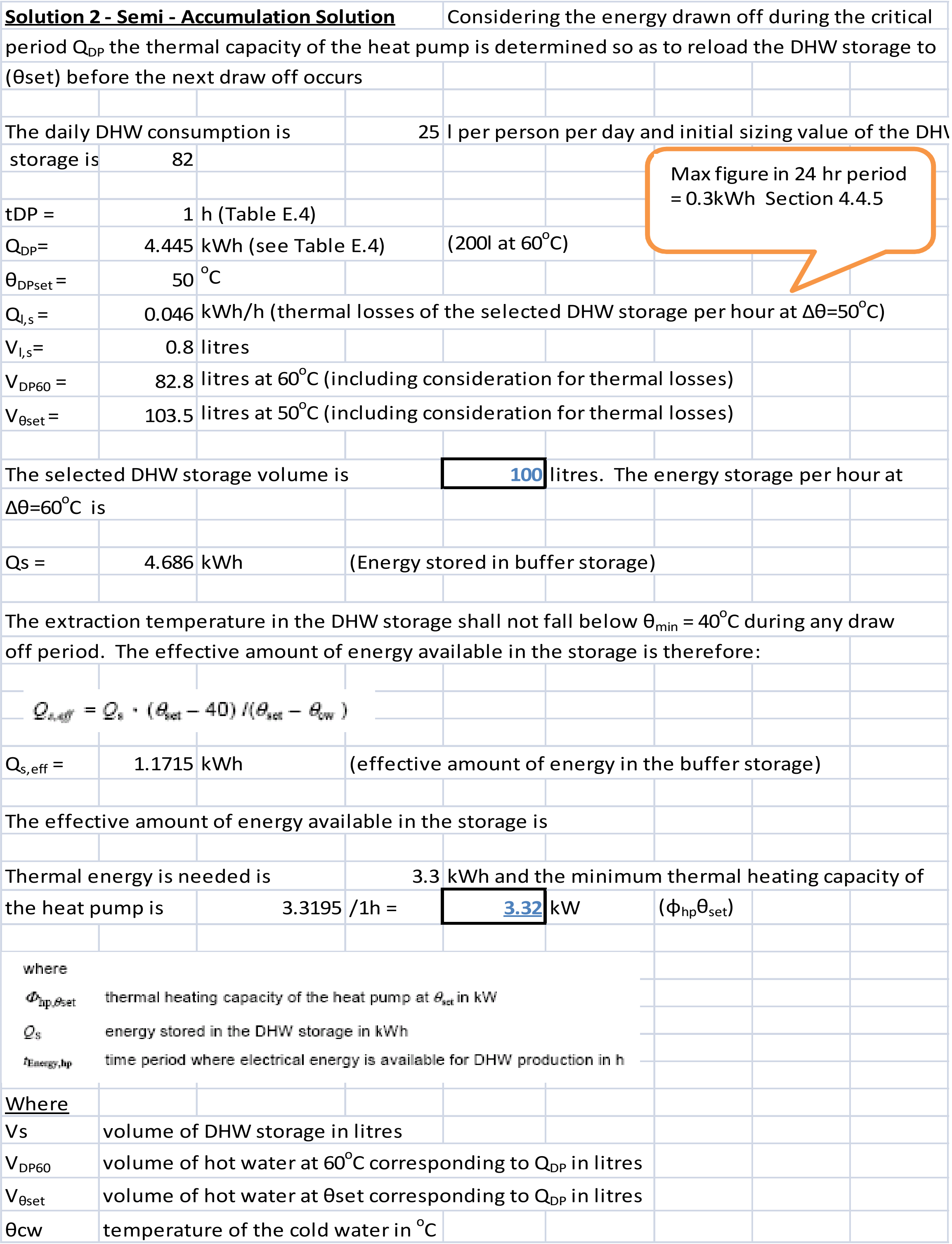
$\Phi_{hp,\theta set}$ thermal heating capacity of the heat pump at θ_{set} in kW

Q_s energy stored in the DHW storage in kWh

$t_{Energy,hp}$ time period where electrical energy is available for DHW production in h

Source: EN15450:2007 (E)

Table I4 – Solution 2 – Semi- Accumulation Solution - House Types F, I, J



Solution 2 - Semi - Accumulation Solution Considering the energy drawn off during the critical period Q_{DP} the thermal capacity of the heat pump is determined so as to reload the DHW storage to (θset) before the next draw off occurs

The daily DHW consumption is 25 l per person per day and initial sizing value of the DH
storage is 82

Max figure in 24 hr period = 0.3kWh Section 4.4.5

tDP =	1	h (Table E.4)
Q_{DP}=	4.445	kWh (see Table E.4) (200l at 60°C)
$θ_{DPset}$ =	50	°C
$Q_{l,s}$ =	0.046	kWh/h (thermal losses of the selected DHW storage per hour at Δθ=50°C)
$V_{l,s}$=	0.8	litres
V_{DP60} =	82.8	litres at 60°C (including consideration for thermal losses)
$V_{θset}$ =	103.5	litres at 50°C (including consideration for thermal losses)

The selected DHW storage volume is 100 litres. The energy storage per hour at Δθ=60°C is

Qs =	4.686	kWh (Energy stored in buffer storage)

The extraction temperature in the DHW storage shall not fall below $θ_{min}$ = 40°C during any draw off period. The effective amount of energy available in the storage is therefore:

$$Q_{s,eff} = Q_s \cdot (\theta_{set} - 40) / (\theta_{set} - \theta_{cw})$$

$Q_{s,eff}$ =	1.1715	kWh (effective amount of energy in the buffer storage)

The effective amount of energy available in the storage is

Thermal energy is needed is 3.3 kWh and the minimum thermal heating capacity of the heat pump is 3.3195 /1h = 3.32 kW ($\phi_{hp}\theta_{set}$)

where

$\Phi_{hp,\theta set}$	thermal heating capacity of the heat pump at θ_{set} in kW
Q_s	energy stored in the DHW storage in kWh
$t_{Energy,hp}$	time period where electrical energy is available for DHW production in h

<u>Where</u>

Vs	volume of DHW storage in litres
V_{DP60}	volume of hot water at 60°C corresponding to Q_{DP} in litres
$V_{θset}$	volume of hot water at θset corresponding to Q_{DP} in litres
θcw	temperature of the cold water in °C

Source: EN15450:2007 (E)

Table I5 – Solution 1 – Accumulation Solution - House Types G & H

The heat pump and DHW storage is to be sized for a single family dwelling with **3.67** persons

at a set DHW temperature of **50** ^{o}C with shower use only

<u>Solution 1 - Accumulation Solution -</u> <u>The thermal capacity of the heat pump for DHW production is</u> sized to heat up the storage tank with nightsaver tariff

The daily DHW consumption is doubled **50** litres per person per day, and the initial sizing value of the DHW storage is **183.5** lires

The daily thermal losses of the DHW storage (Ql,s) shall be integrated in this calculation as an added volume corresponding to the set temperature

The heat pump & DHW storage is to be sized for a single family with 3.67 persons at a set DHW temperature of 50^{o}C

Design Values

t_{DP}	**24**	h	
$Q_{l,s}$	**2.2**	kWh/d	(daily thermal losses for defined temperature difference of 45K)
θ_{DPset}	**50**	^{o}C	Interpolated from Table 5 EN 15450:2007

The volume amounting to the thermal losses of the DHW storage is:

$$V_{l,s} = \frac{Q_{l,s}}{0{,}001\,16 \cdot (\theta_{DP,60} - \theta_{cw})}$$ = **38** litres

V_{DP60}	221	l @60^{o}C (including consideration of thermal losses)
$V_{\theta set}$	277	l @50^{o}C (including consideration of thermal losses)

The selected DHW storage volume **300** litres. The energy stored in the DHW storage is

Qs = **16.12** kWh

The effective amount of energy available in the storage is:

With $t_{ENERGY,HP}$ = 8 hours, the minimum thermal power dedicated to DHW should be greater than $\phi_{hp}\theta_{set}$ = <u>2.0</u> kW

where

$\Phi_{hp,\theta set}$	thermal heating capacity of the heat pump at θ_{set} in kW
Q_s	energy stored in the DHW storage in kWh
$t_{Energy,hp}$	time period where electrical energy is available for DHW production in h

Source: EN15450:2007 (E)

Table I6 – Solution 2 – Semi- Accumulation Solution - House Types G & H

Solution 2 - Semi - Accumulation Solution Considering the energy drawn off during the critical period Q_{DP} the thermal capacity of the heat pump is determined so as to reload the DHW storage to (θset) before the next draw off occurs

The daily DHW consumption is 25 l per person per day and initial sizing value of the DHW storage is 91.75

Max figure in 24 hr period = 0.3kWh

tDP = 1 h (Table E.4)

Q_{DP}= 4.445 kWh (see Table E.4) (200l at 60°C)

θ_{DPset} = 50 °C

$Q_{l,s}$ = 0.046 kWh/h (thermal losses of the selected DHW storage per hour at Δθ=50°C)

$V_{l,s}$= 0.8 litres

V_{DP60} = 92.5 litres at 60°C (including consideration for thermal losses)

$V_{\theta set}$ = 115.7 litres at 50°C (including consideration for thermal losses)

The selected DHW storage volume is **120** litres. The energy storage per hour at Δθ=60°C is

Qs = 5.614 kWh (Energy stored in buffer storage)

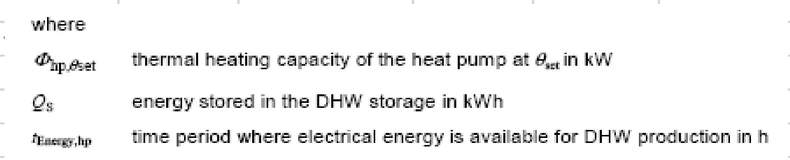
The extraction temperature in the DHW storage shall not fall below θ_{min} = 40°C during any draw off period. The effective amount of energy available in the storage is therefore:

$$Q_{s,eff} = Q_s \cdot (\theta_{set} - 40) / (\theta_{set} - \theta_{cw})$$

$Q_{s,eff}$ = 1.4035 kWh (effective amount of energy in the buffer storage)

The effective amount of energy available in the storage is

Thermal energy is needed is 3.1 kWh and the minimum thermal heating capacity of the heat pump is 3.09 /1h = **3.09** kW ($\phi_{hp}\theta_{set}$)



where

$\Phi_{hp,\theta set}$ thermal heating capacity of the heat pump at θ_{set} in kW

Q_S energy stored in the DHW storage in kWh

$t_{Energy,hp}$ time period where electrical energy is available for DHW production in h

Where

Vs	volume of DHW storage in litres
V_{DP60}	volume of hot water at 60°C corresponding to Q_{DP} in litres
$V_{\theta set}$	volume of hot water at θset corresponding to Q_{DP} in litres
θcw	temperature of the cold water in °C

Source: EN15450:2007 (E)

Table I7 – Ref Table 5 in calculation tables J1-J6

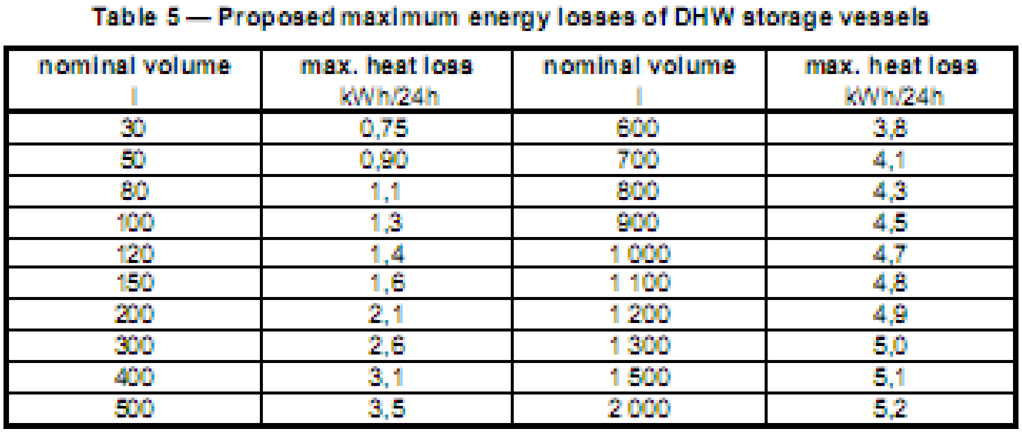


Table 5 — Proposed maximum energy losses of DHW storage vessels

nominal volume l	max. heat loss kWh/24h	nominal volume l	max. heat loss kWh/24h
30	0,75	600	3,8
50	0,90	700	4,1
80	1,1	800	4,3
100	1,3	900	4,5
120	1,4	1 000	4,7
150	1,6	1 100	4,8
200	2,1	1 200	4,9
300	2,6	1 300	5,0
400	3,1	1 500	5,1
500	3,5	2 000	5,2

Source: EN15450:2007 (E)

Table I8 – Ref Table E4 in calculation tables J1-J6

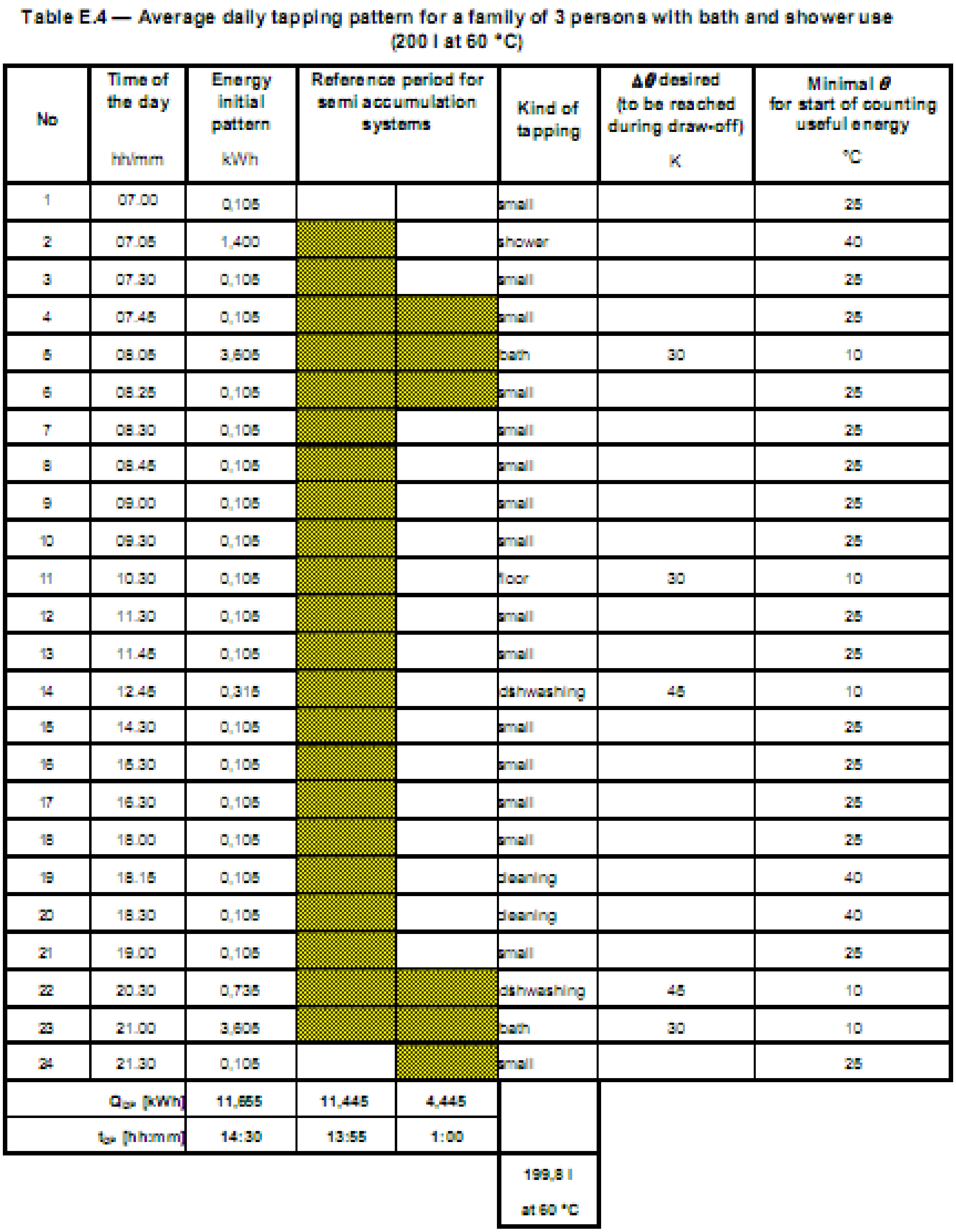


Table E.4 — Average daily tapping pattern for a family of 3 persons with bath and shower use (200 l at 60 °C)

No	Time of the day hh/mm	Energy initial pattern kWh	Reference period for semi accumulation systems		Kind of tapping	$\Delta\theta$ desired (to be reached during draw-off) K	Minimal θ for start of counting useful energy °C
1	07.00	0,105			small		25
2	07.05	1,400	▨		shower		40
3	07.30	0,105	▨		small		25
4	07.45	0,105	▨	▨	small		25
5	08.05	3,605	▨	▨	bath	30	10
6	08.25	0,105	▨	▨	small		25
7	08.30	0,105	▨		small		25
8	08.45	0,105	▨		small		25
9	09.00	0,105	▨		small		25
10	09.30	0,105	▨		small		25
11	10.30	0,105	▨		floor	30	10
12	11.30	0,105	▨		small		25
13	11.45	0,105	▨		small		25
14	12.45	0,315	▨		dishwashing	45	10
15	14.30	0,105	▨		small		25
16	15.30	0,105	▨		small		25
17	16.30	0,105	▨		small		25
18	18.00	0,105	▨		small		25
19	18.15	0,105	▨		cleaning		40
20	18.30	0,105	▨		cleaning		40
21	19.00	0,105	▨		small		25
22	20.30	0,735	▨	▨	dishwashing	45	10
23	21.00	3,605	▨	▨	bath	30	10
24	21.30	0,105		▨	small		25
Q_{tap} [kWh]		11,655	11,445	4,445			
t_{tap} [hh:mm]		14:30	13:55	1:00			
					199,8 l at 60 °C		

Source: EN15450:2007 (E)

Appendix J – Heat Loss Calculations – Before Improvement Measures

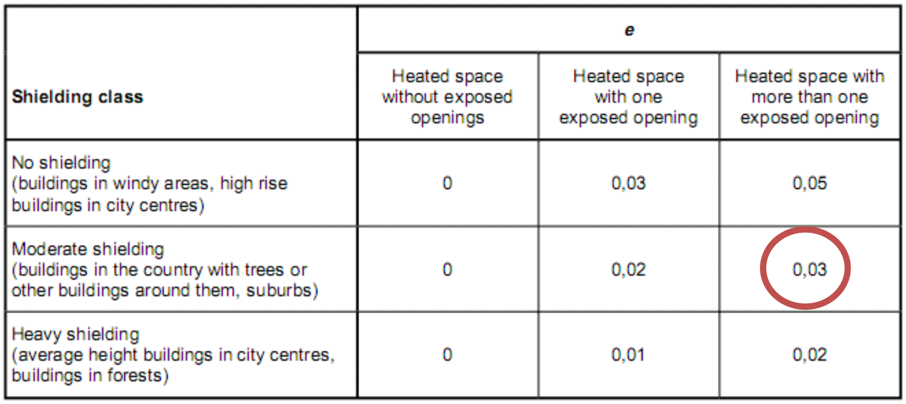
The following calculation have been carried out in accordance with the heat loss calculation method as prescribed in BS EN 12831:2003 Heating systems in buildings – Method for calculation of the design heat load, this method is the method referenced in BS EN Heating Systems in buildings – Design of heat pump heating systems;

Table J1 states the default correction factors adopted and as prescribed in BS EN 12831:2003 see Table J2 and J3 for primary data:

Table J1

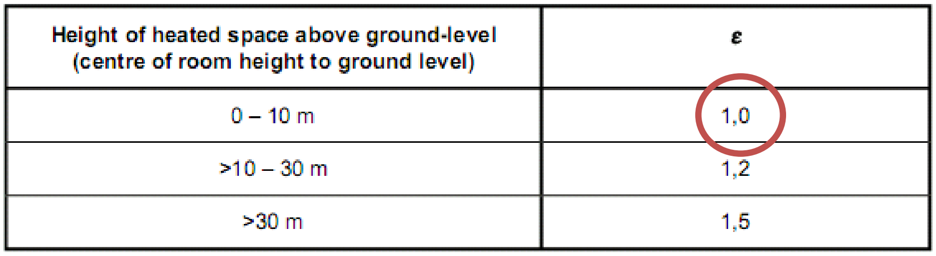
Notes:
Default Value of Correction Factor e_k = 1 in the absence of national values
Heat Losses through the ground - $H_{T,ig}$
Default Correction Factors f_{g1} = 1.45 and f_{g2} =0.267 and G_w = 1.00 Therefore $fg_1fg_2G_W$ = 0.387
Natural Ventilation Calculation
It is assumed that no ventilation system is installed. The degree of air tightness was established from BRE Test Data. A moderate shiedling coefficient for a heat edspace with more that one exposed opening is assumed (e) = 0.03, Height correction factor ε = 1

Table J2 – Shielding coefficient, e



Shielding class	*e*		
	Heated space without exposed openings	Heated space with one exposed opening	Heated space with more than one exposed opening
No shielding (buildings in windy areas, high rise buildings in city centres)	0	0,03	0,05
Moderate shielding (buildings in the country with trees or other buildings around them, suburbs)	0	0,02	0,03
Heavy shielding (average height buildings in city centres, buildings in forests)	0	0,01	0,02

Table J3 – Height correction factor, e



Height of heated space above ground-level (centre of room height to ground level)	ε
0 – 10 m	1,0
>10 – 30 m	1,2
>30 m	1,5

Source: BS EN 12831:2003

Table J4 – House Type A - Heat loss calculation before improvement measures

	Deap Age Band			**A_{1SDG}**	**A_{1SSG}**	**A_{2SDG}**	**A_{2SSG}**	
	Amount of Houses		—	14050	13179	9059	8497	
Building Areas	Floor Area	A_{floor}	m^2	142	142	71	71	CSO & INSHQ
	Roof Area	A_{roof}	m^2	149	149	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	97	97	147	147	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.1	2.1	2.1	2.1	INSHQ Data
	Area of Doors	A_{door}	m2	5.74	5.74	5.74	5.74	
	Wall Area (net of glazing and doors)	A_{wall}		91.27	91.27	141.27	141.27	
	Total Exposed Area	ΣA_{exp}	m2	270	270	246	246	
	Heat Loss directly to exterior due to Thermal Bridging $H_{TD}= 0.15\Sigma A_{exp}$	**H_{TB}**	**W/K**	**40.5**	**40.5**	**36.9**	**36.9**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	2.1	2.1	2.1	2.1	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	2.3	2.3	2.3	2.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.68	0.68	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**380**	**763**	**620**	**661**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	**$H_{T,ie}$**	**W/K**	**420**	**804**	**657**	**698**	
	Total heat loss coefficient through the ground	**$H_{T,ig}$**	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,I} = H_{T,ie} + H_{T,ig} + H_{T,ij}$	**$H_{T,i}$**	**W/K**	**878**	**1645**	**1338**	**1419**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.6	0.6	0.6	0.6	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	12	12	12	12	Low degree of tightness
	Building Volume	V_i	m^3	341	341	341	341	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	245	245	245	245	
	Design ventilation heat loss coefficient $H_{v,I} = 0.34.V_{inf,i}$	**$H_{v,i}$**	**W/K**	**83**	**83**	**83**	**83**	
Design Heating Load			W/K	961	1728	1421	1503	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J5 – House Type B - Heat loss calculation before improvement measures

	Deap Age Band			B_{1SDG}	B_{1SSG}	B_{2SDG}	B_{2SSG}	
	Amount of Houses		—	10840	10168	6989	6555	
Building Areas	Floor Area	A_{floor}	m^2	142	142	71	71	CSO & INSHQ
	Roof Area	A_{roof}	m^2	149	149	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	97	97	147	147	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.1	2.1	2.1	2.1	INSHQ Data
	Area of Doors	A_{door}	m2	5.74	5.74	5.74	5.74	
	Wall Area (net of glazing and doors)	A_{wall}		91.27	91.27	141.27	141.27	
	Total Exposed Area	ΣA_{exp}	m2	270	270	246	246	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**40.5**	**40.5**	**36.9**	**36.9**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	2.1	2.1	2.1	2.1	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	2.3	2.3	2.3	2.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.68	0.68	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**723**	**763**	**620**	**661**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**763**	**804**	**657**	**698**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,i}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**1563**	**1645**	**1338**	**1419**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.6	0.6	0.6	0.6	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	12	12	12	12	Low degree of tightness
	Building Volume	V_i	m^3	341	341	341	341	
	Infiltration Air Flow Rate $V_{inf,i}$ = 2.V_i.n_{50}.e.ε	$V_{inf,i}$	m^3/hr	245	245	245	245	
	Design ventilation heat loss coefficient $H_{v,i}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**83**	**83**	**83**	**83**	
Design Heating Load			W/K	1647	1728	1421	1503	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J6 – House Type C - Heat loss calculation before improvement measures

	Deap Age Band			**C_{1SDG}**	**C_{1SSG}**	**C_{2SDG}**	**C_{2SSG}**	
	Amount of Houses		—	8935	6993	9840	6686	
Building Areas	Floor Area	A_{floor}	m^2	142	142	71	71	CSO & INSHQ
	Roof Area	A_{roof}	m^2	149	149	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	97	97	147	147	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.2	2.2	2.2	2.2	INSHQ Data
	Area of Doors	A_{door}	m2	5.92	5.92	5.92	5.92	
	Wall Area (net of glazing and doors)	A_{wall}		91.08	91.08	141.08	141.08	
	Total Exposed Area	ΣA_{exp}	m2	270	270	246	246	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA$_{exp}$	**H_{TB}**	**W/K**	**40.5**	**40.5**	**36.9**	**36.9**	
U-Values	Exposed Wall U-Value	U_{wall}	W/(m^2.K)	2.1	2.1	2.1	2.1	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	W/(m^2.K)	2.3	2.3	2.3	2.3	Table S5 DEAP
	U-Value Floor	U_{floor}	W/(m^2.K)	0.68	0.68	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	W/(m^2.K)	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	W/(m^2.K)	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**723**	**763**	**621**	**661**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	**$H_{T,ie}$**	**W/K**	**763**	**804**	**657**	**698**	
	Total heat loss coefficient through the ground	**$H_{T,ig}$**	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,i}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	**$H_{T,i}$**	**W/K**	**1564**	**1645**	**1338**	**1420**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.8	0.8	0.8	0.8	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	16	16	16	16	Low degree of tightness
	Building Volume	V_i	m^3	341	341	341	341	
	Infiltration Air Flow Rate $V_{inf,i}$ = 2.V_i.n_{50}.e.ε	$V_{inf,i}$	m^3/hr	327	327	327	327	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	**$H_{v,i}$**	**W/K**	**111**	**111**	**111**	**111**	
Design Heating Load			W/K	1675	1757	1449	1531	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J7 – House Type D - Heat loss calculation before improvement measures

	Deap Age Band			**D_{1SDG}**	**D_{1SSG}**	**D_{2SDG}**	**D_{2SSG}**	
	Amount of Houses		—	7421	3961	13602	7260	
Building Areas	Floor Area	A_{floor}	m^2	143	143	72	72	CSO & INSHQ
	Roof Area	A_{roof}	m^2	151	151	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	98	98	148	148	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.2	2.2	2.2	2.2	INSHQ Data
	Area of Doors	A_{door}	m2	5.92	5.92	5.92	5.92	
	Wall Area (net of glazing and doors)	A_{wall}		92.08	92.08	142.08	142.08	
	Total Exposed Area	ΣA_{exp}	m2	273	273	247	247	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**40.95**	**40.95**	**37.05**	**37.05**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	2.1	2.1	2.1	2.1	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	2.3	2.3	2.3	2.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.67	0.67	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**729**	**769**	**624**	**664**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**770**	**810**	**661**	**701**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,i}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**1576**	**1658**	**1345**	**1426**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.7	0.7	0.7	0.7	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	14	14	14	14	Low degree of tightness
	Building Volume	V_i	m^3	343	343	346	346	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	288	288	290	290	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**98**	**98**	**99**	**99**	
Design Heating Load			W/K	1674	1756	1443	1525	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J8 – House Type E - Heat loss calculation before improvement measures

	Deap Age Band			**E_{1SDG}**	**E_{1SSG}**	**E_{2SDG}**	**E_{2SSG}**	
	Amount of Houses		—	11510	6188	22605	12154	
Building Areas	Floor Area	A_{floor}	m^2	147	147	74	74	CSO & INSHQ
	Roof Area	A_{roof}	m^2	155	155	77	77	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	99	99	151	151	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.3	2.3	2.3	2.3	INSHQ Data
	Area of Doors	A_{door}	m2	6.11	6.11	6.11	6.11	
	Wall Area (net of glazing and doors)	A_{wall}		92.90	92.90	144.90	144.90	
	Total Exposed Area	ΣA_{exp}	m2	278	278	252	252	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	**H_{TB}**	**W/K**	**41.7**	**41.7**	**37.8**	**37.8**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	2.1	2.1	2.1	2.1	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	2.3	2.3	2.3	2.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.67	0.67	0.83	0.83	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**743**	**784**	**636**	**676**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	**$H_{T,ie}$**	**W/K**	**784**	**825**	**673**	**714**	
	Total heat loss coefficient through the ground	**$H_{T,ig}$**	**W/K**	**38**	**38**	**24**	**24**	
	Total Transmission Heat loss coefficient $H_{T,i}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	**$H_{T,i}$**	**W/K**	**1607**	**1689**	**1370**	**1452**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.7	0.7	0.7	0.7	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	14	14	14	14	Low degree of tightness
	Building Volume	V_i	m^3	353	353	355	355	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	296	296	298	298	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	**$H_{v,i}$**	**W/K**	**101**	**101**	**101**	**101**	
Design Heating Load			W/K	1708	1789	1472	1553	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J9 – House Type F - Heat loss calculation before improvement measures

	Deap Age Band			**F_{1SDG}**	**F_{1SSG}**	**F_{2SDG}**	**F_{2SSG}**	
	Amount of Houses		—	7684	3511	12616	6006	
Building Areas	Floor Area	A_{floor}	m^2	152	152	76	76	CSO & INSHQ
	Roof Area	A_{roof}	m^2	160	160	80	80	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	105	105	157	157	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	21	21	21	21	SAP Appendix S
	No of Doors			2.3	2.3	2.3	2.3	INSHQ Data
	Area of Doors	A_{door}	m2	6.11	6.11	6.11	6.11	
	Wall Area (net of glazing and doors)	A_{wall}		98.90	98.90	150.90	150.90	
	Total Exposed Area	ΣA_{exp}	m2	286	286	258	258	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	**H_{TB}**	**W/K**	**42.9**	**42.9**	**38.7**	**38.7**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	1.1	1.1	1.1	1.1	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.4	0.4	0.4	0.4	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.52	0.52	0.63	0.63	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**335**	**371**	**329**	**365**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	**$H_{T,ie}$**	**W/K**	**378**	**414**	**368**	**404**	
	Total heat loss coefficient through the ground	**$H_{T,ig}$**	**W/K**	**31**	**31**	**19**	**19**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	**$H_{T,i}$**	**W/K**	**787**	**858**	**754**	**826**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.6	0.6	0.6	0.6	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	12	12	12	12	Low degree of tightness
	Building Volume	V_i	m^3	365	365	365	365	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	263	263	263	263	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	**$H_{v,i}$**	**W/K**	**89**	**89**	**89**	**89**	
Design Heating Load			W/K	876	948	844	915	
DHW Load				2100	2100	2100	2100	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J10 – House Type G - Heat loss calculation before improvement measures

	Deap Age Band			G_{1SDG}	G_{1SSG}	G_{2SDG}	G_{2SSG}	
	Amount of Houses		—	19505	7178	24525	9025	
Building Areas	Floor Area	A_{floor}	m^2	156	156	78	78	CSO & INSHQ
	Roof Area	A_{roof}	m^2	164	164	82	82	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	105	105	158	158	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	22	22	22	22	SAP Appendix S
	No of Doors			2.2	2.2	2.2	2.2	INSHQ Data
	Area of Doors	A_{door}	m2	5.92	5.92	5.92	5.92	
	Wall Area (net of glazing and doors)	A_{wall}		99.08	99.08	152.08	152.08	
	Total Exposed Area	ΣA_{exp}	m2	291	291	262	262	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA$_{exp}$	H_{TB}	**W/K**	**43.65**	**43.65**	**39.3**	**39.3**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.6	0.6	0.6	0.6	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.4	0.4	0.4	0.4	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.52	0.52	0.63	0.63	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	4.8	3.1	4.8	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**292**	**330**	**259**	**297**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**336**	**373**	**298**	**336**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**31**	**31**	**19**	**19**	
	Total Transmission Heat loss coefficient $H_{T,I} = H_{T,ie} + H_{T,ig} + H_{T,ij}$	$H_{T,i}$	**W/K**	**703**	**778**	**616**	**691**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	10	10	Low degree of tightness
	Building Volume	V_i	m^3	374	374	374	374	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	225	225	225	225	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**76**	**76**	**76**	**76**	
Design Heating Load			W/K	779	854	692	767	
DHW Load				2100	2100	2100	2100	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J11 – House Type H - Heat loss calculation before improvement measures

	Deap Age Band			H_{1SDG}	H_{1SSG}	H_{2SDG}	H_{2SSG}	
	Amount of Houses		—	21188	2650	18735	3121	
Building Areas	Floor Area	A_{floor}	m^2	174	174	87	87	CSO & INSHQ
	Roof Area	A_{roof}	m^2	183	183	91	91	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	109	109	165	165	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	25	25	25	25	SAP Appendix S
	No of Doors			2.4	2.4	2.4	2.4	INSHQ Data
	Area of Doors	A_{door}	m2	6.29	6.29	6.29	6.29	
	Wall Area (net of glazing and doors)	A_{wall}		102.71	102.71	158.71	158.71	
	Total Exposed Area	ΣA_{exp}	m2	317	317	281	281	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**47.55**	**47.55**	**42.15**	**42.15**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.55	0.55	0.55	0.55	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.35	0.35	0.35	0.35	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.37	0.37	0.43	0.43	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	3.3	3.1	3.3	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**281**	**286**	**253**	**258**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**329**	**334**	**295**	**300**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**25**	**25**	**14**	**14**	
	Total Transmission Heat loss coefficient $H_{T,i}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**683**	**693**	**605**	**615**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	10	10	Low degree of tightness
	Building Volume	V_i	m^3	418	418	418	418	
	Infiltration Air Flow Rate $V_{inf,i}$ = 2.V_i.n_{50}.e.ε	$V_{inf,i}$	m^3/hr	251	251	251	251	
	Design ventilation heat loss coefficient $H_{v,i}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**85**	**85**	**85**	**85**	
Design Heating Load			W/K	768	778	690	700	
DHW Load				2000	2000	2000	2000	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J12 – House Type I - Heat loss calculation before improvement measures

	Deap Age Band			I_{1SDG}	I_{1SSG}	I_{2SDG}	I_{2SSG}	
	Amount of Houses		—	30146	299	22100	219	
Building Areas	Floor Area	A_{floor}	m^2	194	194	97	97	CSO & INSHQ
	Roof Area	A_{roof}	m^2	204	204	102	102	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	115	115	174	174	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	27	27	27	27	SAP Appendix S
	No of Doors			2.7	2.7	2.7	2.7	INSHQ Data
	Area of Doors	A_{door}	m2	6.85	6.85	6.85	6.85	
	Wall Area (net of glazing and doors)	A_{wall}		108.16	108.16	167.16	167.16	
	Total Exposed Area	ΣA_{exp}	m2	346	346	303	303	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**51.9**	**51.9**	**45.45**	**45.45**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.55	0.55	0.55	0.55	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.35	0.35	0.35	0.35	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.36	0.36	0.42	0.42	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	2.2	3.3	2.2	3.3	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**281**	**310**	**248**	**278**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**333**	**362**	**294**	**323**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**27**	**27**	**16**	**16**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**692**	**752**	**603**	**663**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	10	10	Low degree of tightness
	Building Volume	V_i	m^3	466	466	466	466	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	279	279	279	279	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**95**	**95**	**95**	**95**	
Design Heating Load			W/K	787	847	698	758	
DHW Load				2000	2000	2000	2000	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table J13 – House Type J - Heat loss calculation before improvement measures

	Deap Age Band			J_{1SDG}	J_{2SDG}	
	Amount of Houses		—	12642	22100	
Building Areas	Floor Area	A_{floor}	m^2	219	110	CSO & INSHQ
	Roof Area	A_{roof}	m^2	230	115	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	120	182	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	31	31	SAP Appendix S
	No of Doors			2.7	2.7	INSHQ Data
	Area of Doors	A_{door}	m2	6.85	6.85	
	Wall Area (net of glazing and doors)	A_{wall}		113.16	175.16	
	Total Exposed Area	ΣA_{exp}	m2	381	328	
	Heat Loss directly to exterior due to Thermal Bridging $H_{TD}= 0.15\Sigma A_{exp}$	H_{TB}	**W/K**	**57.15**	**49.2**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.37	0.37	Default value take as stone, Ref Appendix S DEAP
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.25	0.25	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.31	0.34	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	2.2	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**256**	**220**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**313**	**269**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**26**	**14**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**653**	**552**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	Low degree of tightness
	Building Volume	V_i	m^3	526	528	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	315	317	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**107**	**108**	
Design Heating Load			W/K	760	660	
DHW Load				2000	2000	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Appendix K

Table K1 – House Type A – Heat loss calculation post fabric improvement measures

	Deap Age Band			A_{1SDG}	A_{1SSG}	A_{2SDG}	A_{2SSG}	
	Amount of Houses		—	14050	13179	9059	8497	419742
Building Areas	Floor Area	A_{floor}	m^2	142	142	71	71	CSO & INSHQ
	Roof Area	A_{roof}	m^2	149	149	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	97	97	147	147	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.1	2.1	2.1	2.1	INSHQ Data
	Area of Doors	A_{door}	m2	5.74	5.74	5.74	5.74	
	Wall Area (net of glaxing and doors)	A_{wall}		91.27	91.27	141.27	141.27	
	Total Exposed Area	ΣA_{exp}	m2	270	270	246	246	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**40.5**	**40.5**	**36.9**	**36.9**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to 0.27W/m^{2o}K
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.68	0.68	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**260**	**239**	**216**	**195**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**301**	**279**	**253**	**231**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**639**	**596**	**529**	**486**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.6	0.6	0.6	0.6	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	12	12	12	12	Low degree of tightness
	Building Volume	V_i	m^3	341	341	341	341	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	245	245	245	245	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**83**	**83**	**83**	**83**	
Design Heating Load			W/K	722	679	613	569	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K2 – House Type B – Heat loss calculation post fabric improvement measures

	Deap Age Band			**B_{1SDG}**	**B_{1SSG}**	**B_{2SDG}**	**B_{2SSG}**	
	Amount of Houses		—	10840	10168	6989	6555	419742
Building Areas	Floor Area	A_{floor}	m^2	142	142	71	71	CSO & INSHQ
	Roof Area	A_{roof}	m^2	149	149	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	97	97	147	147	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.1	2.1	2.1	2.1	INSHQ Data
	Area of Doors	A_{door}	m2	5.74	5.74	5.74	5.74	
	Wall Area (net of glaxing and doors)	A_{wall}		91.27	91.27	141.27	141.27	
	Total Exposed Area	ΣA_{exp}	m2	270	270	246	246	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= $0.15\Sigma A_{exp}$	**H_{TB}**	**W/K**	**40.5**	**40.5**	**36.9**	**36.9**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to $0.27W/m^{2o}K$
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.68	0.68	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**260**	**239**	**216**	**195**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	**$H_{T,ie}$**	**W/K**	**301**	**279**	**253**	**231**	
	Total heat loss coefficient through the ground	**$H_{T,ig}$**	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	**$H_{T,i}$**	**W/K**	**639**	**596**	**529**	**486**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.6	0.6	0.6	0.6	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	12	12	12	12	Low degree of tightness
	Building Volume	V_i	m^3	341	341	341	341	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	245	245	245	245	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	**$H_{v,i}$**	**W/K**	**83**	**83**	**83**	**83**	
Design Heating Load			W/K	722	679	613	569	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K3 – House Type C – Heat loss calculation post fabric improvement measures

	Deap Age Band			C_{1SDG}	C_{1SSG}	C_{2SDG}	C_{2SSG}	
	Amount of Houses		—	8935	6993	9840	6686	419742
Building Areas	Floor Area	A_{floor}	m^2	142	142	71	71	CSO & INSHQ
	Roof Area	A_{roof}	m^2	149	149	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	97	97	147	147	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.2	2.2	2.2	2.2	INSHQ Data
	Area of Doors	A_{door}	m2	5.92	5.92	5.92	5.92	
	Wall Area (net of glaxing and doors)	A_{wall}		91.08	91.08	141.08	141.08	
	Total Exposed Area	ΣA_{exp}	m2	270	270	246	246	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	**H_{TB}**	**W/K**	**40.5**	**40.5**	**36.9**	**36.9**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to 0.27W/m^{2o}K
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.68	0.68	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**261**	**239**	**217**	**195**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	**$H_{T,ie}$**	**W/K**	**301**	**280**	**254**	**232**	
	Total heat loss coefficient through the ground	**$H_{T,ig}$**	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	**$H_{T,i}$**	**W/K**	**640**	**597**	**530**	**487**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.8	0.8	0.8	0.8	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	16	16	16	16	Low degree of tightness
	Building Volume	V_i	m^3	341	341	341	341	
	Infiltration Air Flow Rate $V_{inf,i}$ = 2.V_i.n_{50}.e.ε	$V_{inf,i}$	m^3/hr	327	327	327	327	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	**$H_{v,i}$**	**W/K**	**111**	**111**	**111**	**111**	
Design Heating Load			W/K	751	708	641	598	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K4 – House Type D – Heat loss calculation post fabric improvement measures

	Deap Age Band			D_{1SDG}	D_{1SSG}	D_{2SDG}	D_{2SSG}	
	Amount of Houses		—	7421	3961	13602	7260	419742
Building Areas	Floor Area	A_{floor}	m^2	143	143	72	72	CSO & INSHQ
	Roof Area	A_{roof}	m^2	151	151	75	75	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	98	98	148	148	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.2	2.2	2.2	2.2	INSHQ Data
	Area of Doors	A_{door}	m2	5.92	5.92	5.92	5.92	
	Wall Area (net of glaxing and doors)	A_{wall}		92.08	92.08	142.08	142.08	
	Total Exposed Area	ΣA_{exp}	m2	273	273	247	247	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**40.95**	**40.95**	**37.05**	**37.05**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to 0.27W/m^{2o}K
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.67	0.67	0.84	0.84	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**261**	**239**	**218**	**196**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**302**	**280**	**255**	**233**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**37**	**37**	**23**	**23**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**641**	**598**	**533**	**490**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.7	0.7	0.7	0.7	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	14	14	14	14	Low degree of tightness
	Building Volume	V_i	m^3	343	343	346	346	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	288	288	290	290	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**98**	**98**	**99**	**99**	
Design Heating Load			W/K	739	696	632	589	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K5 – House Type E – Heat loss calculation post fabric improvement measures

	Deap Age Band			E_{1SDG}	E_{1SSG}	E_{2SDG}	E_{2SSG}	
	Amount of Houses		—	11510	6188	22605	12154	419742
Building Areas	Floor Area	A_{floor}	m^2	147	147	74	74	CSO & INSHQ
	Roof Area	A_{roof}	m^2	155	155	77	77	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	99	99	151	151	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	24	24	24	24	SAP Appendix S
	No of Doors			2.3	2.3	2.3	2.3	INSHQ Data
	Area of Doors	A_{door}	m2	6.11	6.11	6.11	6.11	
	Wall Area (net of glaxing and doors)	A_{wall}		92.90	92.90	144.90	144.90	
	Total Exposed Area	ΣA_{exp}	m2	278	278	252	252	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	$\mathbf{H_{TB}}$	**W/K**	**41.7**	**41.7**	**37.8**	**37.8**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to $0.27W/m^{2o}K$
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.67	0.67	0.83	0.83	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**266**	**244**	**221**	**199**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$\mathbf{H_{T,ie}}$	**W/K**	**307**	**286**	**259**	**237**	
	Total heat loss coefficient through the ground	$\mathbf{H_{T,ig}}$	**W/K**	**38**	**38**	**24**	**24**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$\mathbf{H_{T,i}}$	**W/K**	**653**	**609**	**541**	**498**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.7	0.7	0.7	0.7	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	14	14	14	14	Low degree of tightness
	Building Volume	V_i	m^3	353	353	355	355	
	Infiltration Air Flow Rate $V_{inf,i}$ = $2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	296	296	298	298	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$\mathbf{H_{v,i}}$	**W/K**	**101**	**101**	**101**	**101**	
Design Heating Load			W/K	753	710	642	599	
DHW Load				1800	1800	1800	1800	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K6 – House Type F – Heat loss calculation post fabric improvement measures

	Deap Age Band			F_{1SDG}	F_{1SSG}	F_{2SDG}	F_{2SSG}	
	Amount of Houses		—	7684	3511	12616	6006	419742
Building Areas	Floor Area	A_{floor}	m^2	152	152	76	76	CSO & INSHQ
	Roof Area	A_{roof}	m^2	160	160	80	80	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	105	105	157	157	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	21	21	21	21	SAP Appendix S
	No of Doors			2.3	2.3	2.3	2.3	INSHQ Data
	Area of Doors	A_{door}	m2	6.11	6.11	6.11	6.11	
	Wall Area (net of glaxing and doors)	A_{wall}		98.90	98.90	150.90	150.90	
	Total Exposed Area	ΣA_{exp}	m2	286	286	258	258	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**42.9**	**42.9**	**38.7**	**38.7**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to $0.27W/m^{2o}K$
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.52	0.52	0.63	0.63	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**240**	**221**	**201**	**182**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**283**	**264**	**239**	**220**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**31**	**31**	**19**	**19**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**597**	**559**	**497**	**459**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.6	0.6	0.6	0.6	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	12	12	12	12	Low degree of tightness
	Building Volume	V_i	m^3	365	365	365	365	
	Infiltration Air Flow Rate $V_{inf,i}$ = 2.V_i.n_{50}.e.ε	$V_{inf,i}$	m^3/hr	263	263	263	263	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**89**	**89**	**89**	**89**	
Design Heating Load			W/K	686	648	586	549	
DHW Load				2100	2100	2100	2100	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K7– House Type G – Heat loss calculation post fabric improvement measures

	Deap Age Band			G_{1SDG}	G_{1SSG}	G_{2SDG}	G_{2SSG}	
	Amount of Houses		—	19505	7178	24525	9025	419742
Building Areas	Floor Area	A_{floor}	m^2	156	156	78	78	CSO & INSHQ
	Roof Area	A_{roof}	m^2	164	164	82	82	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	105	105	158	158	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	22	22	22	22	SAP Appendix S
	No of Doors			2.2	2.2	2.2	2.2	INSHQ Data
	Area of Doors	A_{door}	m2	5.92	5.92	5.92	5.92	
	Wall Area (net of glaxing and doors)	A_{wall}		99.08	99.08	152.08	152.08	
	Total Exposed Area	ΣA_{exp}	m2	291	291	262	262	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**43.65**	**43.65**	**39.3**	**39.3**	
U-Values	Exposed Wall U-Value	U_{wall}	W/(m^2.K)	0.3	0.3	0.3	0.3	Wall Insulatin to 0.27W/m^{2o}K
	U-Value Roof	U_{roof}	W/(m^2.K)	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	W/(m^2.K)	0.52	0.52	0.63	0.63	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	W/(m^2.K)	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	W/(m^2.K)	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**246**	**226**	**205**	**186**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**290**	**270**	**245**	**225**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**31**	**31**	**19**	**19**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**611**	**571**	**508**	**469**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	10	10	Low degree of tightness
	Building Volume	V_i	m^3	374	374	374	374	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	225	225	225	225	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**76**	**76**	**76**	**76**	
Design Heating Load			W/K	687	647	585	545	
DHW Load				2100	2100	2100	2100	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K8– House Type H – Heat loss calculation post fabric improvement measures

	Deap Age Band			H_{1SDG}	H_{1SSG}	H_{2SDG}	H_{2SSG}	
	Amount of Houses		—	21188	2650	18735	3121	419742
Building Areas	Floor Area	A_{floor}	m^2	174	174	87	87	CSO & INSHQ
	Roof Area	A_{roof}	m^2	183	183	91	91	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	109	109	165	165	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	25	25	25	25	SAP Appendix S
	No of Doors			2.4	2.4	2.4	2.4	INSHQ Data
	Area of Doors	A_{door}	m2	6.29	6.29	6.29	6.29	
	Wall Area (net of glaxing and doors)	A_{wall}		102.71	102.71	158.71	158.71	
	Total Exposed Area	ΣA_{exp}	m2	317	317	281	281	
	Heat Loss directly to exterior due to Thermal Bridging $H_{TD}= 0.15\Sigma A_{exp}$	H_{TB}	**W/K**	**47.55**	**47.55**	**42.15**	**42.15**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to $0.27W/m^{2o}K$
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.37	0.37	0.43	0.43	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	3.1	2.2	3.1	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**246**	**224**	**209**	**186**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**294**	**272**	**251**	**228**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**25**	**25**	**14**	**14**	
	Total Transmission Heat loss coefficient $H_{T,I} = H_{T,ie} + H_{T,ig} + H_{T,ij}$	$H_{T,i}$	**W/K**	**613**	**568**	**516**	**471**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	10	10	Low degree of tightness
	Building Volume	V_i	m^3	418	418	418	418	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	251	251	251	251	
	Design ventilation heat loss coefficient $H_{v,I} = 0.34.V_{inf,i}$	$H_{v,i}$	**W/K**	**85**	**85**	**85**	**85**	
Design Heating Load			W/K	698	653	601	556	
DHW Load				2000	2000	2000	2000	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K9– House Type I – Heat loss calculation post fabric improvement measures

	Deap Age Band			I_{1SDG}	I_{1SSG}	I_{2SDG}	I_{2SSG}	
	Amount of Houses		—	30146	299	22100	219	419742
Building Areas	Floor Area	A_{floor}	m^2	194	194	97	97	CSO & INSHQ
	Roof Area	A_{roof}	m^2	204	204	102	102	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	115	115	174	174	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	27	27	27	27	SAP Appendix S
	No of Doors			2.7	2.7	2.7	2.7	INSHQ Data
	Area of Doors	A_{door}	m2	6.85	6.85	6.85	6.85	
	Wall Area (net of glaxing and doors)	A_{wall}		108.16	108.16	167.16	167.16	
	Total Exposed Area	ΣA_{exp}	m2	346	346	303	303	
	Heat Loss directly to exterior due to Thermal Bridging $H_{TD}= 0.15\Sigma A_{exp}$	H_{TB}	**W/K**	**51.9**	**51.9**	**45.45**	**45.45**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Wall Insulatin to $0.27W/m^{2o}K$
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.3	0.3	0.3	0.3	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.36	0.36	0.42	0.42	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	2.2	2.2	2.2	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**243**	**243**	**201**	**201**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**295**	**295**	**247**	**247**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**27**	**27**	**16**	**16**	
	Total Transmission Heat loss coefficient $H_{T,I} = H_{T,ie} + H_{T,ig} + H_{T,ij}$	$H_{T,i}$	**W/K**	**618**	**618**	**510**	**510**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	10	10	Low degree of tightness
	Building Volume	V_i	m^3	466	466	466	466	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	279	279	279	279	
	Design ventilation heat loss coefficient $H_{v,I} = 0.34.V_{inf,i}$	$H_{v,i}$	**W/K**	**95**	**95**	**95**	**95**	
Design Heating Load			W/K	713	713	604	604	
DHW Load				2000	2000	2000	2000	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Table K10– House Type J – Heat loss calculation post fabric improvement measures

	Deap Age Band			J_{1SDG}	J_{2SDG}	
	Amount of Houses		—	12642	22100	419742
Building Areas	Floor Area	A_{floor}	m^2	219	110	CSO & INSHQ
	Roof Area	A_{roof}	m^2	230	115	Pitched Roof of 18deg incline assumed average + 5%
	Wall Area (net of glazing but inclusive of doors)		m^2	120	182	Rectangle x * 2x assumed less window area
	Window Area	A_{window}	m^2	31	31	SAP Appendix S
	No of Doors			2.7	2.7	INSHQ Data
	Area of Doors	A_{door}	m2	6.85	6.85	
	Wall Area (net of glaxing and doors)	A_{wall}		113.16	175.16	
	Total Exposed Area	ΣA_{exp}	m2	381	328	
	Heat Loss directly to exterior due to Thermal Bridging H_{TD}= 0.15ΣA_{exp}	H_{TB}	**W/K**	**57.15**	**49.2**	
U-Values	Exposed Wall U-Value	U_{wall}	$W/(m^2.K)$	0.27	0.27	Wall Insulatin to $0.27W/m^{2o}K$
	U-Value Roof	U_{roof}	$W/(m^2.K)$	0.25	0.25	Table S5 DEAP
	U-Value Floor	U_{floor}	$W/(m^2.K)$	0.31	0.34	Table S8 DEAP
	U-Value Glazing	$U_{glazing}$	$W/(m^2.K)$	2.2	2.2	Table S9 Deap and Building regulation current at time of build, lag for build/planning time accounted for
	U-Value Door	U_{door}	$W/(m^2.K)$	3	3	Table 6a DEAP Solid Wooden Door (All Doors assumed to be single Doors of Area 1.85m2)
Conductive Heat Losses	**Heat Losses Directly to Exterior**		**W/K**	**245**	**202**	
	Total Heat Loss coefficient directly to the exterior H_{TD} & H_F	$H_{T,ie}$	**W/K**	**302**	**251**	
	Total heat loss coefficient through the ground	$H_{T,ig}$	**W/K**	**26**	**14**	
	Total Transmission Heat loss coefficient $H_{T,I}$ = $H_{T,ie}$ +$H_{T,ig}$+$H_{T,ij}$	$H_{T,i}$	**W/K**	**630**	**517**	
Ventilation Losses	Ventilation Rate Ac/hr		h^{-1}	0.5	0.5	BRE
	Air Exchange Rate at 50 pa	n_{50}	h^{-1}	10	10	Low degree of tightness
	Building Volume	V_i	m^3	526	528	
	Infiltration Air Flow Rate $V_{inf,i} = 2.V_i.n_{50}.e.\varepsilon$	$V_{inf,i}$	m^3/hr	315	317	
	Design ventilation heat loss coefficient $H_{v,I}$ =0.34.$V_{inf,i}$	$H_{v,i}$	**W/K**	**107**	**108**	
Design Heating Load			W/K	737	625	
DHW Load				2000	2000	By Calculation EN 15450:2007(E) based on typical cccupancies (CSO 2006 &

Appendix L

House Type A

Table L1a

House Type A - Total Savings resulting for Fabric Improvement Measures and high efficiency condensing Boiler					
	Cost Savings			CO_2 Savings (kg/CO_2)	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	14,050	€ 4,101	€ 57,612,199	17,852	250,827,532
1SSG-DG	13,179	€ 4,491	€ 59,182,233	19,551	257,663,510
2SDG	9,050	€ 3,580	€ 32,395,123	17,555	158,875,312
2SSG-DG	8,497	€ 4,032	€ 34,258,762	17,555	149,167,240
Total	44,776	€ 16,203	€ 183,448,317	72,514	816,533,595

Table L2a

House Type A - Total Savings (Post Improvement Measures) with Heat Pump use							
		Cost Savings			CO_2 Savings (kg/CO_2)		
Grand 31	Quantity of Houses	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings per annum	Savings after 10 Years	Savings after 15 Years
1SDG	14050	€ 12,156,040	€ 238,467,633	€ 238,467,633	55,129,718	551,297,183	826,945,775
1SSG-DG	13179	€ 13,482,221	€ 161,525,239	€ 268,854,049	50,880,830	508,808,303	763,212,455
2SDG	9059	€ 7,065,909	€ 77,675,294	€ 139,105,136	31,135,931	311,359,314	467,038,971
2SSG-DG	8497	€ 6,278,634	€ 78,786,129	€ 123,714,709	27,415,066	274,150,665	411,225,997
Total	44785	€ 38,982,805	€ 556,454,295	€ 770,141,527	164,561,547	1,645,615,466	2,468,423,198

Table L3a

House Type A - Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
	1SDG				1SSG -DG				2SDG				2SSG -DG			
Heat Pump	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	18	€ 861	€ 10,209	€ 16,879	18	€ 851	€ 10,467	€ 16,712								
Oschner 19/Grand 61	17	€ 884	€ 10,500	€ 17,378	17	€ 880	€ 10,467	€ 17,340	17	€ 798	€ 9,504	€ 15,751	18	€ 755	€ 8,985	€ 14,895
Grandezza 51	6	€ 808	€ 9,552	€ 15,757	6	€ 802	€ 9,483	€ 15,657	6	€ 724	€ 8,574	€ 14,162	6	€ 687	€ 8,144	€ 13,457
Oschner 14	14	€ 949	€ 11,310	€ 18,763	14	€ 936	€ 11,169	€ 18,540	15	€ 851	€ 10,161	€ 16,876	16	€ 805	€ 9,618	€ 15,978
Grand 31	7	€ 865	€ 16,973	€ 16,973	6	€ 1,023	€ 12,256	€ 20,400	7	€ 780	€ 9,272	€ 15,355	8	€ 739	€ 8,789	€ 14,560
Oschner 9/Grand 25	15	€ 829	€ 9,807	€ 16,193	15	€ 824	€ 9,769	€ 16,145	16	€ 762	€ 9,042	€ 14,961	17	€ 725	€ 8,618	€ 14,268

Table L4a

House Type A - CO_2 Savings by Heat Pump Installation (kg of CO2)

	1SDG			1SSG - DG			2SDG			2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	4147	41469	62203	4069	40692	61038						
Oschner 19/Grand 61	4229	42294	63441	4175	41752	62628	3729	37294	55940	3491	34914	52371
Grandezza 51	3924	39238	58857	3861	38608	57911	3437	34370	51555	3226	32264	48397
Oschner 14	4485	44850	67275	4406	44055	66083	3962	39618	59427	3962	39618	59427
Grand 31	4267	40603	60904	4192	39883	59825	3364	32012	48018	3541	33691	50537
Oschner 9/Grand 25	3904	39043	58564	3865	38649	57973	3536	35361	53041	3536	35361	53041

House Type B

Table L1b

House Type B - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler

House Type	**Cost Savings**			**CO_2 Savings (kg/CO_2)**	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	10,840	€ 4,101	€ 44,449,554	17,852	193,521,029
1SSG-DG	10,168	€ 4,491	€ 45,660,896	19,551	198,795,248
2SDG	6,989	€ 3,580	€ 25,017,626	17,555	122,693,873
2SSG-DG	6,555	€ 4,032	€ 26,428,879	17,555	115,074,881
Total	34,552	€ 16,203	€ 141,556,955	72,514	630,085,031

Table L2b

House Type B - Total Savings post improvement measures with Heat Pump use

Grand 31	**Quantity of Houses**	**Cost Savings**			**CO_2 Savings (kg/CO_2)**		
		Savings after 1st Year	**Savings after 10 Years**	**Savings after 15 Years**	**Savings per annum**	**Savings after 10 Years**	**Savings after 15 Years**
1SDG	10840	€ 9,378,753	€ 183,984,992	€ 183,984,992	42,534,245	425,342,453	638,013,679
1SSG-DG	10168	€ 10,401,944	€ 124,621,643	€ 207,429,090	39,256,111	392,561,107	588,841,661
2SDG	6989	€ 5,451,335	€ 59,926,330	€ 107,319,328	24,021,308	240,213,075	360,319,613
2SSG-DG	6555	€ 4,843,645	€ 60,779,461	€ 95,439,557	21,149,319	211,493,187	317,239,780
Total	34552	€ 30,075,676	€ 429,312,426	€ 594,172,967	126,960,982	1,269,609,822	1,904,414,733

Table L3b

House Type B - Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	B1SDG				B1SSG -DG				B2SDG				B2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	18	€ 861	€ 10,209	€ 16,879	18	€ 851	€ 10,467	€ 16,712								
Oschner 19/Grand 61	17	€ 884	€ 10,500	€ 17,378	17	€ 880	€ 10,467	€ 17,340	17	€ 798	€ 9,504	€ 15,751	18	€ 755	€ 8,985	€ 14,895
Grandezza 51	6	€ 808	€ 9,552	€ 15,757	6	€ 802	€ 9,483	€ 15,657	6	€ 724	€ 8,574	€ 14,162	6	€ 687	€ 8,144	€ 13,457
Oschner 14/Grand 31	14	€ 949	€ 11,310	€ 18,763	14	€ 936	€ 11,169	€ 18,540	15	€ 851	€ 10,161	€ 16,876	16	€ 805	€ 9,618	€ 15,978
Grandezza 31	7	€ 865	€ 16,973	€ 16,973	6	€ 1,023	€ 12,256	€ 20,400	7	€ 780	€ 9,272	€ 15,355	8	€ 739	€ 8,789	€ 14,560
Oschner 9/Grand 25	15	€ 829	€ 9,806	€ 16,191	15	€ 824	€ 9,769	€ 16,145	16	€ 762	€ 9,042	€ 14,961	17	€ 725	€ 8,618	€ 14,268

Table L4b

House Type B - CO_2 Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	1SDG			1SSG - DG			B2SDG			B2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	4147	41469	62203	4069	40692	61038						
Oschner 19/Grand 61	4229	42294	63441	4175	41752	62628	3729	37294	55940	3491	34914	52371
Grandezza 51	3924	39238	58857	3861	38608	57911	3437	34370	51555	3226	32264	48397
Oschner 14/Grand 31	4485	44850	67275	4406	44055	66083	3962	39618	59427	3962	39618	59427
Grandezza 31	4267	40603	60904	4192	39883	59825	3364	32012	48018	3541	33691	50537
Oschner 9/Grand 25	3904	39043	58564	3865	38649	57973	3536	35361	53041	3536	35361	53041

House Type C

Table L1c

House Type C - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	Cost Savings			CO_2 Savings (kg/CO_2)	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	8,935	€ 4,117	€ 36,782,670	17,921	160,122,242
1SSG-DG	6,993	€ 4,567	€ 31,935,795	19,883	139,044,998
2SDG	9,840	€ 3,789	€ 37,283,071	15,660	154,093,529
2SSG-DG	6,686	€ 4,058	€ 27,132,177	17,623	117,824,556
Total	32,454	€ 16,531	€ 133,133,712	71,087	571,085,324

Table L2c

House Type C - Total Savings post improvement measures with Heat Pump use							
		Cost Savings			CO_2 Savings (kg/CO_2)		
Grand 31	Quantity of Houses	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings per annum	Savings after 10 Years	Savings after 15 Years
1SDG	8935	€ 7,947,027	€ 155,794,536	€ 155,794,536	39,349,272	374,398,398	561,597,596
1SSG-DG	6993	€ 6,053,725	€ 71,881,132	€ 118,949,806	29,690,518	282,497,797	423,746,695
2SDG	9840	€ 7,817,854	€ 92,834,546	€ 153,630,703	41,778,164	397,508,697	596,263,046
2SSG-DG	6686	€ 4,942,150	€ 58,647,994	€ 97,014,105	25,896,181	246,395,632	369,593,449
Total	32454	€ 26,760,756	€ 379,158,208	€ 525,389,149	136,714,135	1,300,800,524	1,951,200,786

Table L3c

House Type C - Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	C1SDG				C1SSG -DG				C2SDG				C2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	18	€ 888	€ 10,527	€ 17,403	17	€ 861	€ 10,590	€ 16,915	20	€ 785	€ 9,321	€ 15,418				
Oschner 19/Grand 61	16	€ 910	€ 10,801	€ 17,872	16	€ 891	€ 10,590	€ 17,542	28	€ 808	€ 9,609	€ 15,912	19	€ 784	€ 9,327	€ 15,459
Grandezza 51	6	€ 833	€ 9,842	€ 16,231	6	€ 811	€ 9,597	€ 15,843	6	€ 733	€ 8,664	€ 14,295	6	€ 712	€ 8,430	€ 13,926
Oschner 14	14	€ 976	€ 11,634	€ 19,297	14	€ 947	€ 11,298	€ 18,753	15	€ 869	€ 10,368	€ 17,210	15	€ 810	€ 9,656	€ 16,023
Grand 31	6	€ 889	€ 17,436	€ 17,436	7	€ 866	€ 10,279	€ 17,010	7	€ 794	€ 9,434	€ 15,613	8	€ 739	€ 8,772	€ 14,510
Oschner 9/Grand 25	15	€ 848	€ 10,022	€ 16,540	15	€ 832	€ 9,856	€ 16,286	16	€ 771	€ 9,143	€ 15,115	16	€ 749	€ 8,900	€ 14,730

Table L4c

House Type C- CO_2 Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	C1SDG			C1SSG - DG			C2SDG			C2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	4296	42962	64443	4127	41267	61900	3730	37297	559456.4			
Oschner 19/Grand 61	4374	43737	65605	4233	42326	63488	4233	42326	63488	3648	36482	54724
Grandezza 51	4061	40610	60915	3914	39142	58713	3914	39142	58713	3514	35142	52714
Oschner 14	4629	46285	69428	4462	44623	66934	4462	44623	66934	4071	40707	61061
Grand 31	4404	41902	62854	4246	40397	60596	4246	40397	60596	3873	36852	55279
Oschner 9/Grand 25	4003	40027	60041	3905	39045	58568	3905	39045	58568	3484	34842	52263

House Type D

Table L1d

House Type D - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	Cost Savings			CO_2 Savings (kg/CO_2)	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	7,421	€ 4,151	€ 30,802,228	18,069	134,091,410
1SSG-DG	3,961	€ 4,601	€ 18,223,818	20,360	80,646,334
2SDG	13,602	€ 3,602	€ 49,000,143	15,684	213,333,196
2SSG-DG	7,260	€ 4,054	€ 29,428,774	17,647	128,114,492
Total	32,244	€ 16,407	€ 127,454,963	71,760	556,185,432

Table L2d

House Type D - Total Savings post improvement measures with Heat Pump use							
		Cost Savings			CO_2 Savings (kg/CO_2)		
Grand 31	Quantity of Houses	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings per annum	Savings after 10 Years	Savings after 15 Years
1SDG	7421	€ 6,525,432	€ 127,959,082	€ 127,959,082	32,262,287	306,967,523	460,451,284
1SSG-DG	3961	€ 3,386,955	€ 40,222,188	€ 66,566,621	15,350,531	146,056,432	219,084,648
2SDG	13602	€ 10,696,799	€ 127,035,375	€ 210,244,672	52,713,437	501,555,058	752,332,587
2SSG-DG	7260	€ 5,330,270	€ 63,275,617	€ 104,692,702	27,791,123	264,425,526	396,638,289
Total	32244	€ 25,939,456	€ 358,492,262	€ 509,463,077	128,117,377	1,219,004,538	1,828,506,808

Table L3d

House Type D- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	1SDG				1SSG -DG				2SDG				2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	after 15 Years	Payback	after 1st Year	after 10 Years	after 15 Years	Payback	after 1st Year	after 10 Years	after 15 Years
Oschner 25	18	€ 877	€ 10,395	€ 17,186	17	€ 850	€ 10,456	€ 16,693	20	€ 777	€ 9,222	€ 15,256				
Oschner 19/Grand 61	16	€ 899	€ 10,679	€ 17,671	17	€ 879	€ 10,456	€ 17,321	28	€ 800	€ 9,508	€ 15,746	19	€ 775	€ 9,221	€ 15,284
Grandezza 51	5	€ 794	€ 9,363	€ 15,420	6	€ 711	€ 8,349	€ 13,717	6	€ 726	€ 8,585	€ 14,167	6	€ 704	€ 8,342	€ 13,782
Oschner 14	14	€ 965	€ 11,499	€ 19,074	14	€ 935	€ 11,157	€ 18,521	15	€ 860	€ 10,261	€ 17,033	15	€ 804	€ 9,586	€ 15,909
Grandezza 31	7	€ 879	€ 17,243	€ 17,243	7	€ 855	€ 10,155	€ 16,806	7	€ 786	€ 9,339	€ 15,457	8	€ 734	€ 8,716	€ 14,420
Oschner 9/Grand 25	15	€ 840	€ 9,935	€ 16,399	15	€ 824	€ 9,761	€ 16,132	16	€ 764	€ 9,063	€ 14,985	16	€ 742	€ 8,814	€ 14,589

Table L4d

House Type D- CO$_2$ Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	1SDG			1SSG - DG			2SDG			2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	4234	42344	63516	3737	37367	56051	3683	36834	552503.7			
Oschner 19/Grand 61	4315	43146	64719	3843	38427	57640	3843	38427	57640	3600	35996	53993
Grandezza 51	3903	39030	58545	3474	34740	52111	3474	34740	52111	3474	34740	52110
Oschner 14	4569	45692	68537	4073	40731	61096	4073	40731	61096	4023	40232	60348
Grandezza 31	4347	41365	62047	3875	36874	55310	3875	36874	55310	3828	36422	54633
Oschner 9/Grand 25	3963	39628	59441	3534	35340	53010	3534	35340	53010	3433	34331	51497

House Type E

Table L1e

House Type E - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	**Cost Savings**			**CO$_2$ Savings (kg/CO$_2$)**	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	11,510	€ 4,236	€ 48,760,543	18,445	212,304,509
1SSG-DG	6,188	€ 4,683	€ 28,981,446	20,391	126,178,819
2SDG	22,605	€ 3,466	€ 78,360,044	15,094	341,197,354
2SSG-DG	12,154	€ 4,129	€ 50,182,558	17,977	218,489,965
Total	52,457	€ 16,515	€ 206,284,592	71,907	898,170,647

Table L2e

House Type E - Total Savings post improvement measures with Heat Pump use							
Grand 31	**Quantity of Houses**	**Cost Savings**			**CO$_2$ Savings (kg/CO$_2$)**		
		Savings after 1st Year	**Savings after 10 Years**	**Savings after 15 Years**	**Savings per annum**	**Savings after 10 Years**	**Savings after 15 Years**
1SDG	11510	€ 10,410,619	€ 204,361,448	€ 204,361,448	51,356,319	292,722,930	292,722,930
1SSG-DG	6188	€ 5,289,610	€ 62,756,121	€ 103,793,243	26,054,109	90,094,259	148,579,386
2SDG	22605	€ 19,323,147	€ 229,250,503	€ 379,160,676	95,176,653	329,117,765	542,766,165
2SSG-DG	12154	€ 9,315,173	€ 110,749,847	€ 183,424,948	51,173,503	159,791,231	263,964,994
Total	52457	€ 44,338,549	€ 607,117,920	€ 870,740,316	223,760,584	871,726,186	1,248,033,475

Table L3e

House Type E- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	1SDG				1SSG -DG				2SDG				2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	18	€ 904	€ 10,727	€ 17,745	17	€ 850	€ 10,371	€ 16,663	18	€ 850	€ 10,077	€ 16,663				
Oschner 19/Grand 61	16	€ 932	€ 11,076	€ 18,341	17	€ 873	€ 10,371	€ 17,166	17	€ 873	€ 10,371	€ 17,166	19	€ 785	€ 9,339	€ 15,479
Grandezza 51	5	€ 816	€ 9,632	€ 15,871	5	€ 779	€ 9,191	€ 15,148	5	€ 779	€ 9,191	€ 15,148	6	€ 713	€ 8,438	€ 13,939
Oschner 14	14	€ 991	€ 11,816	€ 19,606	14	€ 937	€ 11,171	€ 18,535	14	€ 937	€ 11,171	€ 18,535	15	€ 836	€ 9,982	€ 16,580
Grandezza 31	6	€ 904	€ 17,755	€ 17,755	7	€ 855	€ 10,142	€ 16,773	7	€ 855	€ 10,142	€ 16,773	7	€ 766	€ 9,112	€ 15,092
Oschner 9/Grand 25	15	€ 862	€ 10,197	€ 16,838	15	€ 821	€ 9,714	€ 16,042	15	€ 821	€ 9,714	€ 16,042	16	€ 747	€ 8,874	€ 14,684

Table L4e

House Type E- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	1SDG				1SSG -DG				2SDG				2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	18	€ 1,304	€ 15,408	€ 25,415	17	€ 1,224	€ 14,930	€ 23,833	18	€ 1,224	€ 14,455	€ 23,833				
Oschner 19/Grand 61	16	€ 1,349	€ 15,971	€ 26,377	17	€ 1,262	€ 14,930	€ 24,644	17	€ 1,262	€ 14,930	€ 24,644	19	€ 1,139	€ 13,512	€ 22,343
Grandezza 51	5	€ 1,163	€ 13,641	€ 22,391	5	€ 1,110	€ 13,026	€ 21,388	5	€ 1,110	€ 13,026	€ 21,388	6	€ 1,023	€ 12,060	€ 19,858
Oschner 14	14	€ 1,444	€ 17,164	€ 28,419	14	€ 1,365	€ 16,221	€ 26,853	14	€ 1,365	€ 16,221	€ 26,853	15	€ 1,222	€ 14,551	€ 24,119
Grandezza 31	6	€ 1,305	€ 25,432	€ 25,432	7	€ 1,233	€ 14,560	€ 24,011	7	€ 1,233	€ 14,560	€ 24,011	7	€ 1,110	€ 13,147	€ 21,718
Oschner 9/Grand 25	15	€ 1,236	€ 14,553	€ 23,952	15	€ 1,177	€ 13,870	€ 22,831	15	€ 1,177	€ 13,870	€ 22,831	16	€ 1,079	€ 12,763	€ 21,061

House Type F

Table L1f

House Type F - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	Cost Savings			CO_2 Savings (kg/CO_2)	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	7,684	€ 1,255	€ 9,647,033	5,464	41,982,911
1SSG-DG	3,511	€ 1,652	€ 5,799,363	7,191	25,249,114
2SDG	12,616	€ 1,449	€ 18,281,182	6,307	79,568,773
2SSG-DG	6,006	€ 1,838	€ 11,040,115	8,004	48,071,675
Total	29,817	€ 6,194	€ 44,767,693	26,966	194,872,473

Table L2f

House Type F - Total Savings post improvement measures with Heat Pump use							
		Cost Savings			CO$_2$ Savings (kg/CO$_2$)		
Grand 31	Quantity of Houses	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings per annum	Savings after 10 Years	Savings after 15 Years
1SDG	7684	€ 4,434,925	€ 83,544,689	€ 83,544,689	24,391,020	232,074,404	348,111,605
1SSG-DG	3511	€ 2,057,562	€ 23,943,975	€ 39,094,608	11,056,949	105,204,081	157,806,121
2SDG	12616	€ 7,141,935	€ 83,433,276	€ 136,582,292	39,730,694	378,027,537	567,041,305
2SSG-DG	6006	€ 3,462,326	€ 40,654,190	€ 66,779,665	17,814,387	169,499,405	254,249,108
Total	29817	€ 17,096,748	€ 231,576,129	€ 326,001,253	92,993,050	884,805,426	1,327,208,140

Table L3f

House Type F- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	1SDG				1SSG -DG				2SDG				2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	25	€ 612	€ 7,116	€ 11,614	22	€ 609	€ 6,596	€ 11,618	26	€ 582	€ 6,815	€ 11,171	26	€ 585	€ 6,815	€ 11,310
Oschner 19/Grand 61	25	€ 557	€ 6,430	€ 10,441	25	€ 568	€ 6,596	€ 10,752	25	€ 552	€ 6,431	€ 10,514	23	€ 566	€ 6,641	€ 10,901
Grandezza 51	7	€ 659	€ 7,709	€ 12,630	8	€ 640	€ 7,498	€ 12,295	8	€ 602	€ 7,060	€ 11,591	7	€ 703	€ 8,357	€ 13,835
Oschner 14	19	€ 669	€ 7,834	€ 12,844	18	€ 672	€ 7,893	€ 12,972	19	€ 643	€ 7,580	€ 12,480	20	€ 648	€ 7,658	€ 12,640
Grandezza 31	9	€ 577	€ 10,873	€ 10,873	9	€ 586	€ 6,820	€ 11,135	10	€ 566	€ 6,613	€ 10,826	11	€ 576	€ 6,769	€ 11,119
Oschner 9/Grand 25	22	€ 535	€ 6,149	€ 9,960	21	€ 546	€ 6,319	€ 10,279	22	€ 531	€ 6,170	€ 10,067	18	€ 546	€ 6,392	€ 10,474

Table L4f

House Type F- CO$_2$ Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	1SDG			1SSG - DG			2SDG			2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	3100	31000	46500	3049	30488	45733	2856	28565	428471			
Oschner 19/Grand 61	2881	28810	43216	2885	28853	43280	2885	28853	43280	2814	28142	42213
Grandezza 51	3270	32698	49046	3157	31572	47358	3157	31572	47358	2919	29190	43786
Oschner 14	3336	33361	50042	3310	33098	49648	3310	33098	49648	3117	31174	46761
Grandezza 31	3174	30202	45303	3149	29964	44946	3149	29964	44946	2966	28222	42333
Oschner 9/Grand 25	2706	27065	40597	2725	27251	40877	2725	27251	40877	3082	30817	46226

House Type G

Table L1g

House Type G - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	**Cost Savings**			**CO_2 Savings (kg/CO_2)**	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	19,505	€ 944	€ 18,413,001	3,879	75,655,951
1SSG-DG	7,178	€ 1,359	€ 9,752,356	5,683	40,793,402
2SDG	24,525	€ 933	€ 22,879,942	3,831	93,946,878
2SSG-DG	9,025	€ 1,348	€ 12,161,676	5,635	50,855,651
Total	60,233	€ 4,583	€ 63,206,975	19,028	261,251,882

Table L2g

House Type G - Total Savings post improvement measures with Heat Pump use							
		Cost Savings			**CO_2 Savings (kg/CO_2)**		
Grand 51	**Quantity of Houses**	**Savings after 1st Year**	**Savings after 10 Years**	**Savings after 15 Years**	**Savings per annum**	**Savings after 10 Years**	**Savings after 15 Years**
1SDG	19505	€ 12,119,229	€ 141,110,719	€ 230,485,875	62,641,364	626,413,642	939,620,463
1SSG-DG	7178	€ 4,341,128	€ 50,641,702	€ 82,822,272	22,486,835	224,868,354	337,302,531
2SDG	24525	€ 13,797,963	€ 161,135,441	€ 263,722,386	76,830,543	768,305,431	1,152,458,146
2SSG-DG	9025	€ 6,387,357	€ 75,945,672	€ 125,787,551	25,973,717	259,737,170	389,605,755
Total	60233	€ 36,645,677	€ 428,833,534	€ 702,818,084	187,932,460	1,879,324,596	2,818,986,894

Table L3 g

House Type G- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	1SDG				1SSG -DG				2SDG				2SSG -DG			
	Payback	**Savings after 1st Year**	**Savings after 10 Years**	**Savings after 15 Years**	**Payback**	**Savings after 1st Year**	**Savings after 10 Years**	**Savings after 15 Years**	**Payback**	**Savings after 1st Year**	**Savings after 10 Years**	**Savings after 15 Years**	**Payback**	**Savings after 1st Year**	**Savings after 10 Years**	**Savings after 15 Years**
Oschner 25	20	€ 564	€ 6,518	€ 10,592	>25	€ 556	€ 5,697	€ 10,487	>25	€ 519	€ 6,019	€ 9,810	>25	€ 513	€ 6,019	€ 9,764
Oschner 19/Grand 61	>25	€ 490	€ 5,591	€ 9,005	0.35	€ 496	€ 5,697	€ 9,215	>25	€ 465	€ 5,344	€ 8,656	>25	€ 474	€ 5,486	€ 8,927
Grandezza 51	7	€ 621	€ 7,235	€ 11,817	9	€ 605	€ 7,055	€ 11,538	9	€ 563	€ 6,570	€ 10,753	9	€ 708	€ 8,415	€ 13,938
Oschner 14	20	€ 610	€ 7,091	€ 11,571	21	€ 607	€ 7,089	€ 11,596	21	€ 566	€ 6,615	€ 10,830	21	€ 565	€ 6,631	€ 10,885
Grandezza 31	10	€ 515	€ 9,531	€ 9,531	11	€ 519	€ 5,976	€ 9,692	11	€ 485	€ 5,602	€ 9,096	11	€ 491	€ 5,697	€ 9,288
Oschner 9/Grand 25	24	€ 473	€ 5,383	€ 8,650	25	€ 476	€ 5,448	€ 8,789	25	€ 446	€ 5,110	€ 8,255	25	€ 453	€ 5,229	€ 8,487

Table L4 g

House Type G- CO_2 Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	1SDG			1SSG - DG			2SDG			2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	3006	30057	45086	2958	29582	44373	2723	27230	408454.758			
Oschner 19/Grand 61	2711	27109	40664	2720	27203	40804	2720	27203	40804	2668	26677	40016
Grandezza 51	3212	32116	48173	3133	31327	46991	3133	31327	46991	2878	28780	43170
Oschner 14	3215	32152	48228	3190	31898	47846	3190	31898	47846	2944	29442	44163
Grandezza 31	3059	29107	43661	3035	28877	43316	3035	28877	43316	2801	26654	39981
Oschner 9/Grand 25	2585	25849	38773	2585	25852	38778	2585	25852	38778	2907	29066	43599

House Type H

Table L1h

House Type H - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	**Cost Savings**			**CO_2 Savings (kg/CO_2)**	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	21,188	€ 867	€ 18,374,042	3,543	75,073,014
1SSG-DG	2,650	€ 1,048	€ 2,776,274	4,330	11,475,607
2SDG	18,735	€ 875	€ 16,398,199	3,576	66,998,806
2SSG-DG	3,121	€ 1,056	€ 3,294,935	4,363	13,618,055
Total	45,694	€ 3,846	€ 40,843,450	15,813	167,165,483

Table L2h

House Type H - Total Savings post improvement measures with Heat Pump use							
Grand 51	**Quantity of Houses**	**Cost Savings**			**CO_2 Savings (kg/CO_2)**		
		Savings after 1st Year	**Savings after 10 Years**	**Savings after 15 Years**	**Savings per annum**	**Savings after 10 Years**	**Savings after 15 Years**
1SDG	21188	€ 12,568,307	€ 145,654,952	€ 237,151,454	63,523,129	635,231,289	952,846,934
1SSG-DG	2650	€ 1,544,175	€ 17,952,672	€ 29,293,496	7,838,841	78,388,408	117,582,612
2SDG	18735	€ 10,293,357	€ 119,791,600	€ 195,598,102	55,419,126	554,191,256	831,286,884
2SSG-DG	3121	€ 1,667,427	€ 19,461,083	€ 31,838,348	8,614,739	86,147,395	129,221,092
Total	45694	€ 26,073,266	€ 302,860,308	€ 493,881,399	135,395,835	1,353,958,349	2,030,937,523

Table L2h

House Type H- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	H1SDG				H1SSG -DG				H2SDG				H2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	20	€ 533	€ 6,127	€ 9,914	>25	€ 525	€ 5,007	€ 9,815	>25	€ 496	€ 5,731	€ 9,307	>25	€ 489	€ 5,731	€ 9,226
Oschner 19/Grand 61	>25	€ 438	€ 4,932	€ 7,869	0.35	€ 442	€ 5,007	€ 8,030	>25	€ 420	€ 4,769	€ 7,660	>25	€ 428	€ 4,909	€ 7,933
Grandezza 51	7	€ 593	€ 6,874	€ 11,193	9	€ 583	€ 6,775	€ 11,054	9	€ 549	€ 6,394	€ 10,440	9	€ 534	€ 6,236	€ 10,201
Oschner 14/Grand 31	20	€ 563	€ 6,500	€ 10,552	21	€ 559	€ 6,478	€ 10,546	21	€ 529	€ 6,134	€ 9,996	21	€ 528	€ 6,153	€ 10,061
Grandezza 31	10	€ 464	€ 8,423	€ 8,423	11	€ 467	€ 5,322	€ 8,569	11	€ 443	€ 5,064	€ 8,165	11	€ 449	€ 5,174	€ 8,385
Oschner 9/Grand 25	24	€ 437	€ 4,922	€ 7,854	25	€ 434	€ 4,912	€ 7,867	25	€ 413	€ 4,682	€ 7,512	25	€ 414	€ 4,735	€ 7,635

Table L4h

House Type H- CO_2 Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	1SDG			1SSG - DG			2SDG			2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	2782	27825	41737	2750	27498	41247	2571	25710	385643.7			
Oschner 19/Grand 61	2405	24051	36077	2419	24191	36287	2419	24191	36287	2529	25287	37931
Grandezza 51	2998	29981	44971	2958	29581	44371	2958	29581	44371	2760	27602	41404
Oschner 14/Grand 31	2936	29362	44043	2920	29202	43803	2920	29202	43803	2734	27339	41008
Grandezza 31	2794	26582	39872	2778	26436	39655	2778	26436	39655	2601	24750	37125
Oschner 9/Grand 25	2372	23720	35580	2360	23605	35407	2360	23605	35407	2718	27180	40770

House Type I

Table L1i

House Type I - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	Cost Savings			CO_2 Savings (kg/CO_2)	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	299	€ 893	€ 266,919	3,653	1,092,379
1SSG-DG	299	€ 1,123	€ 335,689	4,656	1,392,276
2SDG	22,100	€ 896	€ 19,796,595	3,669	81,080,077
2SSG-DG	22,100	€ 1,127	€ 24,901,695	4,034	89,157,688
Total	44,798	€ 4,038	€ 45,300,897	16,013	172,722,420

Table L2i

House Type I - Total Savings post improvement measures with Heat Pump use							
		Cost Savings			CO_2 Savings (kg/CO_2)		
Grand 51	Quantity of Houses	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings per annum	Savings after 10 Years	Savings after 15 Years
1SDG	299	€ 185,714	€ 2,156,908	€ 3,516,986	952,700	9,527,001	14,290,501
1SSG-DG	299	€ 185,714	€ 2,156,908	€ 3,516,986	952,700	9,527,001	14,290,501
2SDG	22100	€ 12,512,298	€ 145,895,300	€ 238,530,650	70,416,961	704,169,609	1,056,254,414
2SSG-DG	22100	€ 19,256,125	€ 230,323,573	€ 382,962,299	63,666,302	636,663,021	954,994,532
Total	44798	€ 32,139,852	€ 380,532,689	€ 628,526,920	135,988,663	1,359,886,632	2,039,829,948

Table L3i

House Type I- Cost Savings by Heat Pumps Installation (Post Improvement Measures)																
Heat Pump	1SDG				1SSG -DG				2SDG				2SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	>25	€ 558	€ 6,419	€ 10,402	17	€ 558	€ 5,282	€ 10,402	>25	€ 516	€ 5,978	€ 9,726	>25	€ 516	€ 5,978	€ 9,726
Oschner 19/Grand 61	>25	€ 467	€ 5,282	€ 8,457	>25	€ 467	€ 5,282	€ 8,457	>25	€ 451	€ 5,159	€ 8,326	>25	€ 451	€ 5,159	€ 8,326
Grandezza 51	8	€ 621	€ 7,214	€ 11,762	8	€ 621	€ 7,214	€ 11,762	8	€ 566	€ 6,602	€ 10,793	5	€ 871	€ 10,422	€ 17,329
Oschner 14/Grand 31	21	€ 594	€ 6,871	€ 11,177	20	€ 594	€ 6,871	€ 11,177	21	€ 558	€ 6,498	€ 10,616	20	€ 558	€ 6,498	€ 10,616
Grandezza 31	10	€ 494	€ 9,030	€ 9,030	11	€ 494	€ 5,617	€ 9,030	11	€ 473	€ 5,440	€ 8,806	10	€ 473	€ 5,440	€ 8,806
Oschner 9/Grand 25	>25	€ 458	€ 5,170	€ 8,267	>25	€ 458	€ 5,170	€ 8,267	>25	€ 436	€ 4,976	€ 8,011	>25	€ 436	€ 4,976	€ 8,011

Table L4i

House Type I- CO_2 Savings by Heat Pump Installation (kg of CO2)												
Heat Pump	1SDG			1SSG - DG			2SDG			2SSG-DG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	2956	29561	44342	2956	29561	44342	2704	27035	405526.9			
Oschner 19/Grand 61	2597	25967	38950	2597	25967	38950	2597	25967	38950	3341	33410	50115
Grandezza 51	3186	31863	47794	3186	31863	47794	3186	31863	47794	2881	28808	43212
Oschner 14/Grand 31	3132	31323	46985	3132	31323	46985	3132	31323	46985	2902	29025	43537
Grandezza 31	2980	28357	42535	2980	28357	42535	2980	28357	42535	2762	26276	39414
Oschner 9/Grand 25	2508	25084	37627	2508	25084	37627	2508	25084	37627	3493	34928	52392

House Type J

Table L1j

House Type J - Total Savings resulting from Fabric Improvement Measures c/w High Efficiency Condensing Boiler					
House Type	Cost Savings			CO_2 Savings (kg/CO_2)	
	Quantity of Houses	Cost Saving per Annum	Total	CO2 Saving/annum	Total
1SDG	12,642	€ 713	€ 9,010,280	2,116	26,747,684
2SDG	22,100	€ 683	€ 15,100,760	2,088	46,148,163
Total	34,742	€ 1,396	€ 24,111,040	4,204	72,895,847

Table L2j

House Type J - Total Savings post improvement measures with Heat Pump use							
Grand 51	Quantity of Houses	Cost Savings			CO_2 Savings (kg/CO_2)		
		Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings per annum	Savings after 10 Years	Savings after 15 Years
1SDG	12642	€ 6,391,807	€ 72,702,193	€ 116,846,942	36,301,652	363,016,524	544,524,787
2SDG	22100	€ 11,722,883	€ 135,689,573	€ 220,739,833	69,085,052	690,850,522	1,036,275,783
Total	34742	€ 18,114,690	€ 208,391,766	€ 337,586,775	105,386,705	1,053,867,047	1,580,800,570

Table L3j

House Type J- Cost Savings by Heat Pumps Installation (Post Improvement Measures)								
Heat Pump	1SDG				1SSG -DG			
	Payback	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Payback	Savings after 1st Year	Savings after 10 Years	after 15 Years
Oschner 25	>25	€ 459	€ 5,165	€ 8,241	17	€ 477	€ 4,301	€ 8,850
Oschner 19/Grand 61	>25	€ 351	€ 3,820	€ 5,940	>25	€ 384	€ 4,301	€ 6,842
Grandezza 51	8	€ 506	€ 5,751	€ 9,243	8	€ 530	€ 6,140	€ 9,988
Oschner 14/Grand 31	21	€ 468	€ 5,276	€ 8,430	20	€ 496	€ 5,715	€ 9,261
Grandezza 31	10	€ 357	€ 6,063	€ 6,063	11	€ 405	€ 4,575	€ 7,312
Oschner 9/Grand 25	>25	€ 383	€ 4,214	€ 6,613	>25	€ 392	€ 4,406	€ 7,023

Table L4j

House Type J - CO_2 Savings by Heat Pump Installation (kg of CO2)						
Heat Pump	1SDG			2SDG		
	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years	Savings after 1st Year	Savings after 10 Years	Savings after 15 Years
Oschner 25	3005	30047	45071	3077	30772	46158
Oschner 19/Grand 61	2581	25811	38717	2706	27064	40597
Grandezza 51	2872	28715	43073	3126	31260	46890
Oschner 14/Grand 31	2779	27787	41681	3049	30486	45729
Grandezza 31	2644	25156	37734	2901	27599	41399
Oschner 9/Grand 25	2404	24042	36063	2593	25930	38895