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MSc in Applied Construction Cost Management

Valuing potential savings as a result of upgrading existing dwellings to comply with Part L of 2011 Building Regulations Standards -A Simulation Approach

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eclaration Page

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knowledgements

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Finally I would like to dedicate this dissertation to my family and friends, in particular my parents JJ and Philomena for all their support and encouragement throughout the course of my education, and practically the past year which has been most challenging.

Abstract

The rational for reducing energy consumption would appear to be very clear. Global demand for energy is outstripping supply with resulting inflationary pressure on energy prices. In addition the price of oil is notoriously volatile and is particularly sensitive to political instability amongst its major producers and exporters: security of energy supply also remains a constant concern. The cost of energy will most likely continue to rise. This provides a strong incentive to save money by using less energy, in all aspects of life. With energy efficiency of buildings being a contributing factor with respect to energy consumption the consideration of the building fabric is of substantial importance.

The reduction in ñnew buildsò within the Irish Construction sector has resulted in increased investment in green infrastructure and housing solution, including a national energy retrofit programme to help to achieve targets set out in the Kyoto Protocol. Professional construction bodies claim that such initiatives have the potential to support the industry, which is experiencing unprecedented difficulties, and providing direct benefits to the economy and exchequer through creating additional employment. The following study identifies the importance of energy efficiency, investigates the development of the Irish Building Regulations with particular attention to Part L, the potential energy savings achieved as a result of the implementation of Part L, and examination of the net present value of these savings over a 20 year study period.

Results

To produce a creditable study both a qualitative and a quantitative research approach is taken. The quantitative aspect of the study involves examining the energy consumption relationship between a building constructed in accordance with Part L of 2011 Building Regulations and that of a typical 1970ôs building, through the use of a building model. The qualitative aspect of the study involves investigating the implementation of energy efficiency measures. An interview process was carried out with a local authority to establish this. It is established that the most effective measure to establish energy savings in accordance with the 2011 Building Regulations was the replacement of an inefficient boiler system, followed by the improvement of air tightness within the building, this was followed by insulation of the external wall and ceiling, followed by the replacement of windows along the insulation of the

riod of between 7-9 years dependent on measures taken of the savings achieved due to a reduction in energy consumption; an annual energy saving of ú4,786 can be anticipated. Providing an assumed discount rate of 4% and an escalation rate of 8% a net present value saving of ú100,000 to ú110,000 can be anticipated if a 1970ôs building is upgraded to comply with the Part L of the 2011 Building Regulations.

Conclusion

A theoretical analysis, backed by relevant industry professionalôs opinions, indicates that the upgrading of energy inefficient buildings has the potential to give considerable support the industry. Having said this it is also clear that the primary reasons hindering the expansion of such upgrades is lack of knowledge about the achievable results and the initial capital investment required by the consumer to carry out such works. The quantitative research outlines the upgrading of a buildings energy efficiency does require capital investment, but if a long term outlook is taken these extra costs can be recouped and ultimately a large energy and financial saving can be made.

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TER 1: INTRODUCTION

1.1 Introduction

Throughout history mankind has strived to improve its living and working environment and architectural heritage represents some of humanityøs finest achievement. However, construction activity also has a number of significant negative impacts on the environment. It consumes considerable quantities of land and raw materials and generates large volumes of waste. Construction activity also requires significant energy input which consequently produces substantial CO2 emissions. According to Dimoudi (2008) approximately 50% of energy consumption, and consequently CO2 emissions, within the European Union is related to the construction, use and demolition of buildings. Thormark (2006) adds that the 85-95% of the energy used in dwellings is related to their occupation and use. This scale of energy use and emissions is a significant contributor to increasing global warming, resulting in the negative effects of climate change. The minimisation/ elimination of further climate change represents one of the greatest challenges facing world leaders. The Construction Industry clearly has a major part to play in meeting this challenge.

At a more immediate level the rational for reducing energy consumption is also convincing. Global demand for energy is outstripping supply with resulting inflationary pressure on energy prices. In addition the price of oil is notoriously volatile and is particularly sensitive to political instability amongst its major producers and exporters: security of energy supply also remains a constant concern. The cost of energy will most likely continue to rise. This provides a strong incentive to save money by using less energy.

In 1991 The Minister for Environment introduced the Building Regulations which established minimum standards for design and construction, and sought to conserve the use of energy and prevent waste. The Building Regulations, in general relate to new construction work extensions and alterations in existing domestic dwellings. Part L of the Building Regulations *'Conservation of Fuel and Energy'* establishes the requirements for energy efficiency. It was revised and updated in 2011.

Dwellings completed before the introduction of the Building Regulations have been identified as an area with significant potential for reducing national energy consumption

s the SCSI and the IAVI have called for increased nd energy efficient housing, including a national energy retrofit programme to help to achieve targets set out in the Kyoto Protocol. They claim that such initiatives have the added advantage of supporting the industry, which is experiencing unprecedented difficulties, and providing direct benefits to the economy and exchequer through creating additional employment.

This research project investigates the likely costs of bringing a sample pre 1991 dwelling up to the current standards required by Part L of the Building Regulations and estimates the likely energy savings that such an intervention would generate. Similar studies have been carried out at undergraduate level and have resulted in a range of conclusions largely based on individual case studies. This study takes a somewhat different approach in that the author employs a building information modelling approach to generate the data upon which the cost estimates and energy savings will be based. In doing so the study will employ cost and value appraisal techniques which are being increasingly employed by quantity surveyors operating in specialist areas. The study therefore integrates a number of central disciplines within the DT 164 programme. It is therefore considered that this study is topical, timely and relevant to the course objectives.

1.2 Research Question

The research question to be addressed in this research is how much energy can be saved in a simulated building model by upgrading its design to comply with the current performance standards required by Part L of the Building Regulations.

1.3 Aims and Objectives

The following objectives have been identified as key to resolving the research question.

1. To set out the requirements of Part L of the Building Regulations 2011
2. To discuss various options for achieving these standards
3. To develop a building model to test the effect of a design intervention which alters the modelôs design from pre ï 1991 to 2011 standards in terms of compliance with Part L of the Building Regulations.
4. To measure the change in energy consumption resulting from such an intervention.

rventions are economically beneficial.

ential benefits should such interventions be adopted regionally/ locally?

1.4 Scope of Study

The scope of this study is twofold; the primary purpose is to establish the energy savings that can be achieved due to the development of Part L of the Building Regulations. In order to accurately assess this, the use of building simulation is to be utilised. The recent incorporation of the BER certification examines to an extent the energy efficiency of a given building. However within this research a somewhat more comprehensive examination of the efficiency of the Building Regulations will be carried out using the IES software package. The financial savings arising from the possible energy savings that may be achieved are also examined. This will be carried out through a life cycle analysis of the building. The literature review highlights that very little examination of the financial benefits resulting from energy savings has been carried out, for this reason the scope of the study will investigate these. In keeping with the role of the quantity surveyor an examination of financial cost to achieve the current Building Regulation will also be undertaken.

This study is limited by various constraints. The primary limitation is the time constraints. A study period of approximately 6 months it is somewhat unfeasible to expand the study outside of the boundaries outlined. The scope of the work is also affected and it focuses on the residential building sector. If the limitations outlined above did not affect the study it would be recommended that a more extensive study be carried out, to incorporate a broader spectrum of buildings, for example commercial.

1.5 Organisation and Structure

This study comprises of six chapters:

Chapter One sets out the background, rational aims and objectives, scope and structure of this investigation. Chapter Two will present a review of the literature dealing with the issues raised by the introduction, examining the relevant literature with respect to the topic in question, issues such as the development of the Building Regulations, measures which can be taken to achieve these standards. The effects of poor energy efficiency for the consumer are

to this the third chapter describes the methodological esearch, explaining the design adopted to conduct the research. Chapter Four will provide a comprehensive analysis of the findings, outlining observations made as a result of the computer programs which is utilised. Chapter Five presents a discussion of the analysis and a synthesis and interpretation of the findings; it examines key issues and themes. Chapter Six, the concluding chapter brings together work done, and what has been found. It evaluates the methodology and data collection tools used and describes the research contribution to the literature. It reflects on the degree to which the aims and objectives were achieved. It discusses the implications and recommendations for practice arising from the research and comments on the cost / benefits of these. It concludes by presenting recommendations for further research.

2: LITERATURE REVIEW

2.1 Introduction

Literature- A term often used to indicate the secondary written sources for a particular subject, usually located in a library and comprising, descriptive critical and analytical commentary and discussion frequently in the format of monographs and journal articles. Bond (2004)

This chapter evaluates the literature relating to the research question. In broad terms this is how much energy can be saved by upgrading existing dwellings to achieve the performance standards required by Part L of the Building Regulations. In particular it deals with the following objectives set out in Chapter one.

1. To set out the requirements of Part L of the Building Regulations 2011
2. To discuss various options for achieving these standards
3. To discuss whether improvements are economically beneficial

The review commences with a discussion of the context of the study involving examinations of the concept of energy efficiency and its importance at macro, national and individual levels. It then examines the importance of energy efficiency in dwellings, addressing issues such as energy regulation and fuel poverty. It proceeds to review the history of building control in Ireland, concentrating on developments within Part L of the Building Regulations. It reports findings of previous studies into the value of energy efficiencies in dwellings. Following this, details of the various options to achieve Part L of the Building Regulations will be discussed with particular consideration being given to the building fabric. The final section will provide concluding remarks.

2.2 Secondary Data Collection

Secondary data is collected using the desk study approach. The desk study involved the examination of descriptive documentation. This involved the analyses and critical appraisal of the relevant archival documentation. In order to identify such documentation an extensive search for information was carried out. The following outlines the various sources of the

ting bodies and personal, while also briefly providing an ure.

2.2.1 Government Documentation

Due to the relationship between government and the implementation of building regulations the examination of government documentation is fundamental to the study. Government documentation examined throughout the process was primarily sourced from the Department of the Environment, Community and Local Government. Such documentation included but is not limited to:

- Building Regulations 2011Technical Guidance Document L Conservation of Fuel and Energy ï Dwellings
- Regulatory Impact Analysis Conservation of Fuel and Energy in New Dwellings Proposed amendments to Building Regulations Part L and Technical Guidance Document L
- Maximising Irelandôs Energy Efficiency: The National Energy Efficiency Action Plan 2009 ï 2020

Such documentation provided the author with a technical insight into the requirements of Building regulations. Once this information was established it was then imputed into the case study in order to develop a building model which achieves the required energy standards. In addition to this The National Energy Efficiency Action Plan 2009 ï 2020, provided an insight into the govermental approach being taking in relation to energy efficency with in the country.

2.2.2 Journal Articles

There are a vast amount of journal articles in relation to the topic of energy efficiency. The author believes it is vital that such publishing are considered in order to increase validity of the study. The journals examined were primarily sources through the Science Direct database, which is operated by the publisher Elsevier. Such Journals would include:

- Energy and Buildings
- Global Environment Change
- Building Research and Information
- Environmental Health Perspectives

Within these journals a vast amount of information was attained. It is believed that such information is credible and valid, as the research carried out undergoes a process of peer review by a number of referees; these referrers are typically academics in the same field. The research carried out in respect to journal articles reviled research carried out in academic field in Ireland. This appears to be lead by such institutions as the UCD Energy Research Group, School of Architecture, Landscape & Civil Engineering University College Dublin along with the Environmental Research Institute University College Cork. These studies included the development of energy performance benchmarks and building energy ratings for non-domestic buildings along with modelling the impacts of Building Regulations and a property bubble on residential space and water heating. The names which appear to be coming to the fore with respect to such studies in Ireland include Patxi Hernandez, Kevin Burke, J. Owen Lewis, D. Dineena and B.P. Ó Gallachóira. Energy Policy was also a useful source of information, providing an insight into the relationship between that of poor housing standards and that of fuel poverty, the leading contributors in Ireland with respect to this issue appeared to be situated in Urban Institute of Ireland, & Department of Environmental Studies in the University College Dublin, with John D. Healy & J. Peter Clinch to the fore.

2.2.3 Media Publications

The use of media publications was also investigated. The author took into account such information with a sense of caution. Media sources should be considered carefully due to the potential of unreliable information. The information gathered from such resources provided the author with information in relation to increased energy cost which are to be experienced by the consumer. The Irish Independent in particular provided a considerable amount of information. Such information was analysed as it appeared to provide unbiased information for the sole purpose to inform the consumer. Analyse of magazine articles were also carried out. Publications such as Construct Ireland provided the author with industry focused information.

considerable insight into a variety of information from a number of different spectrums. Bodies such as the SEAI Sustainable Energy Authority of Ireland have published numerous reports with respect to energy efficiency encompassing issues such as analysis of residential and small businesses energy efficiency improvements to an energy forecast for energy in Ireland until 2020. Reports issued by the Commission of Energy Regulation were also examined, providing an insight into the demand for energy and the corresponding inflationary pressure on energy prices. The reports provided concise consistent information.

2.2.5 Web page

The author attempted to limit the use of online sources; this is due to the somewhat undependable information which may possible be misconstrued. However the use of a number of web pages was utilised. The use of the internet provided the author with a more external viewpoint in relation to energy efficiency within the broader extremities of the study.

Having examined the various mediums of data the following literature review has been compiled.

2.3 The Need for Energy Efficiency

It has been well documented that climate change is a serious global issue producing harmful effects on the environment, the world financial system, and on living conditions. The effects of climate change are predominately spoken about in the future tense, however this may be misleading. Recent extreme weather events such as the flooding in Dublin (November 2011) and Cork (November 2009) and the particularly harsh winters of 2009 and 2010 have been viewed by some as evidence of the impact of global warming. Extreme weather events have also been recorded across the globe. These events appear not to be isolated incidents which suggest that global warming & climate change is impacting now and on a global scale.

One of the principle causes of climate change is the release of greenhouse gases including carbon dioxide CO2 resulting from combustion of fuel to produce energy. It is essential to

her deterioration in the situation. Energy efficiency is a

According to the Kyoto Protocol the European Union (EU) has committed to a reduction of greenhouse gas emissions by 8% below 1990 levels during a period between 2008 and 2012. In conjunction with this commitment, the European Commission compiled the European Climate Change Programme (ECCP) in 2000, in order to establish a district strategy for the implementation of the Protocol. The first ECCP report outlined cost effective measures for the reduction of green house gas emissions and a list of priority actions at local level were agreed. Improving of the energy performance of buildings was identified as an important component in meeting Kyoto Protocolôs targets Poel (2007), supports this position stating that ñ*increase of building energy performance can constitute an important instrument in the efforts to alleviate the EU energy import dependency and comply with the Kyoto Protocol to reduce carbon dioxide emissions*ò.

In 2005 the Irish construction sector was responsible for the emission of 13.81 $mtCO_{2eq}$, comprising 2.37 mt (17%) of direct on-site emissions, 5.69 mt (41%) upstream indirect domestic emissions and 5.75 mt (42%) upstream indirect emissions outside the state. Domestically arising direct and indirect emissions accounted for 3.44% and 8.26% of national emissions respectively. ñ*The EU Commission's '20-20 by 2020' policy commits Ireland to reducing emissions by 16% over 2005 levels by the year 2020*ò. Acquaye (2009)

The existing building stock *"accounts for over 40% of energy consumption in the European Union (EU) member states with residential building use representing 63% of this figure. A recent directive, Directive 2009/91/EC, on energy performance of buildings was recommended and adopted in late 2002."* EU (2002). *"Within the European construction sector growth in relation to new builds has slowed down over the last decade, and the focus of construction activity has switched to maintenance and renovation of existing dwellings"* Poel (2007).

Refurbishment and renovation of the existing and ageing building stock offers an opportunity to improve their thermal performance with the potential to deliver social, environmental and financial benefits. Protecting the architectural heritage is a primary benefit, but also

effective and is usually more economic than demolition nvestment retrofit operations. In light of sustainability principles and policies, it makes sense to renovate or refurbish old buildings. N. Kohler (1999) has suggested that constructing new buildings should be stopped, thereby forcing the improvement of the functional quality and durability of the existing stock.

ñ*Ireland has its role to play in reducing its environmental impact on the globe*ò. Edwards (2005)

In Ireland the State supports initiatives by private individuals and Local Authorities to achieve better energy efficiency in construction. The National Energy Efficiency Action Plan 2010 -2020 aims that *"all new Irish housing will be carbon neutral... (and) efficiency standards in older homes will be significantly improved through retrofitting action."* The plan continues *"We* (The Department) *have been steadily improving the energy performance requirements for housing since 1992"* Department of Communications (2008).

2.3 Relationship between Energy Efficiency & Fuel Poverty

From a consumerôs perspective the energy efficiency of their home has an obvious financial impact. The cost of maintaining a comfortable living environment is becoming more expensive as energy prices rise. For example The Commission of Energy Regulation (CER) Gas Tariff Review 2011-2012 approved an increase of 21.72% on gas price from the 1st of October 2011. Hennessy (2011) estimates that every home will experience and average ú250 a year increase in their gas and electricity bills resulting from price increases taking effect in 2011. He adds *"In further bad news for under pressure households, Airtricity's half a million customers were yesterday told electricity prices will rise by 12.3% from the start of September, while gas prices will go up by 21.2% from October"* It is estimated that some 300,000 home owners are struggling to pay their gas and electricity bills at present. The average domestic gas bill is ú720 a year, and the average electricity bill is close to ú1,000 Weston (2011). The CER has called for increased investments in energy efficiency measures in order to counteract the price rises.

ñ*classified households which require 10% or more of* *ating standards as being in fuel poverty"* Sefton (2005). This has been defined as ñ*the inability to heat the home adequately because of low household income and energy inefficient housing"* Lewis (1982) Clinch JP (1999). ñ*There is a growing body of evidence linking buildings, especially housing to human health"* Hood (2005). ñ*At the last estimate, using the OECDs definition 7% of homes in Ireland lacked affordable warmth"*, EU-SILC (2005). This situation has no doubt deteriorated as a result of the current severe economic downturn and energy price rises. Fuel poverty results in cold living conditions. According to the Age Action Ireland *"Many households affected by fuel poverty are characterised by older people living alone, often widowed, enduring low housing standards, low income and in buildings with low occupancy rates*ò. In addition an energy action conference also heard ñ*the inability to pay for home heating could be contributing to up to 2,000 winter deaths across Ireland a year"* (Irish Times, 2011).

About 70% of the residential buildings are over 30 years old and about 35% are more than 50 years old. This is an important observation given that most of the building regulations requiring thermal insulations of building envelopes were introduced after the 1970s energy crisis. The older buildings are wasting energy. This is important for policy makers ñ*because many European countries, notably Ireland- are having extreme difficulty in meeting their targets for the stabilisation of greenhouse-gas emissions under the Kyoto Protocol and acidification precursors under the Gothenburg Protocol*ò Clinch (2000).

Clinch and Healy *"demonstrated that a programme aimed at improving the thermal standards of the Irish housing stock would result in a reduction in domestic energy use of quarter, with attendant falls in emission rates of CO2 of 28% and a reduction in the Irish Kyoto 'overshoot' also of 28%"* Clinch (2000). ñ*It is clear that households should be encouraged to retrofit their homes to improve their energy efficiency standards, so that they can achieve affordable heating"* Healy (2002)

2.4 Budget 2012

At the outset of this study the economic position of the country was unstable, this currently remains the case. In an attempt to meet various financial obligations the December 2011

wance and increased carbon taxes Fuel allowance is a ependent on long term social welfare along with those who are not able to meet their own heating requirements. An allowance of ú20 per week is provided to eligible candidates. Budget 2012 reduced the heating season by 6 weeks to a total of 26 weeks. The fuel season for 2011/2012 will end on the week ending Friday, 6 April 2012, resulting in a ú120 loss for those eligible.

In addition the price of home heating oilõs such as kerosene and liquid petroleum have been earmarked to increase from May 1st next year. Carbon tax is also due to increase, the tax is measured by calculating the weight of carbon dioxide emitted by each fuel. The Department of Finance have outlined that a ú5 per tonne increase could result in a yield of ú108 million in a year to the State. Such adjustments will undoubtedly affect the levels of fuel poverty within the State, as people struggle to maintain a comfortable living environment. Timmins (2011) said ñ*that older people on low incomes, who last winter had to choose between food and fuel, would face the same stark challenges next winter, as the cost of fuel will have been inflated by the Carbon Tax and their fuel allowance will have been cut".*

2.5 Building Control in Ireland

"The history of building control everywhere tends to be one of reaction to failure and disaster, a question of belated slamming of stable doors" Pitt (1987)

Building energy regulations and standards were widely adopted abroad after the 1970s oil crisis, and generally focused on limiting heat transmission values of construction elements. This served as a good first approach to reduce energy use for space conditioning. Regulations have evolved over the years and now generally include detailed assessment of building energy use. Building energy certification and rating schemes based on calculated energy use are very common and often mandatory particularly within Europe. ñ*There is also a progressive trend towards regulating for low energy and 'zero energy buildings' as expressed, for example by the International Energy Agency Policy Recommendations on energy efficiency as issued to the G8"* Jollands (2010).

"Building Regulations have historically been developed and drafted relying on groups of

what was an acceptable level of risk and what costs can
*proved health safety or amenity*ò Keane (2003)

"The aims of the Building Regulations are to promote good practice in the design and construction of buildings. They set down minimum standards for design and construction so that building users and occupiers are safe and their health is not put a risk" Keane (2003).

The foundation of building control in Ireland originated in the mid 1930s when the Town and Regional Planning Act to 1934 created local planning authorities. In fact 1963 the Local Government Act provided legislative powers in relation to the creation of national building regulations. Various regulations and bylaws were introduced, primarily to protect public health and safety and these were often expressed in outdated terms. It was not until the introduction of the Building Control Act of 1990 that a framework for building regulation was implemented. This Act supersedes previous regulations and bye laws; its main aims are to:

- Secure the health, safety welfare and convenience of people in or about buildings and of others who may be affected by buildings or matters connected with buildings.
- Further the conservation of fuel and power and preventing waste
- Provide access for the disabled.

This Act sets out the basic framework for introducing and operating building regulations. The Building Regulations introduced under the Building Control Act set out minimum performance standards. The Regulations are very short and contain no technical detail. That is found in a series of 12 approved Technical Guidance Documents (TGDs).

In general terms the Building Regulations apply to all construction apart from small domestic extensions, garages and outbuildings, temporary buildings and certain other categories of exempt buildings. Developers must obtain planning permission: obtain a fire safety certificate; lodge a commencement notice and comply with the Building Regulations. This study is confined to the conservation of fuel and energy, which is dealt with by Part L of the Regulations. For a fuller discussion on the detail of the Building Control Act see Keane (2003).

g stocks are contributing substantially to the residential ‘*The 1999 Green Paper on Sustainable Energy forecast that by 2010, 79% of the energy in the residential sector would come from pre 1981 housing stock* “Keffee (2011). This statistic clearly identifies the potential to make considerable savings if action is to be taken in order to minimise such energy consumption.

2.6 Part L of the Building Regulations

Part L (Conservation of Fuel and Energy) of the Building Regulations sets out the statutory minimum standards of energy efficiency and carbon dioxide emissions that apply to a newly constructed building, a new extension to an existing building or an existing building undergoing a material alteration or a material change of use. The current standards which are to be adhered to are the 2011 Building Regulations. Fig 2.1 presents verbatim, Part L the Conservation of Fuel and Energy requirements as per the 2011 Building Regulations.

"Part L

ERVATION OF FUEL AND ENERGY

L1 A building shall be designed and constructed so as to ensure that the energy performance of the building is such as to limit the amount of energy required for the operation of the building and the amount of carbon dioxide (CO_2) emissions associated with this energy use insofar as is reasonably practicable.

L2 For existing dwellings, the requirements of L1 shall be met by:—

(*a*) limiting heat loss and, where appropriate, maximising heat gain through the fabric of the building;

(*b*) controlling, as appropriate, the output of the space heating and hot water systems;

(*c*) limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air;

(*d*) providing that all oil and gas fired boilers installed as replacements in existing dwellings shall meet a minimum seasonal efficiency of 90% where practicable.

L3 For new dwellings, the requirements of L1 shall be met by:—

(*a*) providing that the energy performance of the dwelling is such as to limit the calculated primary energy consumption and related carbon dioxide (CO_2) emissions insofar as is reasonably practicable, when both energy consumption and carbon dioxide (CO_2) emissions are calculated using the Dwelling Energy Assessment Procedure (DEAP) published by Sustainable Energy Authority of Ireland;

(*b*) providing that, for new dwellings, a reasonable proportion of the energy consumption to meet the energy performance of a dwelling is provided by renewable energy sources;

(*c*) limiting heat loss and, where appropriate, availing of heat gain through the fabric of the building;

(*d*) providing and commissioning energy efficient space and water heating systems with efficient heat sources and effective controls;

(*e*) providing that all oil and gas fired boilers shall meet a minimum seasonal efficiency of 90%;

(*f*) providing to the dwelling owner sufficient information about the building, the fixed building services and their maintenance requirements so that the building can be operated in such a manner as to use no more fuel and energy than is reasonable."

Figure 2. 1 *2011 Building Regulation Part L Conservation of Fuel and Energy*

In relation to the study the most notable section of this document is L2 focusing on the existing building. In order to limit heat loss the building fabric is required to maximise heat

of the boiler efficiency is also considered to be of

2.6.1 Development of Part L of Building Regulations

Table 2.1 below sets out the main developmentôs of Part L since its inception in 1991.

Table 2.1 Development of Part L 1991-2011

Part L Conservation of Fuel and Energy was introduced in the original 1991 Building Regulations. This remained unchanged until the publication of the 2002 Building Regulations, when methods were identified to achieve energy conservation; these Regulations took effect on the 1st of January 2003. The most significant changes of Part L of the Building Regulations occurred as part of the 2005 Building Regulations. The requirement to calculate energy efficiency and in turn CO2 emissions was recognised, this amendment

In 2008 more in-depth calculation of energy efficiency uirement that all oil and gas fired boilers achieved an efficiency of 86%. The most recent amendment was made in 2011, a minor difference in relation to the efficiency of the oil and gas boiler was established, and the efficiency requirement is increased to 90%

2.6.2 Effects of development of Part L

Timeline		2005	2008	2011	2013-2016
Part L (Dwellings)[1]	% Improvement	Baseline	40% and renewables requirement	60%	Nearly Zero Energy Policy (Dwellings)
	Primary Energy[1] (Avg Dwelling) kWh/m2/annum	150	90	60	45
	CO2[1] (Avg Dwelling) kg/m2/annum	30	18	12	10
EPBD	BER (Avg Dwelling)	B3	B1	A3	A2

Table 2. 2 Effects of Development of Part L 2005-2016 Sourced Vaughan (2011)

Table 2.2 highlights the improvements Part L of the Building Regulations has had with respect to primary energy, and CO2 consumption. It also outlines the typical BER certification which corresponds with the development of the regulations. New dwellings are now required to achieve a rating of A3.

2.7 U-Value Construction

The nature of the construction determines the rate at which heat is transferred through it, certain materials referred to as conductors readily permit heat to pass through them while other materials called insulator inhibit heat transfer the rate at which heat passes through a material is referred to as its u value

Column 1 Fabric Elements	Maximum elemental U-value (W/m^2K)[1,2]	
	Column 2 Area-weighted Average Elemental U-Value (Um)	Column 3 Average Elemental U-value – individual element or section of element
Roofs		
Pitched roof		
- Insulation at ceiling	0.16	0.3
- Insulation on slope	0.16	
Flat roof	0.20	
Walls	0.21	0.6
Ground floors[3]	0.21	0.6
Other exposed floors	0.21	0.6
External doors, windows and rooflights	1.6[4]	3.0

Table 2. 3 2011 Building Regulation Department of the Environment (2011)

The construction of the building fabric is a key element in order to fully understand the measures needed to comply with Part L of the 2011 Building Regulations. To achieve the required U ï values of the building envelop is of the upmost importance. Table 2.3 outlines the maximum elemental U ï Value required for each element of the building under the 2011 Building Regulations. The resistance is the thickness multiplied by the conductivity of the material. In order to reduce heat loss the selection of good insulators is required. The figure used to refer to the Heat loss rate is the U ï Value, the unit of measurement is the watt per square metre Kelvin. The U-value is defined as the rate at which thermal energy is conducted through unit area, per Kelvin temperature difference between its two sides.

The lower the U Value the better the insulating structure. For example if a building element has a U-value of 1, 1 J of heat per second will go through each square metre for each degree Celsius difference in temperature between the two sides of the element

Values of each element is generated by identifying the element. The resistance of all layers are then combined in series to give the total resistance for the element. Once the total resistance is calculated the U- Value can be generated. Table 2.3 provide an example of the construction of the external wall U- Value. The Uï Value must comply with the requirements of the 2011 Building Regulations outlined in Table 2.4.

[redacted]

Table 2. 4 External Wall U-Value Construction

This provides an example of how the U ï Value is constructed. The other building elements U- Values are calculated using the same method. The 2011 Building Regulations have a relatively low U- Value as the Building Regulations have evolved and required an improved U- Value. The lower the U Value has led to improved energy efficiency

…rrent Building Regulation Compliance

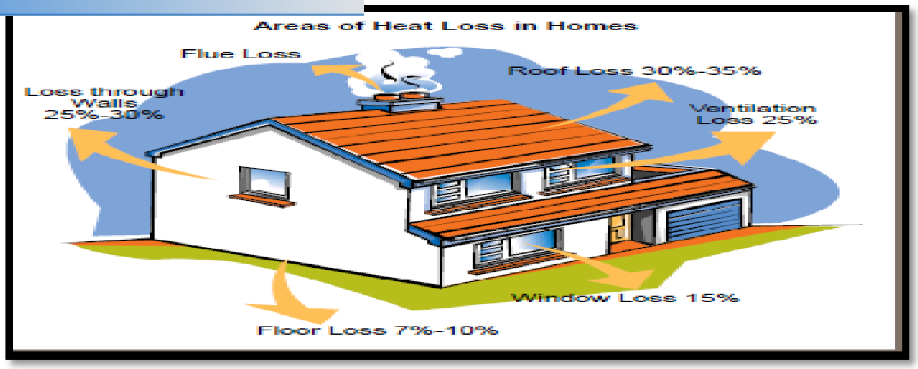

Figure 2.2 Domestic dwelling heat losses (Sources tea.ie (2011))

Although a building may be heated to a comfortable level it does not always mean that it is efficiently heated. In many buildings large quantities of heat are wasted, typically as a result of poor design and poor operating and maintenance practises. The building envelop is a key determinant in relation to the energy efficiency of the building. Figure 2.1 illustrates the typical heat loss from a domestic dwelling. This shows that most heat escapes through the walls and roof. They following are measures which may be taken in order to improve the energy efficiency of the building.

2.8.1 Wall Insulation

As shown in Figure 2.1, 33% of heat loss which occurs from a typical building is through the wall construction. The following are three methods available in order to reduce such heat loss.

2.8.1.1 Cavity Wall Insulation

Figure 2. 3 Cavity Wall Insulation (Sourced firesfireplacesstoves.co.uk (2011))

f brick or concrete block with a space between them see aterial from the outside is the most suitable method of insulating this type of wall. Cavity wall insulation in this manner has minimal disruption to the dwelling occupier. The operation consists of pumping insulation material into the cavity through a series of holes from the outside of the building until the cavity is full. A bonding agent allows the beads to flow freely until cavity is full. Once the adhesive sets the beads form a complete layer, increasing the U-Value of the wall. This reduces the heat transfer through the cavity wall by removing the air space. This prevents the air within the cavity from moving, preventing convection, and can substantially reduce space heating costs.

2.8.1.2 Internal Insulation

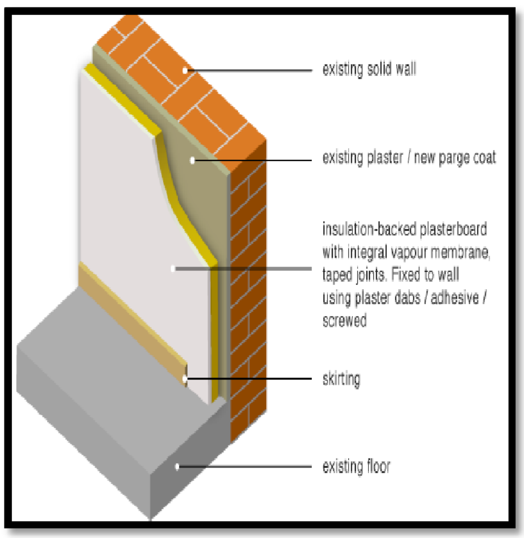

Figure 2. 4 Internal Wall Insulation (SourcedGreenspec.co.uk (2012))

Internal insulation or dry lining is one of the most popular forms of insulation for timber frame or stone wall houses. The process involves the use of foil backed slab plasterboard which is fixed to the internal wall of the building using plaster dabs or adhesive screws. This slab typically has a vapour barrier layer. The slab can then either be skim coated with plaster or taped and jointed. The primary disadvantage of this method is the loss of room space. This can be minimised by using high performance insulation material which are typically less than 50mm thick.

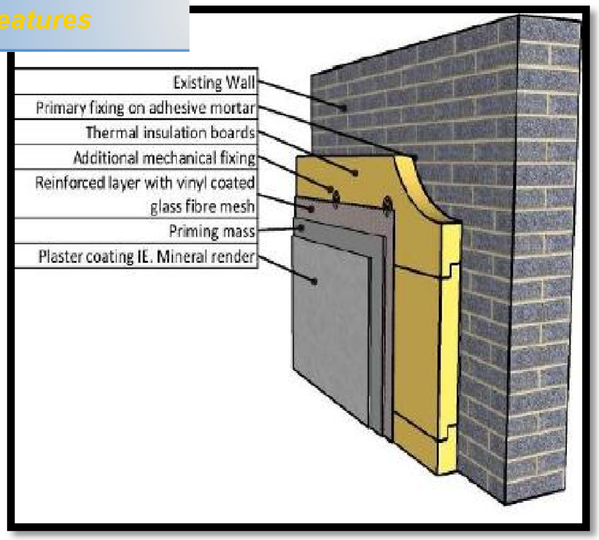

Figure 2. 5 External Wall Insulation (Sourced wallinsulation.ie (2012))

External Insulation is similar to that of internal insulation. It involves fixing insulation to the external surface of the wall. The thickness of the insulation can vary from between 50 - 120mm. Once mechanically fixed the insulation is covered with acrylic based render. In order to provide weather resistance a steel mesh is implanted in the render to increase its strength and impact resistance .In order to avoid thermal bridging a layer of insulation should be applied around the boundaries of window and door openings. The technology of external wall insulation is well established in northern Europe. Additional heat loss at the wall and floor can also be prevented by extending the insulation below ground level; however that may be disruptive as footpaths may need to be removed.

2.8.2 Roof Insulation

Figure 2. 6 Ceiling Insulation (Sourced smartenergyinstallation.ie (2011))

ırs through the roof of the building. This may be reduced ıncommon for consumers to go beyond the required regulations however this is not necessarily going to result in returns. Typically 300mm of fibre glass quilt insulation is sufficient to achieve the requirements. The type of roof installation used is typical dependant on whether the attic space is to be used as a living area. If not the insulation may be installed at ceiling level laying fibre quilt between the joists. If the attic space is to be utilised then insulation is placed between the rafters. Ceiling level insulation is the cheaper and simpler installation option. The U - value requirement under the 2011 Building Regulations on insulation for a pitched roof with insulation at ceiling level is 0.16/Watts per m2K.

2.8.3 Floor Insulation

The measures required to install floor insulation can prove to be difficult. Timber floor boards over time may loss their original shape, and if removed to install insulation, they may be difficult to replace. Floor improvements can potentially be expensive and disruptive so such measures would be recommended in large refurbishment projects. In order to improve thermal conform the sealing of cracks and sealing gaps in floor boards and skirting can also have a positive effect. If the insulation of the ground floor is carried out, high quality insulation material is recommended, in addition to a sealant in order to prevent draughts through cracks.

Figure 2. 7 Suspended Timber Floor Insulation (Sourced sheepwoolinsulation.ie (2011))

Figure 2.7 outlines a typical method of installing floor insulation within a suspended timber ground floor. The process involves placing the insulation between the existing timber joists.

ıthable member or netting. This allows for air circulation may be removed completely and an insulated concrete floor poured. However the first method outlined is very popular in existing buildings, where very little insulation has being installed initially.

2.8.4 Window & Doors

Windows and doors will always be a thermal weak point in a building, even when closed. As the windows and doors typically make up between 10-20% of the wall area as a proportion of window to total wall area, the heat loss through the windows and doors can be similar to that of the wall. The thermal loss coefficient of windows has been reduced by a factor of 8 during the last 30 years. In order to identify the differences in each window type, Dr. Wolfgang Feist, founder of the Passivhaus Institut, carried out an experiment in an attempt to highlight the temperature difference where an internal temperature of 21°C is required and the external temperature of -5°C is present. Table 2.4 outlines the results. Such findings clearly highlight the importance of high quality windows in order to achieve an energy efficient building.

[redacted]

Table 2.5 Window efficiency (Sourced Passivhaus Institut)

The U- Value outlined is the typical value given to each of the respective window type. The adjacent temperature outlines the temperature directly inside the window. A considerable difference is noticeable. The lower the U- Value the higher the adjacent temp within the inner surface of the window.

2.8.5 High Efficiency Oil Boiler

The impact of boiler efficiency can often be underestimated. The efficiency of a boiler will ultimately have the most direct impact on heating costs. As outlined in Table 2.1 above, the

equired where practical, required the installation of a SEAI the efficiency of an oil or gas boiler purchased new, over 15 years ago would typically be less than 80% efficiency. Due to wear and tear over time the efficiency is most likely to be no greater than 70%. In other words for every ú10.00 spent on oil/gas the consumer is receiving ú7.00 worth of heat, the remaining ú3.00 are going ñup the chimneyò. According to the SEAI current boilers have efficiencies greater than 90%. This results in an improvement in efficiency of up to 20%. Increasing the operational efficiency of the boiler by this amount can result in an actual fuel saving approximately 25%. In other words, by replacing an older, low efficiency boiler with a new, high efficiency boiler, the consumer may potentially reduce their fuel bills by a quarter. When considering the replacement of a boiler it is recommended that consideration be given to the highest efficiency boiler possible. The condensing boiler has a much higher efficiency that that of a non-condensing boiler.

Having examined the various options in relation to building upgrades, it should be noted that considerable improvement can be achieved. Capital investment is required, however, in order to carry out such upgrades. The adjustment of the building envelop in addition to the replacement of existing gas/ oil boilers in order to achieve the current building regulations, can result in considerable energy savings being achieved. The potential savings of compliance with the current Building Regulation will be outlined within Chapter Four.

The methods outlined above are typical measures which can be used in order to achieve the 2011 Building Regulations, however this study does not outline all methods of achieve this standard.

2.8.6 Draught Stripping

An issue which can often be overlooked in relation to building upgrades is that of draught stripping. Domestic buildings require fresh air; however ventilation in the form of a draught is not desirable. In order to avoid this draught stripping may be carried out. This is carried out typically around windows and doors. It is a simple and inexpensive way of improving the living environment and in turn reduces the heating bill. Other areas of the building which may be prone to draughts can include suspended wooden floors and gaps around pipes which

tion is often a simple DIY procedure. Sealing products pending on quality and type of product. The two main procedures in draught sealing include the use of seal adhesive foam while is pumped around openings i.e. around pipes exiting through external walls etc. This is a relatively in expensive procedure. The other method used is that of the rubber mouldings, which are fixed around the edges of windows and doors in order to prevent draughts entering the building. This method can be more expensive that the first but will normally be a more durable product. It is believed that the expense of draught sealing will be recouped in a matter of months as a result of the reduction in the heating cost.

2.9 Grants

An important influence affecting the extent of building upgrades nationally scale would be financial and physical resources available to do the works. In order to increase the uptake of such works, the government have incentivised the cost of installing building upgrade measures. The Better Energy Scheme provides assistance to homeowner to reduce energy use, costs and greenhouse gas emissions and in turn improve the comfort levels within the building. The intention of the scheme is multipurpose:

- Encourage market innovation
- Build market ability and proficiency by improving contractor quality and standards
- Reduce energy use costs and greenhouse gas emissions
- Improve consumers awareness in relation to energy performance of their home

The incentives are in the form of a grant system providing financial assistance in order to improve energy efficiency of the building. The grants amount is typically a fixed sum irrespective of home size unless the total expenditure is below the set value of the grant, if so the actual expenditure will be repaid. Table 2.5 outlines the typical cash grants which are available to the consumer, through The Better Energy Scheme.

	Grant Value
	ú200
Wall Insulation - Cavity	
Wall Insulation - Cavity	ú250
Wall Insulation - Internal Dry Lining	
Apartment (any) OR Mid- terrace House	ú900
Semi-detached or End of Terrace	ú1,350
Detached House	ú1,800
Wall Insulation - External	
Apartment (any) OR Mid- terrace House	ú1,800
Semi-detached or End of Terrace	ú2,700
Detached House	ú3,600
Heating	
Heating Controls with Boiler (Oil or Gas) Upgrade.	ú560
Heating Controls Upgrade only	ú400
Solar Heating	ú800

Table 2.6 Better Energy Grant Incentives Sourced SEAI (2010)

2.10 Retrofit Studies

The area of retrofitting of buildings has expanded considerably over the past 2-5 years. A number of studies have been carried out in an attempt to assess the effectiveness of the retrofit process. Figure 2.5 gives an overview of the split of the economical potential efficiency savings between the residential, commercial and industrial sectors. As can seen the residential potential greatly exceeds that of the both the industrial and commercial potential, however Murray (2011) provides the following reasoning. *The commercial sector could be seen to be a more difficult sector to achieve results given the grants schemes available to the residential sector and also the relative simple design of residential buildings in comparison to multi story, commercial/non-residential buildings*

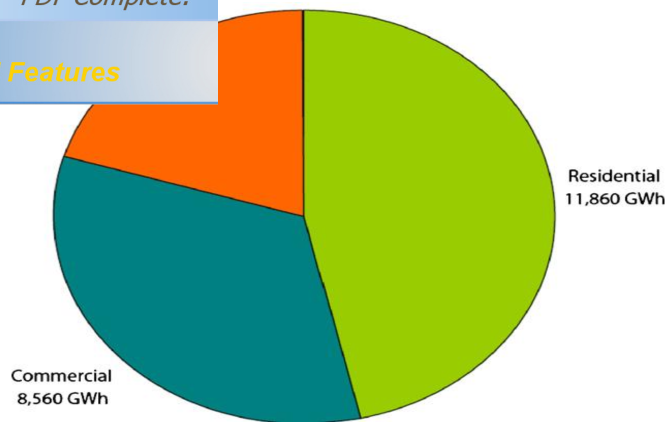

Figure 2. 8 Economic efficiency savings potential by sector (GW h) SEI (2008)

Healy (2003) Table 2.7 which identifies the percentage of households with various energy efficiency measures in northern Europe sourced by Eurostat (1999)

	A	B	DK	FIN	F	D	IRL	NL	NOR	S	UK	Mean
Cavity-wall insulation	26	42	65	100	68	24	42	47	85	100	25	57
Double-glazing	53	62	91	100	52	88	33	78	98	100	61	74
Floor insulation	11	12	63	100	24	15	22	27	88	100	4	42
Roof insulation	37	43	76	100	71	42	72	53	77	100	90	69

Table 2. 7 North Europe Domestic % Energy Efficiency Measures Eurostat (1999)

This is a particularly interesting statistic; highlighting that Ireland is below the mean in all measures of energy efficiency except for roof insulation.

2.11 Life Cycle Analysis

The BS ISO 15686 standard identifies LCC as a process which ñ*allows consistent comparisons to be performed between alternatives with different cash flows and different time frames. The analysis takes into account relevant factors from acquisition, through operation and maintenance, renewal and adaptation, disposal and decommissioning*ò BS-ISO15686 (2011)

Life cycle costing in construction considers the cost of maintaining and operating the building for a set period. Traditionally the main objective was to construct a building as

ible.

An individual who is constructing a building should take into consideration the long term outlook, in an attempt to yield greater savings in the future. In addition to identifying the energy savings achieved as a result of upgrading this study will also investigate the financial savings which may result from the building upgrade, while also identifying the potential payback period.

The payback period refers to the length of time required for the return on an investment to repay the amount of the original investment. This method of analysis should be used with a degree of caution, and should not be used in isolation. There are a number of variables which the ópayback periodô method does not account for, such as, time value of money, risk and financing. Within this study the payback period will be acknowledged, while also a net present value will also be established. The net present value compares the value of a specific amount of money today to the value of the same amount of money in the future, taking into consideration issues such as inflation and discounts.

ñLCC analysis may be applied to a complete asset or to a specific assembly, component or system such as plant, road surface or a roofing assembly.ò (BSI, 2008)

As the BSI identifies a LCC analysis does not have to apply to the building as a whole, but can also be applied to components. This will be carried out within this study, with the component being the building fabric.

Life cycle costing can also play a key role in relation to sustainability in construction Kehily (2010) identifies that *design decisions related to the building's energy efficiency such as orientation thermal efficiency and air tightness can influence the building costs in the use and LCC can be used to evaluate whether additional sustainable attributes and energy efficiency measures are cost effective over a given study period.* Kehily also states *that LCC can also be used to determine the maintenance and replacement cost of a component or system over a study period. The information can inform design decisions on issues such as cleaning maintenance energy efficiency durability and disposal.* This would further substantiate the LCC costing exercise which is to be carried out within the desk study.

This chapter examined the literature with dealing study topic. As the research area expanded it became apparent that the subject was very broad. This has to be limited to a level that could give the required information. The development of Part L of the Building Regulations began in 1991, having said this, not until as recently as 2002 has there appeared to be somewhat meaningful implementation, as requirements were put in place in order to comply with Part L. Following on from the 2002 regulation considerable progress has been made, with further requirements having been outlined in 2008. The adjustment to 2011 revision would appear to be somewhat muted in comparison to previous years, with the most notable being an improvement requirement of gas and boiler efficiency. It is somewhat unfortunate that the most progressive revisions appear to have been made post the 2007 building boom in Ireland resulting in a large amount of the housing stock constructed not requiring to meet the updated revisions. A noteworthy observation resulting from the literature review is ñthat *79% of the energy in the residential sector would come from pre 1981 housing stock"* Keffee (2011).

The importance of residential energy efficiency on both a European and Irish scale has also been addressed. It is quite evident that on a national scale the effects residential energy usage is notable. On a micro scale the consumer implications due to energy inefficiency buildings has also been addressed. The issue of fuel poverty is of a growing concern within the country. In addition the inflationary pressure on energy prices. A key contributor would appear to be the link between ñfuel povertyò and inadequate building stock, further substantiating the need to improve residential energy efficiency in Ireland. The means required to comply with the 2011 Technical Guidance Document have also been outlined.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter sets out the methodological approach used in undertaking this research. The Oxford English Dictionary defines research as ña systematic investigation to discover facts or collect informationò. This definition broadly consists of, the gathering of information and data which facilities the advancement of knowledge ñ*Methodology is the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcome"* Crotty (1998). Research Methodology will not only aid the writer in identifying and describing the various activities, but should also help the proposal reader to understand the continuity of the various activities Wiersma (2009).

A research design should be consistent and effective in achieving the objectives, while also being sufficiently robust to allow confident generalisations. This chapter discusses the tools and techniques employed in the research and also explains why they were chosen. The research design primarily employs a quantitative approach using a desk study to address the following research objectives listed in chapter one.

- To develop a building model to test the effect of a design intervention which alters, the modelôs design from pre 1991 to 2011 standards in terms of compliance with Part L of the Building Regulations.
- To measure the change in energy consumption resulting from such an intervention
- To estimate whether such interventions are economically beneficial

This chapter focuses in turn on the research strategy, methods of data collection, the limitations of the research methods, ethical consideration and finally concluding remarks

3.2 Research Strategy

There are three main research approaches:

*"Quantitative research is objective in nature. It is defined as an inquiry into a social or human problem based on testing a hypothesis or a theory composed of variables, measured with numbers and analysed with statistical procedures, in order to determine whether the hypothesis or the theory hold true".*Creswell (2008) The data collected is not abstract in nature. It employs logic to guarantee the correctness of a conclusion.

Typically the key to the quantitative method is the input of the numbers into a system, resulting in the configuration. Quantitative methods are concerned with the use of numbers and the main advantages are as follows:

- There are well recognized numerical measures for analyzing the data i.e. mean, frequency, Correlation etc.
- Quantitative methods facilitate contrast and examination such as sensitivity analysis.
- Quantitative are suitable to hypothesized questions based on relationships as these can be measured.
- The use of numbers is often considered a more complete unit of measurement, as the study can be assessed for errors and omissions.

The selection of the quantitative approach is determined according to the following circumstances,

- *To find facts about a concept, a question or an attribute*
- *To collect factual evidence and study the relationship between these facts in order to test a particular theory or hypothesis.*Naoum (2007)

3.2.2 Qualitative Research

"Qualitative research relies on the views of the participants and asks broad general questions, collects data largely consisting of words from participants, describes and analyses these words for themes and conducts the inquiry in a subjective manner" Creswell (2008).It involves the development and manipulations of concepts. Qualitative analysis describes methods and findings using ordinary words. Qualitative methods permit a more flexible approach, allowing for an in depth investigation of the topic by presenting particular viewpoints related to the topic. The main advantages of qualitative approaches are:

questions that are not open to strict quantification: , personal and considered response to be obtained from the participants

- The information is clearer and more readable as the concepts and findings are articulated in words and so allowing more scope to elaborate on the topic

Naoum (2007) suggest that qualitative information gathered is classified under two categories, that of exploratory and attitudinal.

Exploratory: This method is utilised when the author has a limited amount of knowledge of the topic. According to Zikmund (1997), this method is used ñ*in diagnosing a situation, screening alternatives and to discover new ideas".*

Attitudinal: Attitudinal research is typically used in a subjective manner in order ñ*to evaluate an opinion or perception of a person towards a particular object"*. Naoum (2007)

3.2.3 Mixed Method Research

A third approach combines the quantitative and qualitative methods and is referred to as mixed methods research. Creswell describes this approach as pragmatic in that it seeks to use the methods which work best to address the research question. It combines the strengths of both approaches by combining quantitative methods which facilitate comparison and analysis along with qualitative methods which seek to provide insights into the topic being investigated. The mixed method or multi methodology approach may provide a more rounded research outcome and in turn improve the credibility of the study. This process is referred to as triangulation.

3.3 Justification of Research Methods

Having identified the primary research approaches available, the author believes that the use of methodological triangulation would be suitable to achieve the most valid and credible results. The reasoning for this is twofold, firstly to provide a more rounded research outcome and in turn improve the credibility of the study and secondly to attempt to ensure the application of the study is in line with the applied nature of the DT 164 program. Both

de vital data. It is of the utmost importance that the ficient in achieving the objectives, while also being adequately robust to allow secure generalisations. It for this reason methodological triangulation is being utilised.

This study compares and analyses the effect of Part L of the Building Regulations on the energy consumption of a model building. It is therefore appropriate to use a quantitative method to address the research question. Qualitative methods are also utilised to address the final objectives set out in chapter one which speculates about the potential benefits should such interventions be adopted on a widespread basis. The study employs a mixed method research strategy which is primarily quantitative in nature.

With respect to the quantitative research approach selected, a desk study will be implemented in order to quantify the theoretical energy savings resulting from the revisions in Part L of the Building Regulations for residential buildings. The desk study will be carried out on a sample bungalow. The qualitative research approach will encompass the explanatory method, through an interview with a local authority.

3.4 Data Collection

Once the research approach has been defined, the next process is to identify the method of data collection. There are a number of different data collection methods available. Typically there are two main sources of data:

"Primary data is collected by the researcher specifically to address the research problem" Malhotra (2006). Primary insinuates first, this is indeed the case, primary data is collected at the source. Hussey (1997) suggest that primary data may include data that is gathered from an uncontrolled environment, by asking questions or making observations. In addition to this Hussey also identifies the conducting of experiments as a primary method of data collection.

Saunders (2007) identifies secondary data as information that was previously gathered for another purpose other than the problem at hand. There are many mediums in which secondary data exists such as books, archives reports articles in journals, electronic data bases

ewspapers.

Due to the multi research method selected, two methods of field work research were carried out. The author believes that the most appropriate methods of primary data collection are that of the case study and the interview.

3.5 Desk Study

A desk study is typically an investigation of relevant available facts and figures. Desk studies are used when the researcher intends to support his/ her argument by an in-depth analysis of a particular project thorough desk research. The method of desk study selected for this study was an analytical desk study, this is similar to that of an analytical survey considering association, counting and relationship, this desk study is however being applied on a detailed case.

The desk study involves designing a building model based on a typical 1970ös specification, measuring its energy performance, updating the design to comply with the current energy performance requirements Building Regulations Part L and measuring the revised energy performance. A life cycle analysis is then carried out to establish whether the various improvements offer value for money.

This may be seen as a form of experiment: FellowsandLiu (2008) would refer to it as a quasi experiment. According to FellowsandLiu (2008) an experiment is ñ*an activity or process, a combination of activities, which produces events possible outcomes*ò. Experimental designs examine the relationship of variables, i.e. the activities carried out and the resultant outcomes. Researchers manipulate the variables in order to observe the effects. They provide an example: monetary rewards and the effect on performance. In this research the variables are the u values of a form of construction (the independent variable) and the quantity of energy transfer (the dependant variable). They add that ideally only one variable should be studied, but note that it may not be practical to isolate individual variables in complex construction project based óexperimentsô. In these situations, the other variables for example location weather etc. óare held approximately constant... ó*Such approaches are called quasi – experiments'*.

ıt at undergraduate level. This study takes a somewhat employs a building information modelling approach to generate the data upon which the cost estimates and energy savings will be based

3.5.1 Why Building Simulation?

"Simulation is commonly held to be the best practice approach to performance analysis in the building industry" Clarke (2001). ñ*Energy simulation of the built environment involves analysis of the actual or predicted energy performance of buildings. It can also involve an analysis of the embodied energy within building materials and of methods used to construct buildings"* InTUBE (2009). ñ*Energy simulation involves comparisons between actual and predicted use of building energy. Comparisons are made against benchmark parameter values used to indicate regulatory requirements, average energy consumption or best practice"*. Cong (2009)

"Energy simulation tools predict the energy performance of a given building and the thermal comfort for its occupants. Such tools support the understanding of how a given building should perform under certain criteria and provide a means to compare different building design alternatives. All competing energy simulation tools have limitations, thus it is necessary to understand the basic principles of energy simulation" Maile (2007). Such limitations may include interoperability with existing packages and computer programs.

Simulating a buildingôs energy usage is a difficult task, requiring not only a model of the buildingôs geometry, its components (such as insulation, windows, foundation, walls and HVAC systems), but also detailed and accurate environmental data. Environmental data includes weather conditions within the proximity of the relevant building, humidity, wind speed and external temperatures over various time periods. In addition, data supporting the buildingôs internal electricity load (lighting devices, electronic equipment, and occupant electricity demands), heating and cooling loads are also required Cong (2009) The accuracy of the simulation is influenced by the number of available input parameters.

The key influence regarding building simulations is that of the available input parameters. IES software provides a wide variety of key parameters with respect to the study in question,

results and in turn accurate analysis. Table 3.1 ...ired approach in order to achieve accurate simulation according to Rafterya (2011)

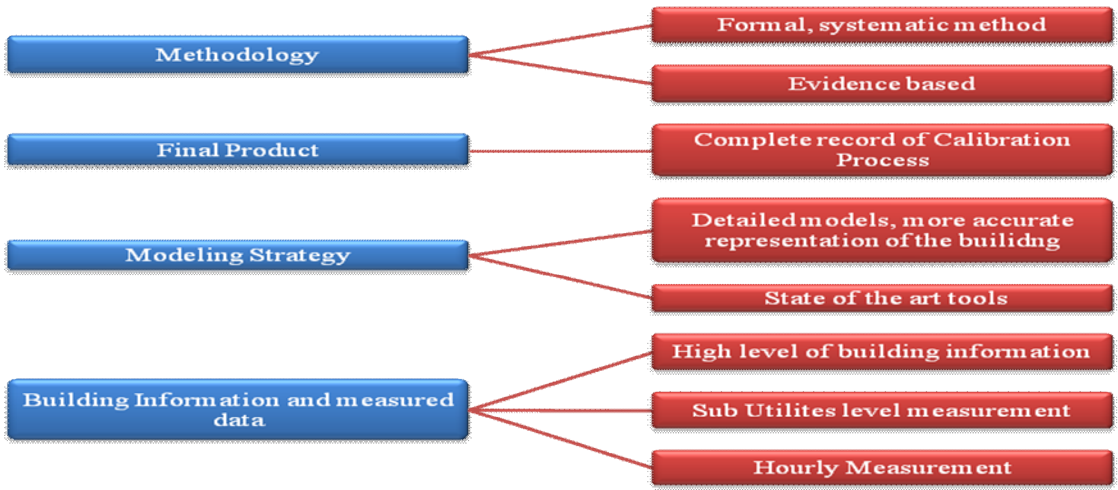

Table 3. 1 Calibrated Simulation cited Rafterya (2011)

Table 3.1 illustrates the requirements of an energy simulation in order to achieve accurate readings. For example the methodology needs to be formal and evidence based. The modelling strategy requires a detailed representation of the building, using state of the art tools. The building information and measured data requires high levels of accuracy. The simulation within this study achieves all of these requirements. The methodology is evidence based, with the use of Building Regulations. The modelling strategy uses state of the art tools, as the latest modelling software is utilised. The energy analysis within the IES software was carried out in hourly increments.

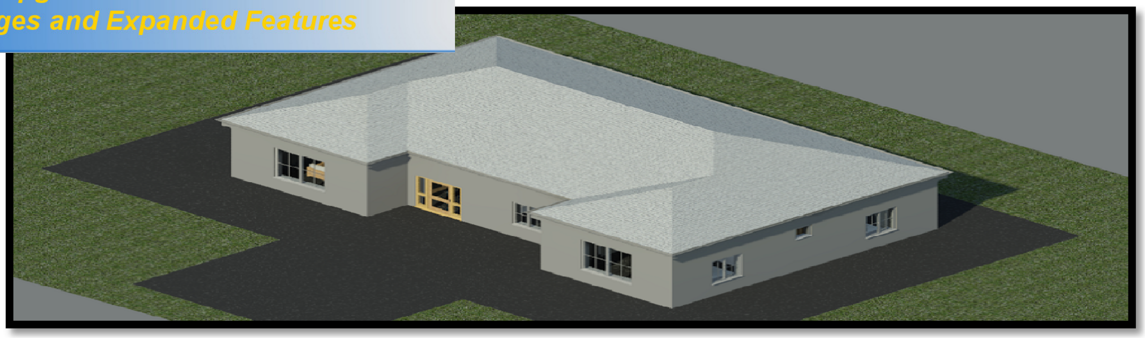

Figure 3. 1 Desk Study Bungalow

The desk study is based on a computer generated residential building model which has been developed using Revit Architecture software, which is a type of Building Information Modelling software (BIM). BIM is a Computer Aided Design (CAD) approach that employs intelligent 3D objects to represent real physical building components such as wall, doors and windows. This program allows the designer to use both 3D and 2D drafting elements. The Revit Software includes specialised tools which enable the user to produce high quality and accurate model based architectural design.

The building design shown in Fig 3.1 and 3.2 has been developed using the Autodesk Revit suite of software. The bungalow design may be considered to be representative in terms of size and layout to many such buildings constructed during the 1970s. It consists of 3 bedrooms (one ensuite), kitchen, living room, toilet, study and utility room, with a total internal gross floor area of 160m2.

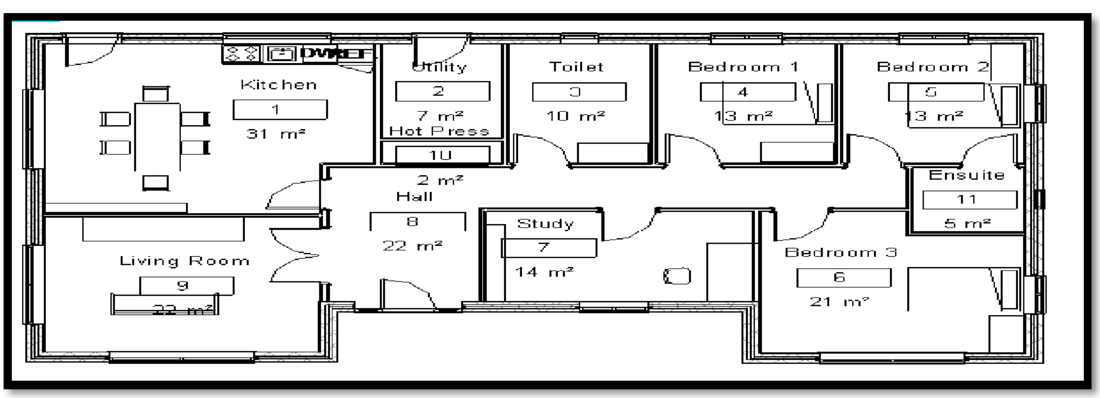

Figure 3. 2 Ground Floor Plan

The bungalow model is imported into software called IES (Integrated Environmental Solution) Virtual Environment. The program consists of is an suite of applications linked by a Common User Interface (CUI) and a single Integrated Data Model (IDM). All applications have a similar ñlook and feelò and that data entered for one applications can be used by the other. This software provides a virtual environment where the energy consumption of the building can be calculated. IES provided the author with conservation of energy compliance software for all regions of the Republic of Ireland. The VE 6.4 version was selected as it takes into consideration a considerable range of variables which enable a more accurate analysis to be carried out. For example the software will take into account the location of the building and in doing so take account of the weather data most applicable to the building location. The thermal analysis programme in the Virtual Environment is called ñApacheò. The programme has facilities for:

- Preparation of entering data for the thermal analysis programs
- Provision of calculations and simulations

The preparation of thermal input data consists of three main tasks:

- Specification of building location and weather data
- Specification of building element data (properties of the building fabric)
- Specification of room data (conditions in each room)

The optional facilities outlined are all set as constant with respect to this desk study, excluding that of the building fabric of the building.

3.5.3.1 Building Location Site and weather data

Weather conditions are extremely important for energy simulation models. The weather data typically provided would include: state/province/region/country, latitude, longitude, time zone, elevation, peak hot and cold temperatures. In addition, daylight savings, average and extreme temperature periods are also included as input data. ñ*The collected weather data are not used to reflect weather conditions for a specific year, but to provide statistical references for typical weather parameters for a specific location*”. Cong (2009)

cation editor for the IES Virtual Environment program. cking the APlocate icon. There is a default site and weather location within the program which caters for generic or typical building scenarios. This desk study is located at Dublin airport which is one of the preset options. Fig 3.3 illustrates the interface provided, highlighting the different variable available. When selecting the location the latitude, longitude and altitude is provided. The terrain is also optional, providing for improved accuracy. This data entered affects the natural ventilation air exchange rates and therefore provides more accurate findings.

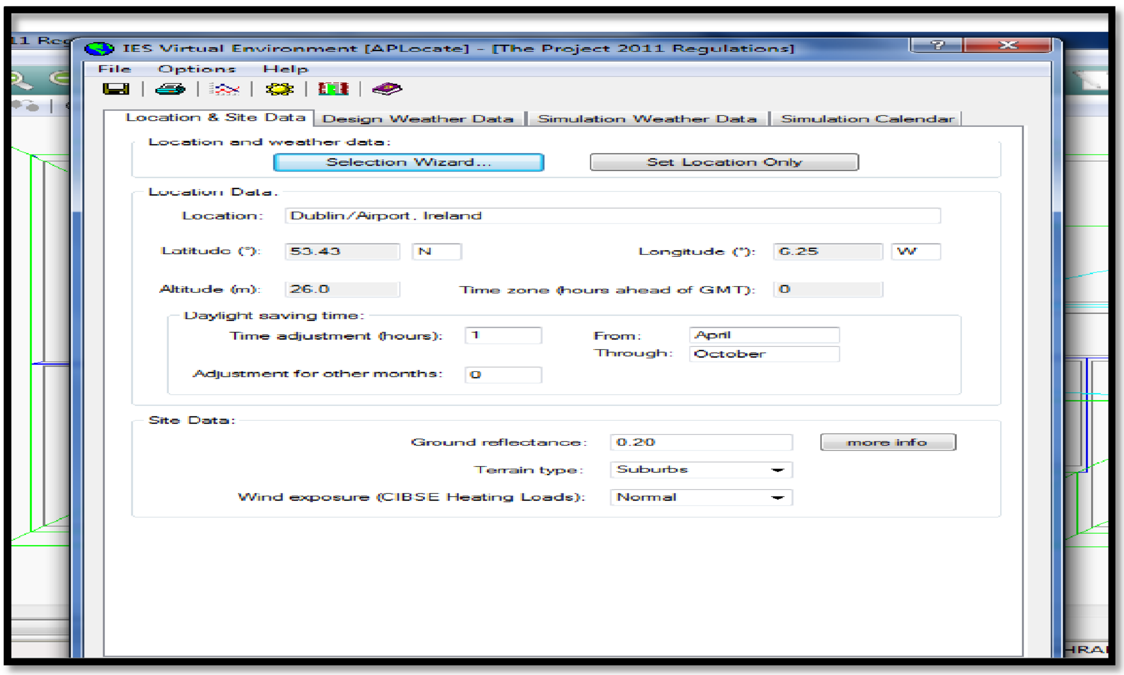

Figure 3. 3 IES Virtual Environment APLocate Application

3.5.3.2 Building Fabric Data

Having selected the location of the building the next process is to create and assign construction profiles for the thermal envelope of the building. This process is of considerable importance. The model is converted into a gbxml file (a format change when transposed from the Revit program to IES) and transposed to the IES Virtual Environment program. When the element is created within the program, its construction type is set by the active Apache Constructions Template. It consists of a layer-by-layer description of the elementǿs thermo

er data such as surface solar absorptivity and emissivity.

The default settings within the programme did not however meet the requirements of Part L of the 2011 Irish Building Regulations. The specification of building elements is then adjusted in order to achieve the required U- Value of the relevant elements in accordance with the Building Regulations.

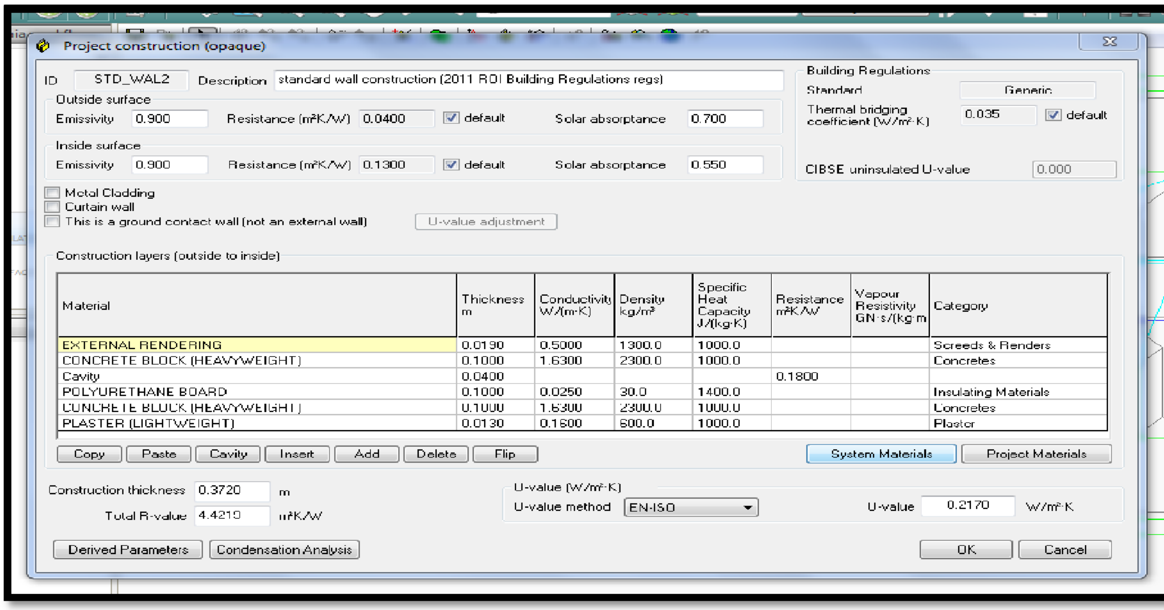

Figure 3. 4 IES Virtual Environment Project Construction

The Apache construction database manager icon is utilised. The project materials tab allows the user to select from a database of materials in order to create the various forms of building construction. This facility allows the user to input the specifications of the building fabric which then calculates the u-value of the particular form of construction. For example fig 3.4 shows the makeup of a composite 372mm thick external wall comprising 19mm thick external render, two skins of 100mm thick solid concrete block work, a 140mm cavity comprising of 40mm clear air space and 100mm polyurethane board, the wall finished with 13mm plaster internally. The u ï value for this wall has been calculated as 0.2178W/m2K. It is possible to adjust the thickness, conductivity, density, specific heat capacity and resistance in order to achieve the required structure and in turn U-Value. The required u value for external wall in the example Fig3.4 would have to be improved by varying the composition of the building construction. The program also takes into consideration thermal bridging and

The process is repeated on the other elements of the ɔ a building profile which is typical of a pre 1970s form of construction.

3.5.3.3 Specification of room data

Within the program each room has a set of attributes that describe conditions in the room. This data known as room data is inputted into the thermal analysis programs. The room data is categorised under five headings. The Virtual Environment programme is typically utilised in projects of a larger scale than that of a domestic building, however as the program has the capabilities to designate room attributes, an accurate analysis can be anticipated. Such information is categorised under a number of templates, these templates are a constant within the study unless otherwise stated:

- Room Attributes: This provides information data relating to the lettable area of the room. The percentage of space is identified as circulation or lettable floor area respectively.
- Constructions: This template provides information with respect to the thermo physical properties of building elements. The building template manager provides for the option of changing the construction of a specified room
- MacroFlo Opening Types: This section is where the window and door opening types are assigned to templates. The opening types available are:
    - Roof light
    - External Glazing
    - Internal Glazing
    - Door
    - Thermal Conditions: Where room thermal conditions are assigned to templates.

Room Conditions: this allows for the control of heating and cooling of rooms within the building model. The program has the capability of creating a heating profile for a building. The profiles within the Virtual Environment software are compiled from daily heating pattern determined by the user. Each of which are used to create time variation patterns over longer periods. Following on from the daily profile, weekly profiles cover a period of one week, and are built up from seven daily profiles. When the weekly pattern is used an assumption is

roughout the year. Fig 3.5 illustrates the interface of the n of the heating and cooling set point is also carried out within thermal conditions tab. Consideration is also given to domestic hot water requirements. As the building in question is naturally cooled, using natural ventilations, a cooling profile is not required.

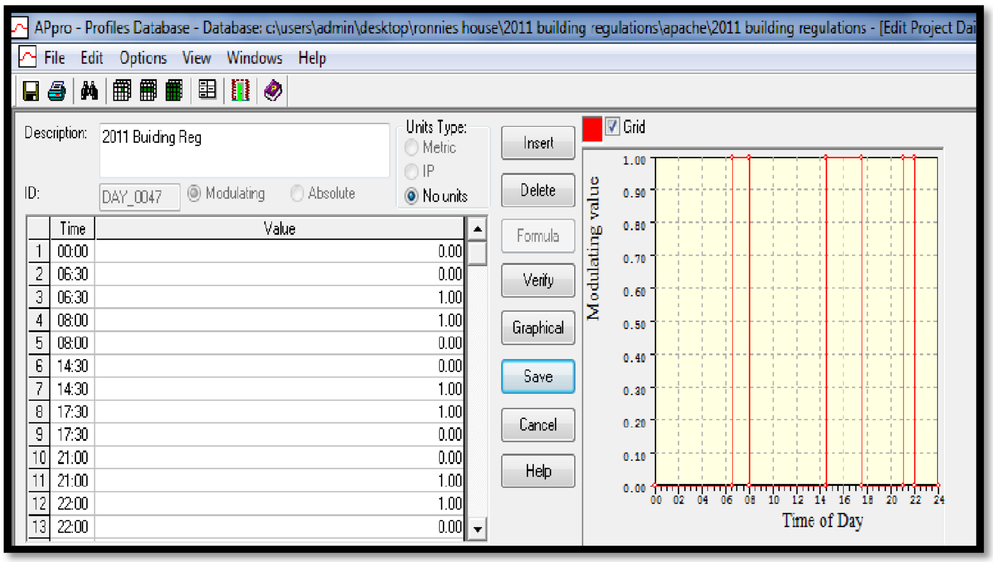

Figure 3. 5 IES Daily Heating Profile

This is where the system that controls the room and supply air condition is selected. This choice dictates the efficiency and primary energy use of the system chosen for heating, cooling, air supply, extraction and any auxiliary mechanical ventilation.

Internal Gains: Consideration is also given to internal gains, examples of which include occupancy, lighting and miscellaneous items.

Air Exchanges: Consideration of air exchanges are accounted for the required number of air changes is inputted here.

3.5.3.4 Modifying the design for compliance with Part L of the 2011 Regulations

Once the assessment of the baseline model has been completed the model is then adjusted to meet the current requirements of Part L of the Building Regulations. Such adjustments will involve adjustment to the building fabric data. These are set out in Chapter Four.

f modification

In keeping with the ethos of the DT 164 program the upgrade options detailed in Chapter Two literature reviews, along with their corresponding costs will be assessed, establishing the energy savings that may be made. Having completed this, a life cycle analysis will be carried out to establish potential financial savings.

3.6 Semi Structured Interview

Qualitative research involves the development and manipulations of concepts. In order to gain an understanding of the implementation of the findings from the desk study, a semi structured interview is carried out. The aim of the interview was to provide in depth qualitative information to substantiate the study by outlining the understanding & willingness of government bodies to upgrade their current housing stock.

The interview process involves three separate stages: preparation, collection and analysis. The preparation stage involves selecting and reviewing the research topic to formulate questions to guide the interview and informing the participant about the nature and purpose of the research and the degree of their involvement the process. The data was gathered by organising, conducting and transcribing the interview. Finally the data was analysed by drawing out the key statements and themes of the interview.

The semi structured interview was carried out with Ms. Sara Clifford a member of Dun Laoghaire/ Rathdown Country Council. The aim of the interview was to provide expert opinion regarding the findings of the desk study and to gauge the attitude of the local authorities towards the importance of energy efficiency, and to investigate their current activities and expenditure in upgrading their current housing stock and their future plans in this regard. The interview also sought to explore their attitudes as to whether the retrofitting measures represent value for money. The findings are set out in chapter four.

The interview centred on the following topics:

- Establish to what level is retrofitting of existing building stock being implemented
- Explore attitude of importance of retrofitting of existing building stock

nvestment available within the department

orecast of potential payback would influence the scale implementation

Interview participants are viewed as meaning makers not passive conduits for retrieving information from an existing vessel of answer. The purpose of this and most other qualitative interviews is to ñ*obtain expert opinion, facts or laws from respondents"* Holstein (2001), to be used within the main body of the study as primary information.

3.7 Research Methods Limitations

The primary constraint within the study is the limited time available. It was considered somewhat unfeasible to expand the study beyond residential construction. This may form the basis for a more expanded further study, perhaps including a broader spectrum of buildings for example commercial buildings. In particular the number of interviews has had to be curtailed. Gillham (2000) notes that interviews are time consuming to administer and that a one hour interview may generate up to fifty hours work in developing, piloting, setting up travelling to and from transcribing and analysing the interview.

The scope of the study means that the findings cannot be fully reprehensive. It does however provide an indication of the savings which may be obtained by various interventions. In order to fully establish the local authorityôs attitudes towards upgrading their current housing stock a national survey would be required.

3.8 Research Validity and Reliability

As there was a number of method used to gather data for the research, threats to the validity and reliability of the study were minimised. Different data collection methods were used which leads to more reliable and valid data. The validity of any research methodology relates to the accuracy, meaningfulness and credibility of the research project as a whole Leedy (2010) .

While carrying out this project there were ethical issues identified by the researcher which needed to be addressed. Quantitative methods of data collection involved in this study consisted of requiring energy bills from householders to quantify operating energy usage in their homes. Also qualitative methods of data collection involved in this study consisted of the attainment of information that may be considered delicate, for example issues such as capital investment of the authority question. Permission was sought from clients to use data which was retrieved from their homes for the purpose of this research. The participants were informed before research began that all information is treated confidentially and in line with ethics policies of the Dublin Institute of Technology. This included personal information such as names and addresses that will not be disclosed.

3.10 Summary

In any research an approach method has to be applied. This helps guide the researcher to achieve the task at hand. Whilst understanding the Methodological Triangulation of research techniques, a method of gathering the information has been established. This forms the basis of the research through the desk study and interview process along with secondary sources. The research methodology also identified limitations within the study, outlines the research validity and reliability while also considering the ethical issues which are required to be dealt with when carrying out a study.

APTER 4: FINDINGS

4.1 Introduction

This chapter outlines the findings from the desk study and interview carried out. The findings of the desk will be identified first, followed by the findings of the interview. This will be followed by concluding remarks.

4.2 Desk Study Findings

The desk study entailed the following:

- To develop a building model to test the effect of a design intervention which alters, the modelôs design from pre 1991 to 2011 standards in terms of compliance with Part L of the Building Regulations.
- To measure the change in energy consumption resulting from such an intervention
- To estimate whether such interventions are economically beneficial

Refer to chapter 3 Methodology for desk study format and development of building model.

4.3 Findings Overview

To investigate the performance of each design intervention the 1970 building was first analysed to establish the energy consumption. The building model was then adjusted to comply with the 2011 Building Regulations requirements. The variables in the study are the building envelope U-Values. The constants within the simulation are outlined in tables 4.1, 4.2. A systematic analysis is then carried out. The design of the 1970 building is altered, implementing each design intervention to establish the change in energy consumption.

ng Simulation Constants	
	Dublin/Airport, Ireland
	Bungalow
Area of House	160m2.
Room No.	9
Occupancy	5
Heating Fuel	Oil
Heating System	Central Heating Radiators
Cooling System	Natural Ventilation
No. of External doors & windows	3 doors, 11 windows
Simulation Date	1st of Sept - 30th of May 2011
Heating Set Point	Kitchen and living room 21°C All other rooms 18°C
Hot Water Consumption	0.270 l/(h/person)
Hot Water Storage	114 liters
Internal Gains	5 People -90 W per person
	Single Family Misc -4.31 W/m2
	Florescent Light- 10.76W/m2
Carbon Emissions Data	Oil- 0.2650kg/CO2/kWH

Table 4. 1 Building Simulation Constants

[redacted]

Table 4. 2 Daily Heating Profile

The constants in table 4.1 consist of circumstances which are particular to the building. These are entered into the IES software. Table 4.2 outlines the makeup of the heating profile for the building. This is a key factor in order to establish the energy consumption of the building; similarly the heat profile is common to all simulations carried out. The energy usage and cost are based on standard usage. The standard usage format assumes that the building is heating to 21°C with in the living areas, an assumption is made that in the building the living areas are the kitchen and living room, and all other areas are heated to 18°C. The building is heated for between 8-9.5hrs a day, as is standard practice when simulating energy usage.

The following tables outline the building fabric make up of the baseline building model; this includes the U- Values which correspond to the building fabric. All relevant information was then inputted into the simulation software.

1970 Building: Building Fabric			
Element	**External Wall (Typical % Heat Loss 25-33)**		
Material	**Thickness m**	**Conductivity w/Mk**	**Resistance (m2K/W)**
External Surface	-	-	0.04
External Render	0.02	0.50	0.04
Hollow Concrete Block	0.22	0.84	0.26
Plaster	0.01	0.43	0.03
Internal Surface	-	-	0.13
Total Resistance			0.49
U-Value of Construction			**2.03**

Table 4. 3 External Wall Construction U- Value

Table 4.3 illustrates the U value of a typical 1970 external wall. A U- Value of 2.03Wm2/k is achieved with very little resistance being provided by the respective materials. It is also important to note that a surface resistance is provided be the external and internal surface of the element, the external resistance being less than that of the internal, this is also considered when calculating the U Value and is considered in all U ï Value calculations.

Element	**External Door (Typical % Heat Loss 15)**		
Material	**Thickness m**	**Conductivity w/Mk**	**Resistance (m2K/W)**
External Surface	-	-	0.04
Wood (Pine)	0.04	0.14	0.29
Internal Surface	-	-	0.13
Total Resistance			0.46
U-Value of Construction			**2.19**

Table 4. 4 External Door U- Value

[illegible]	Ground Floor (Typical % Heat Loss 7-10)		
[illegible]	[illegible]ss m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
Soil	0.95	1.29	0.74
Air Cavity	0.20	0.00	0.18
Timber Flooring	0.03	0.14	0.18
Carpet	0.01	0.06	0.17
Internal Surface	-	-	0.17
Total Resistance			1.47
U-Value of Construction			**0.68**

Table 4. 5 Ground Floor Construction

Table 4.5 outlines the construction of the U value of a typical suspended timber ground floor, the greatest resistance to heat transfer is provided by the soil, with the remaining components providing little or no resistance.

Element	Internal Ceiling		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.10
Gypsum Plaster Board	0.013	0.16	0.08
Plaster	0.015	0.43	0.03
External Surface	-	-	0.10
Total Resistance			0.32
U-Value of Construction			**3.16**

Table 4. 6 Internal Ceiling U – Value Construction

Element	Roof (Typical % Heat Loss 30-35)		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
Concrete Tiles	0.02	1.50	0.01
Air Cavity	0.01	0.00	0.09
Felt	0.01	0.19	0.03
Internal Surface	-	-	0.10
Total Resistance			0.27
U-Value of Construction			**3.71**

Table 4. 7 Roof U- Value Construction

As outlined a considerable amount of heat loss appears to occur within the roof structure of a building. As identified in table 4.6 & 4.7 resistance within the roof space of a 1970 building

Element	Window (softwood frame)(Typical % Heat Loss 15)		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
Clear Float	0.006	1.06	0.01
Internal Surface	-	-	0.13
Total Resistance			0.18
U-Value of Construction			**5.69**

Table 4. 8 Window U- Value Construction

The window is typically the most difficult component within the building envelope. A large proportion of the building can be insulated however this is not feasible with respect to the window. As the windows and doors typically making up between 10-20% of the wall area (proportion of window to total wall area), the heat loss through the windows and doors can be similar to that of the wall. Table 4.8 highlights the poor resistance of a typical single glazed window.

4.3.2 Findings -1970 Building

Following the simulation of the 1970 building, which consisted of the building fabric, outlined in tables 4.4 to 4.8 the following energy consumption and carbon emissions results were established. Table 4.9 outlines the monthly energy consumption of the oil of the building model, in megawatt hours. The monthly totals have then been compiled to establish the annual energy consumption. The next column identifies the total kilowatt hours per metre squared consumption per year. The total Co2 emissions are also outlined.

1970 Building Energy Consumption and Carbon Emission				
Date	Total Energy (MWh)	Total KWh/m2/yr	Total CE (kgCO2)	Total CE (kgCO2/m2/yr)
Sep 01-30	3.68		926	
Oct 01-31	5.55		1421	
Nov 01-30	8.94		2321	
Dec 01-31	10.90		2839	
Jan 01-31	9.63		2500	
Feb 01-28	9.35		2432	
Mar 01-31	9.37		2433	
Apr 01-30	9.10		2363	
May 01-31	4.27		1081	
Total	70.41	440	18316	114.48

Table 4. 9 1970 Building Energy Emission and Carbon Consumption

this building would appear to be energy inefficient. With l, when a mean temperature of 21°C is required in the kitchen and living room and a mean of 18°C in the remanding rooms. This reading will result in an F rating with respect to the BER Certification, a reading of greater than 450KWh/m2/yr signifies a G rating (refer to appendices I). In relation to Co2 emissions the building is again on the negative end of the scale, with 114g/Co2/m2/ year being produced. The air changes in the building have been assumed at 4 air changes per hour (ach), along with a boiler efficiency of 70%. The time period considered is the typical heating season from September to May inclusive.

4.3.3 2011 Building Fabric

Having established the energy consumption along with the Co2 emissions which result from a typically building constructed in the 1970ôs. The next process is to establish the effect of the design intervention resulting from the development of Part L of the 2011 Building Regulations. All constants outlined previously remained for the 2011 building model, the variables consist of the building fabric, adjusted in order to achieve the required u value. Adjustments were also required in relation to Air changes per hour along with boiler efficiency; an improved air change of 0.6 ach along with boiler efficiency of 90% has been imputed. Table 4.7 outlines the building fabric make up of 2011 building model; this includes the u- values which correspond to the building fabric. All relevant information was then inputted into the simulation software.

The following tables outline the building fabric make up of the building which is in compliance with Part L of the 2011 Building Regulations; this includes the U- Values which correspond to the building fabric. All relevant information was then entered into the simulation software.

g Regulations: Building Fabric			
	External Wall		
	s m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
External Render	0.019	0.500	0.04
Concrete Block	0.100	1.630	0.06
Air Cavity	0.040	0.000	0.18
Insulation	0.100	0.024	4.17
Concrete Block	0.100	1.630	0.06
Plaster	0.013	0.180	0.07
Internal Surface	-	-	0.13
Total Resistance			4.75
U-Value of Construction			0.21

Table 4. 10 External Wall Construction U-Value

A considerable improvement of the u value of the external wall has been established. As building technology improved the construction of same also changed, with the implementation of an air cavity to prevent thermal bridging along with the installation of insulation.

Element	External Door		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
Wood (Pine)	0.04	0.14	0.29
Internal Surface	-	-	0.13
Total Resistance			0.46
U-Value of Construction			2.19

Table 4.11 External Door U- Value

Element	Ground Floor		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
Soil	0.95	1.29	0.74
Polystyrene	0.1	0.03	3.23
Cast Concrete	0.15	1.4	0.11
Rubber Underlay	0.025	0.1	0.25
Carpet	0.010	0.06	0.17
Internal Surface	-	-	0.17
Total Resistance			4.70
U-Value of Construction			0.21

Table 4.12 Ground Floor Construction U- Value

or has also evolved with the installation of insulation

e of the element.

Element	Internal Ceiling		
Material	**Thickness m**	**Conductivity w/Mk**	**Resistance (m2K/W)**
External Surface	-	-	0.10
Fiber Glass Quilt	0.25	0.04	6.25
Gypsum Plaster Board	0.01	0.16	0.08
Plaster	0.02	0.43	0.03
External Surface	-	-	0.10
Total Resistance			6.57
U-Value of Construction			0.15

Table 4.13 Internal Ceiling U- Value Construction

Element	Roof		
Material	**Thickness m**	**Conductivity w/Mk**	**Resistance (m2K/W)**
External Surface	-	-	0.04
Concrete Tiles	0.020	1.50	0.01
Air Cavity	0.010	0.00	0.09
Felt	0.005	0.19	0.03
Internal Surface	-	-	0.10
Total Resistance			0.27
U-Value of Construction			3.71

Table 4. 14 Roof U- Value Construction

Approximately 25% of heat loss occurs through the roof of the building. It is not uncommon for consumers to go beyond the required regulations however this is not necessarily going to result in returns. Typically 300mm of insulation is sufficient to achieve the required efficiency. Within the building simulation in question 250mm of fibre glass wool achieves the required U value in accordance with Part L of the Building Regulations. The roof construction remains the same as the 1970 building however as the ceiling insulation is installed a sufficient U value is achieved.

Low-e Double Glazed Window (PVC frame)			
[illegible]	[illegible]s m	Conductivity w/Mk	Resistance (m2K/W)
[illegible]	[illegible]	-	0.04
Karppafloat 6mm	0.006	1.06	0.01
Cavity	0.012	-	0.32
Clear Float 6mm	0.006	1.06	0.01
Internal Surface	-	-	0.13
Total Resistance			0.51
U-Value of Construction			1.98
**Note: Windows, doors and rooflights should have a maximum U-value of 1.6 W/m2K when their combined area is 25% of floor area. Building in question combined area less than 25%*			

Table 4. 15 Window Construction U-Value

4.3.2 Findings -2011 Building Regulation

.

2011 Building Energy Emission and Carbon Consumption				
Date	Total Energy (MWh)	Total KWh/m2/yr	Total CE (kgCO2)	Total CE (kgCO2/m2/yr)
Sep 01-30	0.78		236	
Oct 01-31	0.82		248	
Nov 01-30	1.06		311	
Dec 01-31	1.41		405	
Jan 01-31	1.19		346	
Feb 01-28	1.04		303	
Mar 01-31	1.05		309	
Apr 01-30	0.97		286	
May 01-31	0.81		244	
Summed total	9.14	57.15	2688	16.8

Table 4. 16 2011 Building Energy Emission and Carbon Consumption

Following the simulation of the building which complies with the requirements of Part L of the 2011 Building Regulations consisting of the building fabric outlined in tables 4.11 to 4.16 the following energy consumption results were established. The energy consumption is considerable reduced, with a reading of 57.15 KWh/m2/yr being established. In relation to Co2 emissions the building achieved a reading of 16.8kg/Co2/m2/ year being produced, refer to table 4.17. The air change rate has improved to 2.15 air changes per hour, as a more complete thermal envelop is now in place. The boiler efficiency has also improved to 90%.

consumption due to upgrade measures

The assessment of the energy consumption due to the building upgrade is carried out in individual order; this will establish the energy savings which may be achieved by carrying out each upgrade independently. Following this the effect of an accumulative upgrade will be examined. Upgrade one will involve the installation of external insulation; following this the windows will be upgraded. Next insulation of the ceiling will be carried out; an upgrade of the ground floor will then be examined. Finally the boiler will be replaced in accordance with the 2011 Building Regulations. All upgrades will be in order to comply with the requirements of the 2011 Building Regulations.

4.4.1 Upgrade 1- External Wall Insulations

As illustrated above the typical U-Value with respect external wall construction of the 1970 building was calculated to be 2.1W/m2K. In order to comply with the 2011 Regulations the required u value is 0.21W/m2K. The simulation incorporates sufficient external wall insulation in order to achieve this U- Value. 110mm of Phenloic foam was used in order to achieve this u- value.

Element	External Wall (Typical % Heat Loss 25-33)		
Material	**Thickness m**	**Conductivity w/Mk**	**Resistance (m2K/W)**
External Surface	-	-	0.04
External Render	0.02	0.50	0.04
Phenloic Foam	0.11	0.03	4.40
Hollow Concrete Block	0.22	0.84	0.26
Plaster	0.01	0.43	0.03
Internal Surface	-	-	0.13
Total Resistance			4.89
U-Value of Construction			**0.20**

Table 4. 17 External Wall Upgrade

Table 4.17 outlines the upgrade construction and the resulting new U ï Value. Table 4.18 outlines the energy consumption as a result of the wall installation.

...de 1- External Wall I nsulations					
1970 Building Fabric	Construction	...l Consumption KWh/m2/yr	External Wall Upgrade	U-Value Of Construction	Total Consumption KWh/m2/yr
External Surface	2.03	443	External Surface	0.2	358
External Render			External Render		
Hollow Concrete Block			110mm Phenloic Foam		
			Hollow Concrete Block		
Plaster			Plaster		
Internal Surface			Internal Surface		
Energy Consumption Reduction					85

Table 4.18 Upgrade 1 Energy Consumption Reduction

4.4.2 Upgrade 2 – Replace Windows

The upgrade of windows can also have a considerable impact on energy consumption. The single glazed which are in the original simulation have a u value of 5.69 W/m2K. The windows have been replaced with Low-e Double Glazed Window providing a u value of 2.19 W/m2K.

Element	Window (softwood frame)(Typical % Heat Loss 15)		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.04
Kappafloat	0.006	1.06	0.01
Cavity	0.012	-	0.39
Pilkington	0.006	1.06	0.01
Internal Surface	-	-	0.13
Total Resistance			0.57
U-Value of Construction (including frame)			**2.15**

Table 4. 19 Window Upgrade

Table 4.19 outlines the construction of the new window, along with the resulting U-Value. Table 4.20 outlines the energy consumption as a result of the window upgrade.

...ade 2 Window Replacement					
...Fabric	...Construction	...nsumption KWh/m2/yr	Window Upgrade	U-Value Of Construction	Total Consumption KWh/m2/yr
External Surface	5.67	443	External Surface	2.15	424
Clear Float 6mm			Kappaflow 6mm		
Internal Surface			Cavity		
			Pilkinton K 6mm		
			Internal Surface		
Energy Consumption Reduction					19

Table 4.20 Upgrade 2 Energy Consumption Reduction

4.4.3 Upgrade 3- Ceiling Insulation

The required u-value for a ceiling/ roof in accordance with the 2011 Building Regulations is 0.16 W/m2K. The respective u-value for the 1970 is far greater this requirement, with a u-value of 3.16 W/m2K. In order to achieve the required U-Value 250mm of fibre glass quilt insulation was installed at ceiling level. Table 4.21 outlines the effects of this upgrade

Element	Internal Ceiling		
Material	Thickness m	Conductivity w/Mk	Resistance (m2K/W)
External Surface	-	-	0.10
Fibre Glass Wool	0.25	0.04	6.25
Gypsum Plaster Board	0.013	0.16	0.08
Plaster	0.015	0.43	0.03
External Surface	-	-	0.10
Total Resistance			6.57
U-Value of Construction			**0.15**

Table 4. 21 Internal Ceiling Upgrade

Table 4.22 outlines the energy consumption as a result of the ceiling upgrade.

Upgrade 3 Ceiling Insulation					
1970 Building Fabric	U-Value Of Construction	Total Consumption KWh/m2/yr	Ceiling Upgrade	U-Value Of Construction	Total Consumption KWh/m2/yr
External Surface	3.16	443	External Surface	0.15	368
Gypsum Plaster Board			250mm Fibre Glass Insulation		
			Gypsum Plaster Board		
Plaster			Plaster		
Internal Surface			Internal Surface		
Energy Consumption Reduction					75

Table 4.22 Upgrade 3 Energy Consumption Reductions

The required u-value for a ground floor in accordance with the 2011 Building Regulations is 0.21 W/m2K. The respective u-value for the 1970 is far greater this requirement, with a U-Value of .68 W/m2K. In order to achieve the required U-Value 85mm of Fibre glass quilt insulation is installed under the timber floor.

Element	Ground Floor (Typical % Heat Loss 7-10)		
Material	**Thickness m**	**Conductivity w/Mk**	**Resistance (m2K/W)**
External Surface	-	-	0.04
Soil	0.95	1.29	0.74
Air Cavity	0.12	0.00	0.18
Fibre Glass Quilt	0.09	0.03	3.40
Timber Flooring	0.03	0.14	0.18
Carpet	0.01	0.06	0.17
Internal Surface	-	-	0.17
Total Resistance			4.87
U-Value of Construction			**0.21**

Table 4. 23 Ground Floor Upgrade

Table 4.24 outlines the energy consumption as a result of the Ground Floor Upgrade.

Upgrade 4 Ground Floor Insulation					
1970 Building Fabric	**U-Value Of Construction**	**Total Consumption KWh/m2/yr**	**Ground Floor Upgrade**	**U-Value Of Construction**	**Total Consumption KWh/m2/yr**
External Surface	0.68	443	**External Surface**	0.21	422
Soil			**Soil**		
Air Cavity			**85mm Fibre Glass Quilt**		
Timber Flooring			**Timber Flooring**		
Carpet			**Carpet**		
Internal Surface			**Internal Surface**		
Energy Consumption Reduction					**21**

Table 4.24 Upgrade 4 Energy Consumption Reductions

4.4.5 Upgrade 5- Boiler Upgrade

According to the SEAI typically the ñas newò efficiency of an oil or gas boiler over 15 years old would have been less than 80%. Its present efficiency today, due to wear and tear is unlikely to be greater than 70%. The current range of boilers available today will have

rt L of the 2011 Building Regulation requires a boiler ade of the boiler is also carried out. Table 4.25 outlines the energy consumption as a result of the improved efficiency of a boiler.

Upgrade 5- Boiler Upgrade					
1970 Building	Boiler Efficency	Total Consumption KWh/m2/yr	2011 Building	Boiler Efficency	Total Consumption KWh/m2/yr
Conventional Oil Boiler	70%	443	Boiler Upgrade	90%	346
Energy Consumption Reduction					**97**

Table 4.25 Upgrade 5 Energy Consumption Reductions

4.4.5 Upgrade 6- Air Changes per Hour

Upgrade 6- Air Change per hour					
1970 Building	Air Change Per Hour	Total Consumption KWh/m2/yr	1970 Building Following Upgrade	Air Change Per Hour	Total Consumption KWh/m2/yr
Number of Air Changes	4	443	Number of Air Changes	2.15	357
Energy Consumption Reduction					**86**

Table 4. 26 Upgrade 6 Energy Consumption Reductions

Unlike the previous upgrades carried out, upgrade number six refers to the improvement of the air change ratio within the building. Due to the previous upgrades carried out, an assumption is made that there is a considerable improvement with respect to air tightness within the building. An air change of 2.15 air changes per hour is considered. A blow door test is required to achieve the exact air tightness of the building. For the purpose of this study an assumption is made. As can be seen from table 4.26 a considerable reduction in energy consumption is achieved.

4.5 Establish if interventions are economically beneficial

4.5.1 Establish heating energy consumption and costs

In order to put into context the long term economically benefits the immediate economic benefits need to be established. The economical savings as a result of the reduction in energy consumption is calculated. This does not take into consideration the capital cost involved in

the chapter. The following outlines the typical annual in 2011.

1970 Building

In order to establish the number of litres of oil consumed per annum the total energy consumption is divided by the conversion factor of oil. 1 litre of home heating oil is the equivalent of 10.5kWh units. As outlined the total energy consumption for the 1970 building is 70.414mWh. This is converted to kWh by multiplying by 1000, total energy is 70414kWh.

$$\frac{[illegible]}{[illegible]} [illegible]$$

$$\frac{70414 [illegible]}{10.5 [illegible]} [illegible]\ 6706 [illegible]$$

Having established the annual number of litres used to heat the building the next step is to calculate the financial cost of such usage. The average price per unit of Kerosene according to the SEAI Domestic Fuel Comparison of Energy Cost on Oct 1st is ú0.82 per litre. (see appendix II)

Heating Cost of 1970 Building

$$[illegible]$$

$$6706 [illegible]\ €0.82 [illegible]\ €5{,}499$$

$$[illegible]\ 2\ [illegible]\ €5{,}499\ [illegible]\ 160 [illegible]\ 2\ [illegible]\ €34.36\ [illegible]\ 2$$

2011 Building

The same procedure is carried out in order to establish the cost of heating a building which is built in compliance with part L of the 2011 Building Regulations.

$$\frac{[illegible]}{[illegible]} [illegible]$$

$$\frac{9140 [illegible]}{10.5 [illegible]} [illegible]\ 870.4 [illegible]$$

[illegible]

870.4 [illegible] €0.82 [illegible] €713 [illegible]

[illegible] 2 [illegible] €713 [illegible] 160 [illegible] 2 [illegible] €4.40 [illegible] 2

Energy Cost Comparison

A simplistic comparison has been established. To heat a 1970 building with the profile outlined cost ú5,499 compared to a 2011 building with a cost of ú713 a difference in cost of ú4,786 per annum.

4.5.2 Life Cycle Analysis

Having established that the implementation of upgrades has an effect on the total energy consumption of the building, the next process in the desk study is to establish if such interventions are economically beneficial. To provide a more long-term retrospective analysis, taking into consideration such issues as initial capital investment, discount and inflationary rates, an analysis has been carried out. The aim of the analysis is to establish the net present value of potential savings and ultimately identify to what degree are the interventions economically beneficial.

4.5.2.1 Undiscounted appraisal methods

Payback method

The payback is a basic method where the capital cost of the upgrades is divided into the savings achieved. In order to accurately recognize the payback period, the cost of the upgrades need to be established.

Cost

Throughout the study examination of the costs of upgrades were carried out. In addition to this a number of suppliers were contacted. A variance in cost occurred with respect to a number of upgrade processes. Therefore a historical cost data approach was taken.

ices III).

t the cost of external insulation ranged from between ú10,000- ú20,000 for a four bedroom building of 150m2. Due to the larger area of the building in question, a figure of ú16,000 was taken for the authors study. A cost per m2 was then established.

$$€16{,}000 \div 160m^2 = €100/m^2$$

Internal Insulation (refer to appendices III).

The cost of internal insulation was calculated through the same principals. The cost of insulation ranged from between ú7,000- ú10,000 for a four bedroom building of 150m2. Again a mean cost was taken of ú9,000. A cost per m2 was then established of ú56.00/m2.

$$€9{,}000 \div 160m^2 = €56/m^2$$

Ceiling Insulation (refer to appendices IV)

The cost here was again calculated using the SEAI case studies, the ceiling insulation cost range from ú700-ú1,000 for building of 150m2. Due to the large foot print of the building a cost of ú1,000 was taken and a cost per m2 was established.

$$€1{,}000 \div 160m^2 = €6.25/m^2$$

Boiler Replacement

There appeared to be a considerable price variance with respect to the upgrading of the boiler system, ranging from ú1,800 to ú4,000, a 90% efficient condensing boiler including oil change over and control upgrade was deemed to cost approximately ú 2,800.

Window Replacement

Similarly the cost of window replacement varied considerable. Following receipt of various quotations the author established an approximate cost of ú550/m2 for Low-e Double Glazed Windows.

n prove difficult. The process involves lifting of the floor install mesh, insulate on top of mesh and re lay the floor. The insulation material is the least expensive part of this installation; the labour is the area where the costs are incurred. The insulation and mesh cost approximately ú8.00/m2. A total cost per m2 is approximately ú35.00/m2.

Air Change

Workmanship has a considerable influence with respect to the rate of air changes within the building. A combination of draught sealing measure and high quality workmanship, will ultimately improve the air tightness within the building. It is difficult to apply a cost to this process, for this reason a nominal figure of 15% of the total capital investment will be taken to account for air tightness.

Capital Cost

Upgrade Meaure	Unit	Price	Area/m2	Cost Ex Grant	Grant Available	Cost Inc Grant
Upgrade Boiler	1no	ú2,800		ú2,800	ú560	ú2,240
External Wall Insualtion	m2	ú100	175	ú17,500	ú3,600	ú13,900
Ceiling Insulation	m2	ú6.00	160	ú960	ú200	ú760
Ground Floor Insulation	m2	ú35.00	160	ú5,600	N/A	ú5,600
Repalcement Window	m2	ú550	25	ú13,750	N/A	ú13,750
Improved Airtigtness (15% of total cost)	-	-	-	-	N/A	ú5,437.00
Total Capital Cost						ú41,688

Table 4.27 Option 1- Achieve Part L 2011 Building Regulation Compliance

Upgrade	Unit	Price/m2	Area/m2	Cost Ex Grant		Cost Inc Grant
Upgrade Boiler	1no	ú2,800		ú2,800	ú560	ú2,240
Installation of Dry lining	m2	ú56	175	ú9,800	ú1,800	ú8,000
Ceiling Insulation	m2	ú6.00	160	ú960	ú200	ú760
Ground Floor Insulation	m2	ú35.00	160	ú5,600	N/A	ú5,600
Replacement Window	m2	ú550	25	ú13,750	N/A	ú13,750
Improved Airtigtness (15% of total cost)	-	-	-	-	N/A	ú4,553.00
Total Capital Cost						ú34,903

Table 4.28 Option 2- Achieve Part L 2011 Building Regulation Compliance

The capital cost of the upgrades carried out jointly are outlined in tables 4.27 and 4.28, in order to achieve the requirements of Part L of the 2011 Building Regulations there are two available options explored. Option one outlines the capital cost when incorporating external wall insulation and option two is incorporates dry lining the external wall. The costs also take into consideration the grants available.

The anticipated payback period of the upgrades for each of the proposed interventions are outlined within tables 4.29 and 4.30. As there will be a different payback period due to the differing capital cost, two tables are illustrated.

Proposed Interventions	Energy saving (kWh/m^2/yr)	Revised energy rating (kWh/m^2/yr)	Annual energy saving (kWh/yr)	Conversion Factor	Litres	Fuel Cost per kWh	Energy savings per annum	Capital Cost	Payback period Years
Upgrade Boiler	97.00	346.00	15520	10.5	1478	ú0.82	ú1,212	ú2,240	1.85
External Wall Insulation	85.00	261.00	13600	10.5	1295	ú0.82	ú1,062	ú13,900	13.09
Ceiling Insulation	75.00	186.00	12000	10.5	1143	ú0.82	ú937	ú760	0.81
Ground Floor Insulation	21.00	165.00	3360	10.5	320	ú0.82	ú262	ú5,600	21.34
Replacement Window	19.00	146.00	3040	10.5	290	ú0.82	ú237	ú13,750	57.92
Improved Airtigtness	86.00	60.00	13760	10.5	1310	ú0.82	ú1,075	ú5,437.00	5.06
Total							ú4,786	ú41,687	8.71

Table 4. 29 Option 1-Payback Period (External Wall Insulation)

Proposed Interventions	Energy saving (kWh/m^2/yr)	Revised energy rating (kWh/m^2/yr)	Annual energy saving (kWh/yr)	Conversion Factor	Litres	Fuel Cost per kWh	Energy savings per annum	Capital Cost	Payback period Years
Upgrade Boiler	97.00	346.00	15520	10.5	1478	ú0.82	ú1,212	ú2,240	1.85
Installation of Dry lining	85.00	261.00	13,600	10.5	1,295	ú0.82	ú1,062	ú8,000	7.5
Ceiling Insulation	75.00	186.00	12000	10.5	1143	ú0.82	ú937	ú760	0.81
Ground Floor Insulation	21.00	165.00	3360	10.5	320	ú0.82	ú262	ú5,600	21.34
Replacement Window	19.00	146.00	3040	10.5	290	ú0.82	ú237	ú13,750	57.92
Improved Airtigtness	86.00	60.00	13760	10.5	1310	ú0.82	ú1,075	ú4,553	4.24
Total							ú4,786	ú34,903	7.29

Table 4. 30 Option 2- Payback Period (Dry lining External Wall)

The process by which the payback period is established is simple; it does not take into consideration future costs such as discounting or inflation. Having said this it is an effective method of identifying the most cost effective upgrade. The payback period for a number of upgrades is considerable, and it is difficult to justify. However when combined with the other upgrades the payback period is reduced.

ods- Sensitivity Analysis

x V)

Discounted evaluation methods take into account the time value of money, life of the project, interest rates and other factors. A key purpose of discounting is to take into account that the value of a sum to be received next year is less than the value of the same sum received today. It is important to note that this is not an exact science and results are dependent of the rate of discounts and escalation respectively. The following is a sensitivity analysis from the consumerôs perspective, in relation to the net present value of the savings achieved from upgrading a 1970ôs building in order to comply with Part L of the 2011 Building Regulations.

SPV*- Allows for the incorporation of escalation into the calculation. This factor is used when the cost today is known and a relevant escalation rate is applied over a certain period of time to estimate the future cost

UPV*- The uniform present value modified is used when the amount is escalated on a yearly basis and is discounted proportionally throughout the building life cycle. An example of this is energy costs which can be estimated today. .Kehily (2010)

Scenario 1: Discount rate - 4% Escalation rate - 8%.

Cost Items	Cost Base Year (B) Future (F)	Initial annual future year	PV Factor and Value	PV(BxD)
Boiler Acquisition Cost	ú2,240	0	1	ú2,240
Boiler Residual Cost	ú500	Year 20	SPV*2.127	ú1,064
Boiler Maintenance Cost	ú100	Annual	UPV*30.43	ú3,043
Net Present Boiler Cost				**€4,220**
Remaining Upgrade Investment Cost	ú39,448	0	1	ú39,448
Total Investment Cost				**€43,668**
Annual Energy Savings	ú4,786	Annual	UPV*30.43	ú145,638
Net Present Value Savings				**€101,970**

Table 4. 31 Net Present Value Savings External Wall Insulation

	Cost Base Year (B) Future (F)	Initial annual future year	PV Factor and Value	PV(BxD)
	ú2,240	0	1	ú2,240
Boiler Residual Cost	ú500	Year 20	SPV*2.127	ú1,064
Boiler Maintenance Cost	ú100	Annual	UPV*30.43	ú3,043
Net Present Boiler Cost				**€4,220**
Remaining Upgrade Investment Cost	ú32,663	0	1	ú32,663
Total Investment Cost				**€36,883**
Annual Energy Savings	ú4,786	Annual	UPV*30.43	ú145,638
Net Present Value Savings				**€108,755**

Table 4. 32 Net Present Value Savings Dry Lining

Scenario one takes into consideration the possibility of a discount rate of 4% consistent with current Department of Finance guidelines and an escalation rate of 8%. Table 4.31 outlines the net present value of the savings that may be achieved if the 1970 building was upgraded to 2011 levels using external insulation, table 4.32 deals with dry lining the external wall. The maintenance and residual cost of the boiler needed to be considered, the remaining upgrade investments have been deemed to be a one off payments. A single present value modified and universal present value modified has been used to calculate the present value, see appendices for financial tables.

Scenario 2: Discount rate - 2% Escalation rate - 10%.

Cost Items	Cost Base Year (B) Future (F)	Initial annual future year	PV Factor and Value	PV(BxD)
Boiler Acquisition Cost	ú2,240	0	1	ú2,240
Boiler Residual Cost	ú500	Year 20	SPV*4.527	ú2,264
Boiler Maintenance Cost	ú100	Annual	UPV*48.50	ú4,850
Net Present Boiler Cost				**€4,827**
Remaining Upgrade Investment Cost	ú39,448	0	1	ú39,448
Total Investment Cost				**€44,275**
Annual Energy Savings	ú4,786	Annual	UPV*48.50	ú232,121
Net Present Value Savings				**€187,847**

Table 4. 33 Net Present Value Savings External Wall Insulation

Cost Items	Cost Base Year (B) Future (F)	Initial annual future year	PV Factor and Value	PV(BxD)
Boiler Acquisition Cost	ú2,240	0	1	ú2,240
Boiler Residual Cost	ú500	Year 20	SPV*4.527	ú2,264
Boiler Maintenance Cost	ú100	Annual	UPV*48.50	ú4,850
Net Present Boiler Cost				**€4,827**
Remaining Upgrade Investment Cost	ú32,663	0	1	ú32,663
Total Investment Cost				**€37,490**
Annual Energy Savings	ú4,786	Annual	UPV*48.50	ú232,121
Net Present Value Savings				**€194,632**

Table 4. 34 Net Present Value Savings Dry Lining

ion the possibility of a discount rate of 2% and an seen a considerable saving can be envisaged if such circumstances were to occur. Due to the lower cost of dry lining a greater net present saving may be achieved.

Scenario 3: Discount rate - 10% Escalation rate -4%.

Cost Items	Cost Base Year (B) Future (F)	Initial annual future year	PV Factor and Value	PV(BxD)
Boiler Acquisition Cost	ú2,240	0	1	ú2,240
Boiler Residual Cost	ú500	Year 20	SPV*.326	ú163
Boiler Maintenance Cost	ú100	Annual	UPV*11.69	ú1,169
Net Present Boiler Cost				**€3,246**
Remaining Upgrade Investment Cost	ú39,448	0	1	ú39,448
Total Investment Cost				**€42,694**
Annual Energy Savings	ú4,786	Annual	UPV*11.69	ú55,948
Net Present Value Savings				**€13,254**

Table 4. 35 Net Present Value Savings External Wall Insulation

Cost Items	Cost Base Year (B) Future (F)	Initial annual future year	PV Factor and Value	PV(BxD)
Boiler Acquisition Cost	ú2,240	0	1	ú2,240
Boiler Residual Cost	ú500	Year 20	SPV*.326	ú163
Boiler Maintenance Cost	ú100	Annual	UPV*11.69	ú1,169
Net Present Boiler Cost				**€3,246**
Remaining Upgrade Investment Cost	ú32,663	0	1	ú32,663
Total Investment Cost				**€35,909**
Annual Energy Savings	ú4,786	Annual	UPV*11.69	ú55,948
Net Present Value Savings				**€20,039**

Table 4. 36 Net Present Value Savings Dry Lining

Scenario three takes into consideration the possibility of a discount rate of 10% and an escalation rate of 4%. In the event that the discount rate will outweigh that of the escalation rate, a much reduced pay back may be anticipated. This is somewhat unlikely as the economy moves towards peak oil it is reasonable to assume that escalation rates will be on an upward scale.

Having examined the economic implications of upgrading a building to the current building regulations the author has become aware that some interventions are more beneficial than other. In order to achieve the most positive results it would appear that multiple upgrades would result in the most economically beneficial outcome. In order to substantiate the authorôs findings and establish an expert option in relation to the topic an interview was carried out to gauge the attitude of the local authorities towards the importance of energy efficiency.

An interview was carried out with Ms. Sara Clifford, Executive Architect within Dun Laoghaire/ Rathdown Country Council and was held in the Dun Laoghaire Rathdown County Council's headquarters on the 30th November 2011. Additional information was provided by Maura Hickey, Administrative Office within the Housing Department.

4.6.1 Aim

The aim of the interview was to provide expert opinion, and to gauge the attitude of the local authorities towards the importance of energy efficiency, investigate their current activities and expenditure on upgrading their current housing stock and their future plans in this regard. The interview also explored their attitudes as to whether the retrofitting measures represent value for money.

4.5.2 Format

The interview was of semi structured nature. Typically a structured interview has a limited set of questions which are formalised. The semi structured interview is flexible format, and allows for the development of further questions from the interviewees responses to given questions. The semi structured interview will have a general framework of themes to be explored.

The interview explored the following topics:

- Establish to what level is upgrading of existing building stock being implemented
- Explore attitude towards the importance of upgrading of existing building stock
- Identify the potential capital investment available within the department
- Establish if a more reliable forecast of potential payback would influence the scale implementation

4.6.3 Interview Findings

What level is the upgrading of existing building stock being implemented?

At the outset of the interview, an attempt was made to establish the profile of the Authorities property portfolio; the makeup is as follows

c. 1997-2002: 6.4%

d. 2002-2008 11.8%

It is evident that almost 68% of the properties were built before the implementation of Part L of the building Regulations in 1991.In addition to this the interviewer was informed that all upgrades were carried out on buildings within the Pre 1991 bracket, with little or no upgrades on the properties within the other brackets. Ms. Clifford identified that the upgrading of buildings within the local authority is not necessarily dependant on the age of the building. The upgrade of the building is typically dependant on the occupancy of the building, ñ*if the building is vacant it will be assessed for upgrading measures".* However the older buildings

are of a higher priority for the authority with respect to upgrades particular when they become unoccupied. It was identified that due to the rental tendencies of the local authority, the Building Energy Rating (BER) rating is identified as a measure of rating energy efficiency improvement rather than improvement to a specific building standard. Ms. Clifford identified a typical example of a building for upgrade may have a BER rating of F; the aim for the authority is to improve the rating to C1.

Importance of upgrading of existing building stock

A scaled format was used to investigating the attitude of the Local Authority towards the importance of energy efficiency, Ms. Clifford was asked to rate on a, scale of one to five, how important is carrying out of building upgrades within the council is. She gave a rating of 5 was given; outlining the process as very important. Ms. Clifford also highlighted that the upgrades were primarily consumer focused, ñ*to provide the tenant with a more comfortable living environment".* In the event of a district heating or a communal block of apartments, where the authority funds the heating of buildings, considerable notice is taken with respect to the high energy costs which result from poor energy efficient practices. The local authority highlights the benefits of energy efficiency as twofold, the comfort of the tenant in a one off upgrade and the financial impact on larger buildings.

Capital investment

Having identified the importance of energy efficiency, the interview moved toward the

retrofitting. In an attempt to establish the emphasis on s, the total capital investment for the housing department was sought, the author was informed that *the Capital funding for the Councils housing programme was in the region of €5m in 2011. This includes expenditure on new build construction programme (mostly final accounts), refurbishment (other than energy works) and disabled alterations.* Following this the capital investment allocated to enhance the Energy Efficiency of the Housing Stock was investigated, Ms. Hickey informed me, *the capital funding for retro-fitting works was €875,000 in 2011*.

The funding would appear to be sourced from different areas of the department, including the Housing Maintenance Department, with other funds being sourced from the Department of Environment. Following further discussion it came to the interviewerôs attention that funding from the Department of Environment is given on a percentage basis. *This is dependent on the amount of Kwhm2 is saved, the higher the BER rating the higher the grant. The grant is a maximum of €18,000.* When examining the effects of economic climate on the capital investment, Ms. Clifford identified that *yes there is money available for upgrade work but not general work*. It would appear within the authority a strong case is required in order to accumulate the funding to carry out the works. However it would appear that due to the economic climate improves competitiveness has lead to increased level of expertise in the areas, Ms Hickey added, *In relation to energy retro-fit works adequate funding was provided in 2011. The current economic climate has meant that the Council is achieving better value for money and is able to get more works carried out for the same cost. As people in general are trying to achieve better energy ratings to reduce costs, the level of expertise has also grown in the field which has made it easier to get competent contractors to carry out the works and has also led to greater competition.*

Influence of potential payback

Having examined the level of upgrading being implemented, explored the attitude towards the importance of upgrading existing building stock and discussed the potential capital investment, the financial payback as a result of the implementation of retrofitting measurers was discussed. Ms. Clifford outlined that the authority *are very aware of the savings which may be achieved as a result of increasing the energy efficiency of the housing stock*. Ms. Hickey added *The tenants themselves pay their own energy bills, the only way the Council*

is by having regard to the before and after BER ratings *ties have improved from a G BER rating to a C1 which would have achieved a saving of 300 kWh or more pa*. The following question was then proposed: Would the potential savings which may be achieved influence the scale of implementation of retrofitting? *To some extent but sometimes the payment of the work does not have a good payback time i.e. insulating under an existing floor would take approximately 50 years. That is not usually carried out;* Ms. Hickey added *the ultimate aim of the Council is to improve the energy efficiency of the dwelling and thereby achieve savings on energy costs; however the main influence affecting the scale of implementation would be the resources available to do the works both financial and staffing.* It would appear that the decision to upgrade is dependent on the payback period against the cost of implementation, along with the available resources to do the works, both financial and staffing.

4.7 Conclusion

Having examined the economic implications of upgrading a building to the current building regulations the author has become aware that some interventions are more beneficial than other. In order to achieve the most positive results it would appear that multiple upgrades would result in the most economically beneficial outcome. In order to substantiate the authorôs findings and establish an expert option in relation to the topic an interview was carried out to gauge the attitude of the local authorities towards the importance of energy efficiency.

CHAPTER 5: ANALYSIS

5.1 Introduction

The following chapter analyses the findings established throughout the study. This chapter has been divided with respect to the objectives identified at the outset of the study, and the relevant findings highlighted in relation to each.

5.2 Analysis - Objective 1

Set out the requirements of Part L of the Building Regulations 2011

Part L Conservation of Fuel and Energy would have appeared to have been recognised in principal first in the 1991 Building Regulations. This remained the precedent until the publication of the 2002 Building Regulations, when methods were identified to achieve energy conservation, these regulations commenced on the 1st of January 2003. The most significant changes of Part L of the Building Regulations occurred as part of the 2005 Building Regulations. The requirement to calculate energy efficiency and in turn CO2 emissions was recognised, this amendment commenced on the 1st of June 2006. More in-depth calculation of energy efficiency was introduced, along with improved energy efficiency of all oil and gas fired boilers installed, an efficiency of 86% was required. The most recent amendment was made in 2011, a minor difference in relation to the efficiency of the oil and gas boiler was established, and the efficiency requirement is increased to 90%. Throughout this period the enhancement of the building envelope U-value was continuously developed.

5.3 Analysis - Objective 2

Identify options for achieving current standards

Throughout the literature review a number of methods of achieving the required standard of Part L of the building Regulations were examined. The building envelop is a key contributor in relation to the energy efficiency of the building. Particular attention was given to the most commonly practiced approaches. Many of the upgrades were quite straight forward, for example the upgrading of windows, installation of roof insulation. However the selection of external of internal insulation in order to upgrade the wall merited discussion. The internal

aper option providing the same u value as the external bance must be considered. The issue of upgrading an existing ground floor would appear to be complex. The installation of insulation would appear to be straightforward however the issue of removing and replacing existing floor boards can prove time consuming and expensive. It was also established that Ireland is below the mean in all measures of energy efficiency except for roof insulation.

5.4 Analysis - Objective 3&4

Test the effect of a design intervention which alters the model's design from pre – 1991 to 2011 standards in terms of compliance with Part L of the Building Regulations

It was established that all upgrades provided a reduction in energy consumption. The most effective measure is the upgrading of the boiler system from a 70% efficient boiler to a 90% efficient condensing boiler. Following this the improvement of air tightness within the building would result in a considerable energy saving. At the outset of the study the effect of improved air tightness was underestimated by the author. The findings show that if an air change rate of 2.15ach can be achieved the energy saving would be similar to that of installing external wall insulation or dry lining. Ceiling insulation can provide considerable energy savings. As outlined the implementation of ground floor insulation can prove difficult, as can be seen in table 5.1 the saving resulting from it would appear to be minimal. Similarly the replacement of windows has a surprisingly poor rate of return with respect to energy savings.

Proposed Upgrades	Energy saving ($kWh/m^2/yr$)
Upgrade Boiler	97.00
Improved Airitgtness	86.00
External Wall Insulation	85.00
Dry Lining	85.00
Ceiling Insulation	75.00
Ground Floor Insulation	21.00
Replacement Window	19.00

Table 5. 1 Energy Consumption Findings

are economically beneficial.

A simplistic comparison was established, to heat a 1970 building with the profile outlined cost ú5,499 compared to a 2011 building with a cost of ú713 a difference in cost of ú4,786 per annum.

The individual payback period with respect to upgrade measures, would suggest that a number them are not economically beneficial, practically window replacement and ground floor insulation, and therefore difficult to justify the upgrade. Having said this if all upgrades were to be incorporated the overall payback period is reduced considerably, and an anticipated payback period of between 7 to 9 years can be expected.

If a long term outlook is to be considered, taking a 20 year study period the net present value of upgrading a 1970 building to Part L of the 2011 Building Regulations at a discount rate of 4% and an escalation rate of 8% , can be anticipated to be in the range of ú100,000 and ú110,000. The discount and escalation rate are difficult to predict, however the figures calculated are an indicator of the potential savings that may be achieved of the upgrades measure were to be carried out.

If a short term outlook is to be taken a number of the upgrades do not appear to be of economically benefit however to when a long term view point is considered the benefits to the consumer would appear to be considerable.

5.6 Analysis- Objective 6

To speculate about the potential benefits should such interventions be adopted?

In order to speculate about the potential benefits should such interventions be adopted the semi structured interview was carried out. The interview attempted to clarify a number of issues. The findings have been correlated in accordance with these issues:

1. **Gauge the attitude of the local authorities towards the importance of energy efficiency.**

within the Dun Laoghaire/ Rathdown Country Council rity holds the energy efficiency of housing stock in very high regard. Having highlighted 5 on a scale of 1-5, (very important) clearly outlines the attitude of the local authority towards the importance of energy efficiency. In addition to this the manner in which Ms. Clifford spoke with respect to the topic, with enthusiasm and interest, further outlined the attitude. The percentage of funding allocated to the retrofitting also outlines the attitude of the local authorities towards the importance of energy efficiency.

2. **To investigate local authorities current activities and expenditure in upgrading their current housing stock and their future plans in this regard.**

The findings of the interview show that the upgrade of the authorityôs current housing stock is not necessarily dependant on the age of the building but dependant on the occupancy of the building, however the older buildings are of a higher focus for the authority with respect to retrofitting, once they become void. Interestingly a focus on the BER rating is the primary objective, with little or no consideration of achieving a building regulation standard, a rating of C1 is deemed to be a satisfactory standard.

It would appear that the capital investment in relation to retrofitting is co funded by the Housing Maintenance department along with support from the Department of Environment. The percentage of funding allocated by the Authority to the retrofitting also outlines the attitude of the local authorities towards the importance of energy efficiency, with 17% of the total capital expenditure of ú5,000,000 from the Housing Department going towards retrofitting; however the implementation of the works is hindered by the lack of funding available for the general work. Additionally it was recognized that funding is given on a percentage basis depending on the amount of Kwh/m2 is saved, ñ*the higher the BER rating the higher the grant",* with a maximum grant of ú18,000.

3. **Explore local authority's attitudes as to whether the retrofitting measures represent value for money.**

Having carried out the interview the interviewer identified that, the local authority believe that retrofitting measures represent value for money, until a certain point, Ms. Clifford said

re of the savings which may be achieved as a result of *e housing stock.* However the interview did highlight an additional notable point, that being that the implementation of the retrofitting is highly dependent on the circumstances and payback period of each specific retrofitting measure. The comparison between that of replacing existing windows & insulation an un-insulated ground floor was used. Ms. Clifford highlighted that the initial capital cost of both of these processes would be considered high; therefore the payback period is also quite lengthy. However as the energy efficiency benefits of the replacement of the windows would outweigh that of the insulation an un-insulated ground floor, the replacement of the windows would be made priority. This would appear to the author to signify that the local authorities believe that not all retrofitting measures represent value for money, and this is determined by the benefits gained against that of the payback period. The statement made by Ms. Hickey, that *the ultimate aim of the Council is to improve the energy efficiency of the dwelling and thereby achieve savings on energy costs; however the main influence affecting the scale of implementation would be the resources available to do the works both financial and staffing,* appears to signify the local authority attitude, they are focused on improving the energy efficiency of their housing stock, or in other terms modernising their investment by investing in their own property, but such investment is often hindered by resources available to do the works .

5.7 Summary

The Author has established that the Part L of Building Regulations is a comprehensive document, which developed from 1991 to the present day. The more notable developments occurred within the 2002 edition to the present day regulations.

The findings outline that a number of upgrade measure are available in order to achieve the current regulations. Many of which are non complex, such as replacement of windows, install ceiling insulation, however for the external wall to achieve the required U-Value a number of possibilities are available. Installation of dry lining on the interior of the external wall or the installation of external insulation will achieve the required U-Value. Consideration must be given to disturbance and reduction of internal floor area with the installation of dry lining; this must be considered against the addition financial cost of external wall insulation.

all upgrade measures will result in reduced energy consumption. Also it was established that not all measures, if carried out as a standalone upgrade are economically beneficial. Having said this if efforts were to be made to implement all upgrade measures in unison there would be considerable economical benefits. An anticipated payback period of approximately 7-9 years can be expected. In addition to this the savings over a 20 year study period would be substantial.

The findings would also suggest the primary deterrent for the consumer in relation to implementing such upgrades is lack of financial capital. The interview carried out would support these finding, as the Local Authority point to lack of funding along with resources as restricting factor in relation to increased upgrade measures being carried out.

SIONS AND RECOMMENDATIONS

6.1 Conclusion

The main aim of this dissertation was to value the potential savings as a result of upgrading an existing building to comply with Part L of the 2011 Building Regulations Standards and to speculate about the potential benefits should such interventions be implemented. The methods used to do this were a simulation based project along with a semi structured interview.

A typical 1970ôs domestic bungalow was used as the base model. The building model was then adjusted in order to comply with Part L of the 2011 Building Regulations. The operating energy used to heat the respective houses was examined. Constants within the computer program such as heating profiles, occupancy rates, and internal gains along with location were imputed into the software in order to establish the most accurate readings. The variables within the project included the building fabric along with the efficiency of the boilers, in compliance with the 2011 Building Regulations. This established the energy savings which is to be achieved as a result of the development of the building regulations. Following this the 1970 building underwent ñupgradesò in order to comply with the 2011 building regulations, this identified the individual energy savings which could be achieved as a result of possible upgrades available.

A semi structured interview was also carried out in order to establish the implementation of such measure within the construction industry, in keeping with the applied nature of the DT164 programme.

This study required a detailed literature review of documentation with respect to the benefits of energy efficiency, the relationship between fuel poverty and energy efficiency, the requirements of Part L of the 2011 Building Regulations; upgrade measures available in order to achieve the regulations along with factors effecting the implementation of such upgrades.

The research sought to fill a gap within the literature regarding the potential savings which may be achieved by upgrading an existing 1970 building to comply with Part L of the current 2011 building regulations. Therefore, the following research question needed to be answered:

ñHow much energy can be saved in a simulated building model by upgrading its design to comply with the performance standards required by Part L of the Building Regulations?ò

To answer this research question the following objectives were specified from the outset:

1. To set out the requirements of Part L of the Building Regulations 2011
2. Identify options for achieving these standards
3. Develop a building model to test the effect of a design intervention which alters the modelôs design from pre ï 1991 to 2011 standards in terms of compliance with Part L of the Building Regulations.
4. To measure the change in energy consumption resulting from such an intervention.
5. To estimate whether such interventions are economically beneficial.
6. To speculate about the potential benefits should such interventions be adopted

Steps taken in order to meet these objectives		
Objective	**Objective Fulfilled (Yes/No)**	**Action**
1	Yes	A thorough literature review was undertaken which identified the requirements of Part L of the Building Regulations 2011.
2	Yes	A detailed literature review was carried out in order to investigate the various options in achieving compliance with Part L of the Building Regulations for existing buildings
3	Yes	A detailed desk study was compiled in order to test the effect of a design intervention which alters the modelôs design from pre ï 1991 to 2011 standards in terms of compliance with Part L of the Building Regulations.
4	Yes	An analysis of the energy usage was generated from the researcherôs gatherings.
5	Yes	A LCC analysis was carried out on the long term economic benefit of the selected interventions
6	Yes	A semi structured interview with the local authority was conducted in order to clarify if the potential benefits of such interventions should be adopted

Table 6.1 Steps Taken to Meet Research Objectives

The aim of this dissertation was to value the potential savings as a result of upgrading an existing building to comply with Part L of the 2011 Building Regulations Standards. The ultimate objective was to establish what energy savings the upgrading interventions may achieve while also attempting to establish if such interventions are economically beneficial.
A further aim was to establish the implementation of such measure within the construction industry.

The findings would show if a long term outlook is taken then yes the capital investment required to upgrade a 1970ӧs building to Part L of 2011 Building Regulations costs would appear to be justified. This will provide a considerable reduction in energy consumption for the building, and in turn result in substantial financial savings being achieved over the remainder of the building life. The study also outlined that not all measures, if carried out as a standalone upgrade are economically beneficial.

Lack of financial capital would appear to be the main contributing factor with respect to the level of implementation of upgrades from both a local authority and consumer perspective. However both acknowledge the importance of energy efficiency. The author also noted that the local authority would appear to be focused on improving the BER rating of the building, in preference to achieving the existing building regulation requirements.

In a time of unprecedented unemployment particularly within the construction industry, the upgrading of existing buildings cannot be underestimated. Professional bodies such as the SCSI and the IAVI claim that such initiatives have the added advantage of supporting the industry, which is experiencing unprecedented difficulties, and providing direct benefits to the economy and exchequer through creating additional employment, while also benefiting the consumer as the study proves.

Following a comprehensive analysis of the data, the following recommendations are hereby made:

Prior to carrying out extensive building upgrades the home owner should investigated the benefits of improving air tightness within the building, the study highlights that this measure can result in considerable improvement in energy efficiency with minimal disruption.

In the event of upgrading a building the study would suggest that multiple upgrades should be carried out, for example the payback period for replacement of windows is difficult to justify unless other upgrade measures are implemented.

The study suggests that one of the key factors effecting the implementation of building upgrade measures is lack of financial capital. The author acknowledges that there is assistance provided in the form of government grants, however if the financial incentives for building upgrading were to be improved the author believes that an increase in the practice would result.

Industry professionals have recognised the role building upgrades could play within the construction industry, providing direct benefits to the economy and exchequer through creating additional employment while also having the added advantage of supporting the industry through this unprecedented downturn. The author recommends measures to be put in place at undergraduate level to improved industry knowledge of upgrading and the benefits which can result. In addition to this improved presentation of potential savings to the client will result in clarification of benefits and in turn increase uptake.

Increased utilisation of Building Simulation Modelling, simulation is commonly held to be the best practice approach to performance analysis in the building industry Clarke (2001). As the role of the quantity surveyor evolves to much more than a ñbean counterò an increased examination of the Quantity Surveyors role within Sustainable Development at under graduate level should be carried out.

savings can be achieved on domestic scale. The author y be carried out with respect to commercial buildings as the potential savings could be considerable, while also helping to rejuvenate job creation within the construction sector.

Word Count: 20,279

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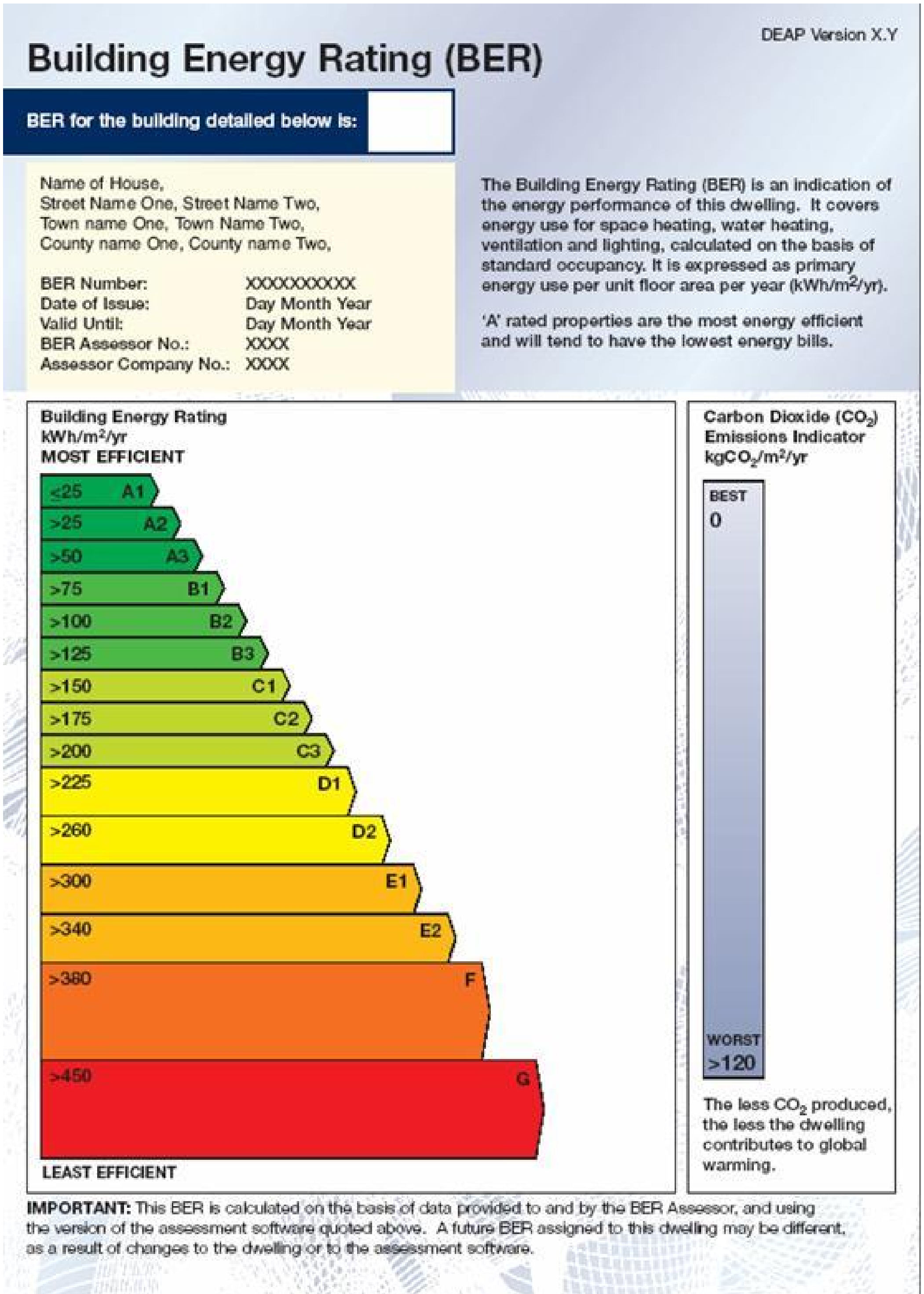
Appendices


DEAP Version X.Y
Building Energy Rating (BER)
BER for the building detailed below is:
Name of House,
Street Name One, Street Name Two,
Town name One, Town Name Two,
County name One, County name Two,
BER Number: XXXXXXXXXX
Date of Issue: Day Month Year
Valid Until: Day Month Year
BER Assessor No.: XXXX
Assessor Company No.: XXXX
The Building Energy Rating (BER) is an indication of the energy performance of this dwelling. It covers energy use for space heating, water heating, ventilation and lighting, calculated on the basis of standard occupancy. It is expressed as primary energy use per unit floor area per year (kWh/m2/yr).
'A' rated properties are the most energy efficient and will tend to have the lowest energy bills.
Building Energy Rating
kWh/m2/yr
MOST EFFICIENT
<25 A1
>25 A2
>50 A3
>75 B1
>100 B2
>125 B3
>150 C1
>175 C2
>200 C3
>225 D1
>260 D2
>300 E1
>340 E2
>380 F
>450 G
LEAST EFFICIENT
Carbon Dioxide (CO2) Emissions Indicator
kgCO2/m2/yr
BEST
0
WORST
>120
The less CO2 produced, the less the dwelling contributes to global warming.
IMPORTANT: This BER is calculated on the basis of data provided to and by the BER Assessor, and using the version of the assessment software quoted above. A future BER assigned to this dwelling may be different, as a result of changes to the dwelling or to the assessment software.

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Domestic Fuels
Comparison of Energy Costs

01 Oct, 2011

Notes:
1. Estimated average price to consumers countrywide.
2. Average price delivered in Munster area.
3. Prices include delivery in Dublin area only.
4. Oil prices assuming 1000L delivered.
   Also inc. government duty 4.726cpl on gas oil.
   From 01/07/2011 prices include those from a selection of suppliers that publish their prices online. Prices vary depending on delivery location.
5. L.P.G. standing charge : €15.20 every 2 months, (incl. tank rental and maintenance)
6. Gas prices are estimated by applying increases announced by suppliers to VAT incl prices from the EU Price Directive Survey for 01/01/2011 to 30/06/2011. The EU Price Directive Survey is updated every six months. For methodology and more details please see the following : http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Electricity_and_Gas_Prices/Electricity_Gas_Prices_in_Ireland.pdf
   Carbon tax of €0.00277 per kWh is included in the prices.
7. Electricity prices are estimated by applying increases announced by suppliers to VAT incl prices from the EU Price Directive Survey for 01/01/2011 to 30/06/2011. The EU Price Directive Survey is updated every six months. For methodology and more details please see the following : http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Electricity_and_Gas_Prices/Electricity_Gas_Prices_in_Ireland.pdf
   From 1/10/2011 the PSO levy was reduced from €2.73 to €1.61 per customer per month, see www.cer.ie for more details.
8. All ROI prices are inclusive of 13.5% VAT. NI rate of 5% VAT applies to wood purchased in the North.
9. Wood fuel prices may vary from the average, given the fragmented supplier network at present.
10. Minimum delivery conditions may apply. Discounts may apply for larger quantities.

Fuel	Form	Unit of Supply	Average[1] Price per Unit (€)	Gross Calorific Value (kWh/unit)	Delivered Energy Cost cent/kWh	Percentage change since 1 July, 2011	Percentage Change since 1 October, 2010
Peat[1]	Briquettes, Baled	Bale	3.90	67.0	5.82	-	+1.3%
Coal	Nuggets (Lignite)	Tonne	325.00	5763.5	5.64	-	-1.5%
	Premium Coal[2]	Tonne	365.00	8267.2	4.42	-	-3.9%
	Standard Coal[2]	Tonne	350.00	7900.0	4.43	-	-2.8%
	Standard Anthracite[3]	Tonne	435.00	8735.2	4.98	-	-3.3%
	Grade A Anthracite[3]	Tonne	475.00	8960.0	5.30	-	+1.1%
	Ovoids (Smokeless)[3]	Tonne	410.00	8850.0	4.63	-	-
Oil[4] Incl Carbon Tax (see note)	Gas Oil	Litre	0.86	10.55	8.16	+2%	n/a
	Kerosene	Litre	0.82	10.18	8.03	+1%	n/a
						N/A due to break in timeseries, new data source	
L.P.G. Incl Carbon Tax (see note)	Bulk L.P.G.[5]	Litre	0.91	7.09	12.78	-	+15.9%
	Bottled Butane	11.35 kg Cylinder	31.53	155.7	20.25	-	+5.8%
	Bottled Propane	34 kg Cylinder	86.85	471.0	18.44	-	+6.8%
	Bottled Propane	47 kg Cylinder	119.16	651.0	18.31	-	+5.8%
Natural Gas[6] Incl Carbon Tax (see note)	Band D1: <20 GJ per annum	kWh	0.067	1.0	6.70	+20%	+11.6%
	Band D2: >=20<200 GJ per annum	kWh	0.061	1.0	6.11	+20%	+16.1%
	Band D3: >=200 GJ per annum	kWh	0.058	1.0	5.82	+20%	+20.1%
Electricity[7] (see note)	Band DA: <1000 kWh per annum	kWh	0.46	1.0	45.71	+7%	+4.2%
	Band DB: >=1000 <2,500 kWh per annum	kWh	0.26	1.0	25.70	+9%	+17.2%
	Band DC: >=2500 <5000 kWh per annum	kWh	0.21	1.0	21.11	+11%	+12.6%
	Band DD: >=5000 <15,000 kWh per annum	kWh	0.18	1.0	17.77	+12%	+5.6%
	Band DE: >=15,000 kWh per annum	kWh	0.15	1.0	14.85	+13%	+4.1%
Wood[8]	Pellets Bulk Delivery[10]	kg	0.23	4.8	4.87	+5.4%	+4.0%
	Pellets Bagged	kg	0.31	4.8	6.41	+1.6%	-4.0%
	Briquettes	kg	0.37	4.8	7.73	-2.6%	+2.1%

Special Notes:

Note: New source for Electricity and Gas Prices from October 2010 : Due to full deregulation of the market, prices are now based on the prices gathered for the EU Gas & Electricity Price Transparency Directive. Prices are updated 6 monthly.
See notes 6 &7 and also http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/ for the latest report.
Electricity - from 1/10/2011 the PSO levy was reduced from €2.73 to €1.61 per customer per month, see www.cer.ie for more details
Carbon Tax was introduced for Oil, L.P.G and Natural Gas on 1st May 2010. See www.revenue.ie for more details.
New source for Gas Oil and Kerosene Prices from July 2011 : Prices are no longer sourced from schedule prices. Prices are now sourced from home heating oil prices which are published online to better reflect bulk discounts. Prices vary depending on delivery location.

Ireland's EU Structural Funds Programmes 2007 - 2013
Co-funded by the Irish Government and the European Union
EUROPEAN UNION STRUCTURAL FUNDS
The Sustainable Energy Authority of Ireland (SEAI) is financed by Ireland's EU Structural Funds Programme co-funded by the Irish Government and the European Union

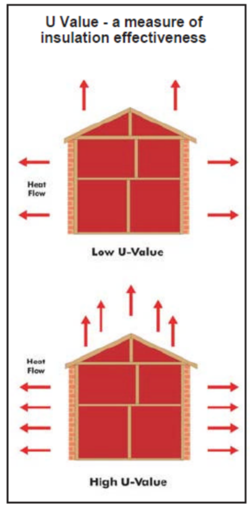
BETTER ENERGY HOMES | seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

WALL INSULATION

Homeowner Information

An un-insulated or poorly insulated wall costs you money and harms the environment. On average, a home loses 20 - 30% of its heat through its walls and even more if they are not properly insulated.

There is now grant aid available through the SEAI Better Energy Homes scheme to help you improve the wall insulation in your home.



Case Study

John has a four bedroom detached house with a footprint of 150 m^2. He has an annual heating bill of €1,600. John previously had no wall insulation in his cavity walls and was advised to install grey pumped polystyrene beads in his walls following advice from SEAI and various contractors he rang. As well as resulting in more comfortable living conditions, this simple measure has resulted in annual savings in his heating bill of approximately €300. John was also able to secure grant aid from the Better Energy Homes scheme to help him with the cost of this. Typical costs for this type of upgrade are approx. €700 - €1,000 (excluding grant). If John had solid masonry or hollow block walls he would need to use internal or external insulation for his home. Even greater savings could be achieved for internal or external insulation given that the walls, prior to insulation, would have poorer heat retention properties. The internal insulation would cost approx. €7,000 - €10,000 (excluding grant), while the external insulation solution would cost him €10,000 - €20,000 (excluding grant). The grant scheme recognises the extra costs associated with these insulation solutions, and provides additional grant aid where they are installed in accordance with the scheme.

The Benefits of Wall Insulation

- Reduction in heating bills
- Increased comfort levels
- Reduction in emissions

The effectiveness of an insulating material is measured using a 'U-value'. A U-value is a measure of how much heat is conducted through a structure. Correctly installed insulation will have a low U-value as it will allow only small amounts of heat to pass through, thereby keeping your home warmer for longer. Homeowners availing of wall insulation grants under the Better Energy Homes scheme are required to install wall insulation which should achieve a U-value of 0.27 W/m K or better (i.e. Lower). It is vital that you ask the installer that the price quoted for will achieve the required U-value or the best U-value that can be achieved for your circumstances.

Key Wall Insulation Facts and Tips

Wall Types

The first step in getting wall insulation is establishing the wall type of your home. The three main wall types are cavity walls, solid walls and hollow block walls. A building contractor or architect will be able to tell you what type of wall your home has if you don't already know yourself.

Wall Insulation Types

There are three main types of wall insulation, Which suit different walls and homes:

A) Cavity wall insulation
B) Internal Insulation
C) External insulation

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BETTER ENERGY HOMES

CEILING LEVEL ROOF INSULATION

Homeowner Information

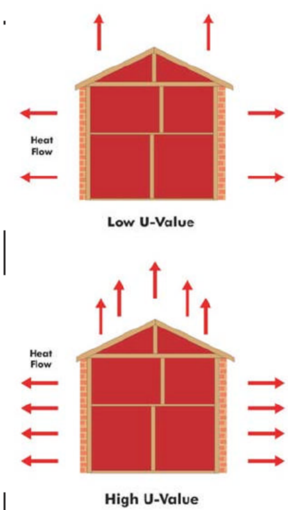
An un-insulated or poorly insulated roof costs you money and harms the environment.

There is now grant aid available through the SEAI Better Energy Homes scheme to help you improve your home using roof insulation.

Up to 30% of the heat produced in your home may be escaping if your roof is uninsulated. Ceiling level roof insulation is generally the most cost effective of any energy efficiency upgrade made to a house and often does not come with a large price tag when the potential savings are considered.

Even if you already have insulation in your roof, you may still be losing heat if it is damaged, less than is necessary or incorrectly installed. For example if you have a thin or worn layer of insulation it would be beneficial to replace it or improve its performance by adding another layer.

U Value - a measure of materials insulation ability



Case Study

Mary has a four bedroom detached house 150 m in size. She has an annual heating bill of €1,600. Mary previously had 100mm of fibreglass insulation in her attic but decided to upgrade the insulation in her attic to the recommended 300mm following advice from SEAI and the various contractors she rang. As well as resulting in more comfortable living conditions, this simple low cost measure now saves Mary over €250 every year on her home heating bill. Mary was also able to secure grant aid from the Better Energy Homes scheme to help her with the cost of this. Typical costs for this type of upgrade are approx. €700 - €1,000 (excluding grant).

The Benefits of Roof Insulation

- Reduction in heating bills
- Increased comfort levels
- Low capital cost
- Short payback periods
- Reduction in Greenhouse Gas emissions

Effectiveness of Insulation

The effectiveness of an insulating material is measured using a 'U-value'. A U-value is a measure of how much heat is conducted through a material. Insulation installed correctly will have a low U-value as it will allow only small amounts of heat to pass through, thereby keeping your home warm. Homeowners availing of attic insulation grants under the Better Energy Homes scheme should aim to achieve a U-value of 0.13 W/m²K or better (i.e. lower). It is vital that you ask the installer that the price quoted for will achieve the required U-value, or the best U-value that can be achieved in your circumstances.

d= 2%

fied Single Present Value Factors

ount Rate d = 2%

Year	Escalation Rates 0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year
1	0.980	0.990	1.000	1.010	1.020	1.029	1.039	1.049	1.059	1.069	1.078	1.088	1.098	1
2	0.961	0.980	1.000	1.020	1.040	1.060	1.080	1.100	1.121	1.142	1.163	1.184	1.206	2
3	0.942	0.971	1.000	1.030	1.060	1.091	1.122	1.154	1.187	1.220	1.254	1.289	1.324	3
4	0.924	0.961	1.000	1.040	1.081	1.123	1.166	1.211	1.257	1.304	1.353	1.402	1.454	4
5	0.906	0.952	1.000	1.050	1.102	1.156	1.212	1.270	1.331	1.394	1.459	1.526	1.596	5
6	0.888	0.943	1.000	1.060	1.124	1.190	1.260	1.333	1.409	1.489	1.573	1.661	1.753	6
7	0.871	0.933	1.000	1.071	1.146	1.225	1.309	1.398	1.492	1.591	1.696	1.807	1.925	7
8	0.853	0.924	1.000	1.081	1.168	1.261	1.360	1.466	1.580	1.701	1.830	1.967	2.113	8
9	0.837	0.915	1.000	1.092	1.191	1.298	1.414	1.538	1.673	1.817	1.973	2.140	2.320	9
10	0.820	0.906	1.000	1.102	1.214	1.336	1.469	1.614	1.771	1.942	2.128	2.329	2.548	10
11	0.804	0.897	1.000	1.113	1.238	1.376	1.527	1.693	1.875	2.075	2.295	2.535	2.798	11
12	0.788	0.888	1.000	1.124	1.262	1.416	1.587	1.776	1.986	2.218	2.475	2.759	3.072	12
13	0.773	0.880	1.000	1.135	1.287	1.458	1.649	1.863	2.102	2.370	2.669	3.002	3.373	13
14	0.758	0.871	1.000	1.146	1.312	1.501	1.713	1.954	2.226	2.533	2.878	3.267	3.704	14
15	0.743	0.863	1.000	1.158	1.338	1.545	1.781	2.050	2.357	2.706	3.104	3.555	4.067	15
16	0.728	0.854	1.000	1.169	1.364	1.590	1.851	2.150	2.496	2.892	3.347	3.869	4.466	16
17	0.714	0.846	1.000	1.180	1.391	1.637	1.923	2.256	2.642	3.091	3.610	4.210	4.903	17
18	0.700	0.837	1.000	1.192	1.418	1.685	1.998	2.366	2.798	3.303	3.893	4.582	5.384	18
19	0.686	0.829	1.000	1.204	1.446	1.735	2.077	2.482	2.962	3.529	4.198	4.986	5.912	19
20	0.673	0.821	1.000	1.215	1.475	1.786	2.158	2.604	3.137	3.772	4.527	5.426	6.492	20
21	0.660	0.813	1.000	1.227	1.503	1.838	2.243	2.732	3.321	4.030	4.883	5.904	7.128	21
22	0.647	0.805	1.000	1.239	1.533	1.892	2.331	2.866	3.517	4.307	5.265	6.425	7.827	22
23	0.634	0.797	1.000	1.252	1.563	1.948	2.422	3.006	3.723	4.603	5.678	6.992	8.594	23
24	0.622	0.789	1.000	1.264	1.594	2.005	2.517	3.154	3.942	4.918	6.124	7.609	9.437	24
25	0.610	0.782	1.000	1.276	1.625	2.064	2.616	3.308	4.174	5.256	6.604	8.281	10.36	25
26	0.598	0.774	1.000	1.289	1.657	2.125	2.719	3.470	4.420	5.617	7.122	9.011	11.38	26
27	0.586	0.766	1.000	1.301	1.689	2.187	2.825	3.640	4.680	6.002	7.681	9.807	12.49	27
28	0.574	0.759	1.000	1.314	1.722	2.252	2.936	3.819	4.955	6.414	8.283	10.67	13.72	28
29	0.563	0.751	1.000	1.327	1.756	2.318	3.051	4.006	5.247	6.854	8.933	11.61	15.06	29
30	0.552	0.744	1.000	1.340	1.791	2.386	3.171	4.203	5.555	7.325	9.633	12.64	16.54	30
35	0.500	0.708	1.000	1.407	1.973	2.758	3.843	5.339	7.393	10.21	14.05	19.29	26.40	35
40	0.453	0.674	1.000	1.477	2.174	3.188	4.658	6.782	9.839	14.23	20.50	29.44	42.14	40
45	0.410	0.642	1.000	1.551	2.396	3.686	5.646	8.615	13.09	19.82	29.90	44.93	67.27	45
50	0.372	0.611	1.000	1.629	2.640	4.260	6.844	10.94	17.43	27.63	43.61	68.6	107.4	50

Note : All amounts end-of-year

d= 4% d= 4%

SPV* - Modified Single Present Value Factors

Discount Rate d = 4%

Year	Escalation Rates 0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year
1	0.962	0.971	0.981	0.990	1.000	1.010	1.019	1.029	1.038	1.048	1.058	1.067	1.077	1
2	0.925	0.943	0.962	0.981	1.000	1.019	1.039	1.059	1.078	1.098	1.119	1.139	1.160	2
3	0.889	0.916	0.943	0.971	1.000	1.029	1.059	1.089	1.120	1.151	1.183	1.216	1.249	3
4	0.855	0.890	0.925	0.962	1.000	1.039	1.079	1.120	1.163	1.207	1.252	1.298	1.345	4
5	0.822	0.864	0.907	0.953	1.000	1.049	1.100	1.153	1.208	1.265	1.324	1.385	1.449	5
6	0.790	0.839	0.890	0.944	1.000	1.059	1.121	1.186	1.254	1.325	1.400	1.478	1.560	6
7	0.760	0.815	0.873	0.935	1.000	1.069	1.143	1.220	1.302	1.389	1.481	1.578	1.680	7
8	0.731	0.791	0.856	0.926	1.000	1.080	1.165	1.255	1.352	1.456	1.566	1.684	1.809	8
9	0.703	0.768	0.840	0.917	1.000	1.090	1.187	1.292	1.404	1.526	1.657	1.797	1.948	9
10	0.676	0.746	0.824	0.908	1.000	1.100	1.210	1.329	1.458	1.599	1.752	1.918	2.098	10
11	0.650	0.725	0.808	0.899	1.000	1.111	1.233	1.367	1.515	1.676	1.853	2.047	2.260	11
12	0.625	0.704	0.792	0.891	1.000	1.122	1.257	1.407	1.573	1.757	1.960	2.185	2.433	12
13	0.601	0.684	0.777	0.882	1.000	1.132	1.281	1.447	1.633	1.841	2.073	2.332	2.621	13
14	0.577	0.664	0.762	0.873	1.000	1.143	1.306	1.489	1.696	1.930	2.193	2.489	2.822	14
15	0.555	0.645	0.747	0.865	1.000	1.154	1.331	1.532	1.761	2.023	2.319	2.657	3.039	15
16	0.534	0.626	0.733	0.857	1.000	1.165	1.356	1.576	1.829	2.120	2.453	2.836	3.273	16
17	0.513	0.608	0.719	0.849	1.000	1.177	1.382	1.622	1.899	2.222	2.595	3.026	3.525	17
18	0.494	0.590	0.705	0.840	1.000	1.188	1.409	1.668	1.973	2.329	2.745	3.230	3.796	18
19	0.475	0.573	0.691	0.832	1.000	1.199	1.436	1.717	2.048	2.440	2.903	3.447	4.088	19
20	0.456	0.557	0.678	0.824	1.000	1.211	1.464	1.766	2.127	2.558	3.070	3.680	4.402	20
21	0.439	0.541	0.665	0.816	1.000	1.223	1.492	1.817	2.209	2.681	3.247	3.927	4.741	21
22	0.422	0.525	0.652	0.809	1.000	1.234	1.521	1.869	2.294	2.810	3.435	4.192	5.106	22
23	0.406	0.510	0.640	0.801	1.000	1.246	1.550	1.923	2.382	2.945	3.633	4.474	5.499	23
24	0.390	0.495	0.627	0.793	1.000	1.258	1.580	1.979	2.474	3.086	3.843	4.775	5.922	24
25	0.375	0.481	0.615	0.785	1.000	1.270	1.610	2.036	2.569	3.235	4.064	5.096	6.377	25
26	0.361	0.467	0.604	0.778	1.000	1.282	1.641	2.095	2.668	3.390	4.299	5.439	6.868	26
27	0.347	0.454	0.592	0.770	1.000	1.295	1.672	2.155	2.770	3.553	4.547	5.805	7.396	27
28	0.333	0.441	0.581	0.763	1.000	1.307	1.705	2.217	2.877	3.724	4.809	6.196	7.965	28
29	0.321	0.428	0.569	0.756	1.000	1.320	1.737	2.281	2.988	3.903	5.087	6.613	8.577	29
30	0.308	0.416	0.558	0.748	1.000	1.333	1.771	2.347	3.103	4.091	5.380	7.058	9.237	30
35	0.253	0.359	0.507	0.713	1.000	1.398	1.948	2.706	3.747	5.173	7.122	9.775	13.38	35
40	0.208	0.310	0.460	0.679	1.000	1.466	2.142	3.119	4.525	6.542	9.427	13.54	19.38	40
45	0.171	0.268	0.417	0.647	1.000	1.538	2.356	3.596	5.465	8.274	12.48	18.75	28.07	45
50	0.141	0.231	0.379	0.617	1.000	1.614	2.592	4.145	6.600	10.46	16.52	25.97	40.67	50

Note : All amounts end-of-year

d= 10%

fied Single Present Value Factors

ount Rate d = 10%

Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year
1	0.909	0.918	0.927	0.936	0.945	0.955	0.964	0.973	0.982	0.991	1.000	1.009	1.018	1
2	0.826	0.843	0.860	0.877	0.894	0.911	0.929	0.946	0.964	0.982	1.000	1.018	1.037	2
3	0.751	0.774	0.797	0.821	0.845	0.870	0.895	0.920	0.946	0.973	1.000	1.028	1.056	3
4	0.683	0.711	0.739	0.769	0.799	0.830	0.862	0.895	0.929	0.964	1.000	1.037	1.075	4
5	0.621	0.653	0.686	0.720	0.755	0.792	0.831	0.871	0.912	0.955	1.000	1.046	1.094	5
6	0.564	0.599	0.636	0.674	0.714	0.756	0.801	0.847	0.896	0.947	1.000	1.056	1.114	6
7	0.513	0.550	0.589	0.631	0.675	0.722	0.772	0.824	0.879	0.938	1.000	1.065	1.134	7
8	0.467	0.505	0.547	0.591	0.638	0.689	0.744	0.802	0.863	0.930	1.000	1.075	1.155	8
9	0.424	0.464	0.507	0.553	0.604	0.658	0.717	0.780	0.848	0.921	1.000	1.085	1.176	9
10	0.386	0.426	0.470	0.518	0.571	0.628	0.690	0.758	0.832	0.913	1.000	1.095	1.197	10
11	0.350	0.391	0.436	0.485	0.540	0.599	0.665	0.738	0.817	0.904	1.000	1.105	1.219	11
12	0.319	0.359	0.404	0.454	0.510	0.572	0.641	0.718	0.802	0.896	1.000	1.115	1.241	12
13	0.290	0.330	0.375	0.425	0.482	0.546	0.618	0.698	0.788	0.888	1.000	1.125	1.264	13
14	0.263	0.303	0.347	0.398	0.456	0.521	0.595	0.679	0.773	0.880	1.000	1.135	1.287	14
15	0.239	0.278	0.322	0.373	0.431	0.498	0.574	0.660	0.759	0.872	1.000	1.145	1.310	15
16	0.218	0.255	0.299	0.349	0.408	0.475	0.553	0.642	0.746	0.864	1.000	1.156	1.334	16
17	0.198	0.234	0.277	0.327	0.385	0.453	0.533	0.625	0.732	0.856	1.000	1.166	1.358	17
18	0.180	0.215	0.257	0.306	0.364	0.433	0.513	0.608	0.719	0.848	1.000	1.177	1.383	18
19	0.164	0.198	0.238	0.287	0.344	0.413	0.495	0.591	0.706	0.841	1.000	1.188	1.408	19
20	0.149	0.181	0.221	0.268	0.326	0.394	0.477	0.575	0.693	0.833	1.000	1.198	1.434	20
21	0.135	0.167	0.205	0.251	0.308	0.376	0.459	0.560	0.680	0.825	1.000	1.209	1.460	21
22	0.123	0.153	0.190	0.235	0.291	0.359	0.443	0.544	0.668	0.818	1.000	1.220	1.486	22
23	0.112	0.140	0.176	0.220	0.275	0.343	0.427	0.529	0.656	0.811	1.000	1.231	1.514	23
24	0.102	0.129	0.163	0.206	0.260	0.327	0.411	0.515	0.644	0.803	1.000	1.243	1.541	24
25	0.092	0.118	0.151	0.193	0.246	0.313	0.396	0.501	0.632	0.796	1.000	1.254	1.569	25
26	0.084	0.109	0.140	0.181	0.233	0.298	0.382	0.487	0.621	0.789	1.000	1.265	1.598	26
27	0.076	0.100	0.130	0.169	0.220	0.285	0.368	0.474	0.609	0.781	1.000	1.277	1.627	27
28	0.069	0.092	0.121	0.159	0.208	0.272	0.354	0.461	0.598	0.774	1.000	1.288	1.656	28
29	0.063	0.084	0.112	0.149	0.197	0.259	0.342	0.448	0.587	0.767	1.000	1.300	1.686	29
30	0.057	0.077	0.104	0.139	0.186	0.248	0.329	0.436	0.577	0.760	1.000	1.312	1.717	30
35	0.036	0.050	0.071	0.100	0.140	0.196	0.274	0.380	0.526	0.726	1.000	1.373	1.879	35
40	0.022	0.033	0.049	0.072	0.106	0.156	0.227	0.331	0.480	0.694	1.000	1.436	2.056	40
45	0.014	0.021	0.033	0.052	0.080	0.123	0.189	0.288	0.438	0.663	1.000	1.503	2.250	45
50	0.009	0.014	0.023	0.037	0.061	0.098	0.157	0.251	0.400	0.633	1.000	1.572	2.462	50

Escalation Rates (column headings 0%–12%)

Note : All amounts end-of-year

Upv Modified

d= 2% **d= 2%**

UPV* - Modified Uniform Present Value Factors

Discount Rate d = 2%

Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year
1	0.980	0.990	1.000	1.010	1.020	1.029	1.039	1.049	1.059	1.069	1.078	1.088	1.098	1
2	1.942	1.971	2.000	2.030	2.059	2.089	2.119	2.149	2.180	2.211	2.241	2.272	2.304	2
3	2.884	2.942	3.000	3.059	3.119	3.180	3.242	3.304	3.367	3.431	3.496	3.561	3.628	3
4	3.808	3.903	4.000	4.099	4.200	4.303	4.408	4.515	4.624	4.735	4.848	4.964	5.081	4
5	4.713	4.855	5.000	5.149	5.302	5.459	5.620	5.785	5.955	6.129	6.307	6.490	6.678	5
6	5.601	5.797	6.000	6.209	6.425	6.649	6.880	7.118	7.364	7.618	7.880	8.151	8.430	6
7	6.472	6.731	7.000	7.280	7.571	7.874	8.189	8.516	8.856	9.209	9.577	9.958	10.35	7
8	7.325	7.655	8.000	8.361	8.739	9.135	9.549	9.982	10.44	10.91	11.41	11.93	12.47	8
9	8.162	8.570	9.000	9.453	9.930	10.43	10.96	11.52	12.11	12.73	13.38	14.07	14.79	9
10	8.983	9.476	10.00	10.56	11.14	11.77	12.43	13.13	13.88	14.67	15.51	16.39	17.34	10
11	9.787	10.37	11.00	11.67	12.38	13.14	13.96	14.83	15.75	16.74	17.80	18.93	20.13	11
12	10.58	11.26	12.00	12.79	13.64	14.56	15.54	16.60	17.74	18.96	20.28	21.69	23.21	12
13	11.35	12.14	13.00	13.93	14.93	16.02	17.19	18.47	19.84	21.33	22.94	24.69	26.58	13
14	12.11	13.01	14.00	15.07	16.24	17.52	18.91	20.42	22.07	23.86	25.82	27.96	30.28	14
15	12.85	13.88	15.00	16.23	17.58	19.06	20.69	22.47	24.43	26.57	28.93	31.51	34.35	15
16	13.58	14.73	16.00	17.40	18.95	20.65	22.54	24.62	26.92	29.46	32.27	35.38	38.82	16
17	14.29	15.58	17.00	18.58	20.34	22.29	24.46	26.88	29.56	32.55	35.88	39.59	43.72	17
18	14.99	16.41	18.00	19.77	21.76	23.98	26.46	29.24	32.36	35.86	39.78	44.17	49.10	18
19	15.68	17.24	19.00	20.98	23.20	25.71	28.54	31.73	35.32	39.39	43.97	49.16	55.02	19
20	16.35	18.06	20.00	22.19	24.68	27.50	30.70	34.33	38.46	43.16	48.50	54.58	61.51	20
21	17.01	18.88	21.00	23.42	26.18	29.33	32.94	37.06	41.78	47.19	53.38	60.49	68.63	21
22	17.66	19.68	22.00	24.66	27.71	31.23	35.27	39.93	45.30	51.50	58.65	66.91	76.46	22
23	18.29	20.48	23.00	25.91	29.28	33.17	37.69	42.93	49.02	56.10	64.33	73.91	85.06	23
24	18.91	21.27	24.00	27.17	30.87	35.18	40.21	46.09	52.96	61.02	70.45	81.52	94.49	24
25	19.52	22.05	25.00	28.45	32.50	37.24	42.82	49.40	57.14	66.27	77.06	89.8	104.9	25
26	20.12	22.82	26.00	29.74	34.15	39.37	45.54	52.87	61.56	71.89	84.18	98.8	116.2	26
27	20.71	23.59	27.00	31.04	35.84	41.56	48.37	56.51	66.24	77.89	91.86	108.6	128.7	27
28	21.28	24.35	28.00	32.36	37.56	43.81	51.30	60.32	71.19	84.31	100.1	119.3	142.4	28
29	21.84	25.10	29.00	33.68	39.32	46.12	54.36	64.33	76.44	91.16	109.1	130.9	157.5	29
30	22.40	25.85	30.00	35.02	41.11	48.51	57.53	68.53	82.00	98.48	118.7	143.5	174.0	30
35	25.00	29.46	35.00	41.92	50.60	61.54	75.35	92.8	115.1	143.4	179.5	225.6	284.5	35
40	27.36	32.90	40.00	49.17	61.07	76.59	96.95	123.7	159.1	205.9	268.1	350.7	460.8	40
45	29.49	36.17	45.00	56.77	72.59	94.00	123.1	163.0	217.7	293.1	397.4	541.8	742.2	45
50	31.42	39.29	50.00	64.76	85.30	114.1	154.9	212.8	295.7	414.6	585.9	833.4	1191	50

Escalation Rates (column headings 0%–12%)

Note : All amounts end-of-year

d= 4%

...ied Uniform Present Value Factors

Discount Rate d = 4%

Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year
							Escalation Rates							
1	0.962	0.971	0.981	0.990	1.000	1.010	1.019	1.029	1.038	1.048	1.058	1.067	1.077	1
2	1.886	1.914	1.943	1.971	2.000	2.029	2.058	2.087	2.117	2.147	2.176	2.206	2.237	2
3	2.775	2.830	2.886	2.943	3.000	3.058	3.117	3.176	3.237	3.298	3.360	3.422	3.486	3
4	3.630	3.720	3.811	3.905	4.000	4.097	4.196	4.297	4.400	4.504	4.611	4.720	4.831	4
5	4.452	4.584	4.719	4.858	5.000	5.146	5.296	5.450	5.607	5.769	5.935	6.105	6.279	5
6	5.242	5.423	5.609	5.801	6.000	6.205	6.417	6.636	6.862	7.095	7.335	7.583	7.839	6
7	6.002	6.237	6.482	6.736	7.000	7.274	7.560	7.856	8.164	8.484	8.816	9.161	9.519	7
8	6.733	7.028	7.338	7.662	8.000	8.354	8.724	9.111	9.516	9.940	10.38	10.84	11.33	8
9	7.435	7.797	8.178	8.578	9.000	9.444	9.911	10.40	10.92	11.47	12.04	12.64	13.28	9
10	8.111	8.543	9.001	9.486	10.00	10.54	11.12	11.73	12.38	13.06	13.79	14.56	15.37	10
11	8.760	9.268	9.809	10.39	11.00	11.66	12.35	13.10	13.89	14.74	15.64	16.61	17.63	11
12	9.385	9.972	10.60	11.28	12.00	12.78	13.61	14.51	15.47	16.50	17.60	18.79	20.07	12
13	9.986	10.66	11.38	12.16	13.00	13.91	14.89	15.95	17.10	18.34	19.68	21.12	22.69	13
14	10.56	11.32	12.14	13.03	14.00	15.05	16.20	17.44	18.80	20.27	21.87	23.61	25.51	14
15	11.12	11.96	12.89	13.90	15.00	16.21	17.53	18.97	20.56	22.29	24.19	26.27	28.55	15
16	11.65	12.59	13.62	14.75	16.00	17.37	18.88	20.55	22.39	24.41	26.64	29.11	31.82	16
17	12.17	13.20	14.34	15.60	17.00	18.55	20.27	22.17	24.29	26.63	29.24	32.13	35.35	17
18	12.66	13.79	15.04	16.44	18.00	19.74	21.68	23.84	26.26	28.96	31.98	35.36	39.14	18
19	13.13	14.36	15.74	17.27	19.00	20.94	23.11	25.56	28.31	31.40	34.89	38.81	43.23	19
20	13.59	14.92	16.41	18.10	20.00	22.15	24.58	27.32	30.43	33.96	37.96	42.49	47.63	20
21	14.03	15.46	17.08	18.91	21.00	23.37	26.07	29.14	32.64	36.64	41.20	46.42	52.38	21
22	14.45	15.98	17.73	19.72	22.00	24.60	27.59	31.01	34.94	39.45	44.64	50.61	57.48	22
23	14.86	16.49	18.37	20.52	23.00	25.85	29.14	32.93	37.32	42.39	48.27	55.08	62.98	23
24	15.25	16.99	19.00	21.32	24.00	27.11	30.72	34.91	39.79	45.48	52.11	59.86	68.90	24
25	15.62	17.47	19.61	22.10	25.00	28.38	32.33	36.95	42.36	48.72	56.18	64.95	75.28	25
26	15.98	17.94	20.22	22.88	26.00	29.66	33.97	39.04	45.03	52.11	60.48	70.39	82.15	26
27	16.33	18.39	20.81	23.65	27.00	30.96	35.64	41.20	47.80	55.66	65.02	76.20	89.54	27
28	16.66	18.83	21.39	24.41	28.00	32.26	37.35	43.41	50.68	59.38	69.83	82.39	97.51	28
29	16.98	19.26	21.96	25.17	29.00	33.58	39.08	45.70	53.67	63.29	74.92	89.01	106.1	29
30	17.29	19.68	22.52	25.92	30.00	34.92	40.85	48.04	56.77	67.38	80.30	96.06	115.3	30
35	18.66	21.58	25.15	29.55	35.00	41.77	50.23	60.83	74.16	90.98	112.2	139.2	173.3	35
40	19.79	23.23	27.54	33.02	40.00	48.97	60.55	75.58	95.17	120.8	154.5	198.8	257.3	40
45	20.72	24.65	29.71	36.32	45.00	56.51	71.89	92.58	120.5	158.6	210.4	281.5	379.0	45
50	21.48	25.88	31.68	39.46	50.00	64.43	84.37	112.2	151.2	206.3	284.5	396.0	555.3	50

Note : All amounts end-of-year

d= 10%　　d= 10%

UPV* - Modified Uniform Present Value Factors

Discount Rate d = 10%

Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year
							Escalation Rates							
1	0.909	0.918	0.927	0.936	0.945	0.955	0.964	0.973	0.982	0.991	1.000	1.009	1.018	1
2	1.736	1.761	1.787	1.813	1.839	1.866	1.892	1.919	1.946	1.973	2.000	2.027	2.055	2
3	2.487	2.535	2.584	2.634	2.684	2.735	2.787	2.839	2.892	2.946	3.000	3.055	3.110	3
4	3.170	3.246	3.324	3.403	3.483	3.566	3.649	3.735	3.821	3.910	4.000	4.092	4.185	4
5	3.791	3.899	4.009	4.123	4.239	4.358	4.480	4.605	4.734	4.865	5.000	5.138	5.279	5
6	4.355	4.498	4.645	4.797	4.953	5.115	5.281	5.453	5.630	5.812	6.000	6.194	6.394	6
7	4.868	5.048	5.234	5.428	5.628	5.837	6.053	6.277	6.509	6.750	7.000	7.259	7.528	7
8	5.335	5.553	5.781	6.019	6.267	6.526	6.796	7.078	7.372	7.680	8.000	8.334	8.683	8
9	5.759	6.017	6.288	6.572	6.871	7.184	7.513	7.858	8.220	8.601	9.000	9.419	9.859	9
10	6.145	6.443	6.758	7.090	7.441	7.812	8.203	8.616	9.053	9.51	10.00	10.51	11.06	10
11	6.495	6.834	7.194	7.575	7.981	8.411	8.868	9.354	9.870	10.42	11.00	11.62	12.28	11
12	6.814	7.193	7.598	8.030	8.491	8.983	9.510	10.07	10.67	11.31	12.00	12.73	13.52	12
13	7.103	7.523	7.972	8.455	8.973	9.530	10.13	10.77	11.46	12.20	13.00	13.86	14.78	13
14	7.367	7.825	8.320	8.853	9.429	10.05	10.72	11.45	12.23	13.08	14.00	14.99	16.07	14
15	7.606	8.103	8.642	9.226	9.860	10.55	11.30	12.11	12.99	13.95	15.00	16.14	17.38	15
16	7.824	8.358	8.941	9.576	10.27	11.02	11.85	12.75	13.74	14.82	16.00	17.29	18.71	16
17	8.022	8.593	9.218	9.903	10.65	11.48	12.38	13.38	14.47	15.67	17.00	18.46	20.07	17
18	8.201	8.808	9.475	10.21	11.02	11.91	12.90	13.98	15.19	16.52	18.00	19.64	21.45	18
19	8.365	9.005	9.713	10.50	11.36	12.32	13.39	14.58	15.89	17.36	19.00	20.83	22.86	19
20	8.514	9.187	9.934	10.76	11.69	12.72	13.87	15.15	16.59	18.20	20.00	22.02	24.30	20
21	8.649	9.353	10.14	11.02	12.00	13.09	14.33	15.71	17.27	19.02	21.00	23.23	25.76	21
22	8.772	9.506	10.33	11.25	12.29	13.45	14.77	16.25	17.94	19.84	22.00	24.45	27.24	22
23	8.883	9.647	10.50	11.47	12.56	13.80	15.20	16.78	18.59	20.65	23.00	25.68	28.76	23
24	8.985	9.776	10.67	11.68	12.82	14.12	15.61	17.30	19.24	21.45	24.00	26.93	30.30	24
25	9.077	9.894	10.82	11.87	13.07	14.44	16.00	17.80	19.87	22.25	25.00	28.18	31.87	25
26	9.161	10.00	10.96	12.05	13.30	14.73	16.38	18.29	20.49	23.04	26.00	29.45	33.46	26
27	9.237	10.10	11.09	12.22	13.52	15.02	16.75	18.76	21.10	23.82	27.00	30.72	35.09	27
28	9.307	10.19	11.21	12.38	13.73	15.29	17.11	19.22	21.70	24.59	28.00	32.01	36.75	28
29	9.370	10.28	11.32	12.53	13.93	15.55	17.45	19.67	22.28	25.36	29.00	33.31	38.43	29
30	9.427	10.36	11.43	12.67	14.11	15.80	17.78	20.11	22.86	26.12	30.00	34.62	40.15	30
35	9.644	10.66	11.84	13.24	14.90	16.88	19.25	22.12	25.59	29.82	35.00	41.36	49.21	35
40	9.779	10.85	12.13	13.65	15.49	17.73	20.48	23.87	28.08	33.36	40.00	48.42	59.13	40
45	9.863	10.98	12.32	13.95	15.94	18.41	21.50	25.39	30.35	36.73	45.00	55.80	69.99	45
50	9.915	11.07	12.46	14.16	16.28	18.95	22.34	26.72	32.43	39.96	50.00	63.52	81.87	50

Note : All amounts end-of-year