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Energy Efficiency in Housing

Drivers and Barriers to Improving Energy Efficiency and Reducing Carbon Dioxide Emissions in Private Housing Sector

Thesis Submitted for the Degree of Doctor of
Philosophy in Architecture

By

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Dedication

This thesis is dedicated to my divine parents, for their unconditional love and support.

Mustafa Haşim Altan & Ayşe Mustafa Altan

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I am forever indebted to my family, who has given me the biggest support of all times to attain this height in my educational pursuit.

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Abstract

Global environmental degradation is one of the most serious threats facing humankind as a result of the expansion of its activities around the globe. Scientific evidence is growing that greenhouse gas emissions are having a noticeable effect on the earth's climate. Sustainable development has become a global issue and its life cycle influences the life cycles of the whole planet dramatically. As widely accepted, CO_2 emissions are the most significant impact on global climate caused by the amount of energy consumed (Kyoto Protocol, 1997). The UK Government has signed the United Nations Framework Convention on Climate Change in 1992 and is therefore committed to reducing the emission of six greenhouse gases with carbon dioxide being the most significant to 12.5% lower than the 1990 levels (DEFRA, 2000). The Government has also indicated that it has an aim of further reducing the emissions with an eventual target of 20% below the 1990 levels by 2010. Energy consumed by the UK building stock approaches 50% of the total while transport is responsible for 28% (DETR, 2000). Accordingly the energy used in housing stock is responsible for about 30% of overall emissions (Shorrock and Walters, 1998), which is a major contributor to global warming and therefore, improving energy efficiency and reducing carbon dioxide emission within housing stock is a key factor for long-term sustainability in the built environment.

This research aims to study the energy efficiency standards, CO_2 emissions and energy ratings of privately rented, university controlled and approved properties within Sheffield. In general, properties in this particular sector account for about 15% of the total housing stock and demonstrate one of the worst conditions of housing standards in the UK (Revell and Leather, 2000). In this research however, properties analysed have shown better characteristics regarding energy efficiency standards especially when compared to the worst housing examples in the country. This is mainly due to properties being controlled and approved by the university standards/requirements, and resulted in achieving higher energy efficiency standards within the privately rented sector. Case study analysis carried out includes over 200 privately rented properties, showing dwelling conditions and examining efficiency of both water and space heating systems.

As a global matter, environmental issues and good building design have also been increasingly important in the UK. For that reason, energy and environmental assessment methods for buildings have been developed in order to accomplish good building design, which could contribute considerably to reducing pollution and improving the environment. These assessment methods identify criteria for a range of issues also concerning the global, national and indoor environments. Due to the importance of building energy and environmental assessment methods, many components have to be discussed for the future of buildings and more emphasis should be paid to encouraging property developers to utilise the appropriate methods in order to design energy conscious buildings. Some of the existing methods concerning 'Environment and Healthy Building' developed and used in the country have been reviewed and discussed in the perspective of global effects.

In this study, having chosen university-controlled properties would therefore help to utilise the university authority to take action effectively and play a key role in guiding energy efficiency improvements within privately rented properties. With university authority, potential improvements in these properties can be encouraged and implemented much effectively, whilst existing legislation and policies are inoperative to enforce retrospective energy standards in existing housing. Furthermore, this has a negative impact on private rented sector and comes into being a major barrier for this particular sector. Therefore, this is an opportunity that will not only increase energy standards of the housing stock in Sheffield, but also help to achieve the rate of improvement required by the Home Energy Conservation Act 1995 and reduce the overall energy consumption caused by the existing housing stock in the country.

INTRODUCTION

CHAPTER ONE: ENERGY AND THE ENVIRONMENT

CHAPTER TWO: HOUSING TYPOLOGY IN THE UK

CHAPTER THREE: ENERGY AND ENVIRONMENTAL ASSESSMENT METHODS FOR BUILDINGS IN THE UK

CHAPTER FOUR: ENERGY CONSUMPTION IN DOMESTIC BUILDINGS

CHAPTER FIVE: CASE STUDIES WITHIN PRIVATE HOUSING SECTOR IN SHEFFIELD

CONCLUSION

APPENDIX A: QUESTIONNAIRE, SAP AND FEEDBACK REPORT

APPENDIX B: GREENHOUSE GASES AND ENERGY CONSERVATION

APPENDIX C: PUBLICATIONS

List of Figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

List of Tables

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

Introduction

1. Background

As broadly accepted, global warming is now forever on the world's agenda. According to the UN Inter-Governmental Panel on Climate Change (IPCC), an immediate reduction in carbon dioxide (CO_2) emissions of at least 60% is required to stabilise concentrations in the atmosphere in the long term. Moreover, the Royal Commission on Environmental Pollution (RCEP) Report on Climate Change (22nd Report) has warned that increasing atmospheric concentrations of greenhouse gases, particularly CO_2, will have serious impacts on the world's climate (DEFRA, 2000). The report further suggests that the evidence is mounting that climate change could have a significant effect on the UK and therefore the UK would have to reduce its emissions by 60% by 2050.

On the other hand, the UK Government's Climate Change Programme set to deliver 20% reduction from 1999 level by 2010 has suggested that this may be insufficient with current measures (DETR, 2000). Given that the domestic sector is a major contributor to the UK's total CO_2 emissions (about 30%), this is an important area to tackle effectively. In the UK, while new buildings achieve a high level of energy efficiency through the standards enforced by Part L of the building regulations, existing housing stock experiences from one of the lowest energy efficiency levels in Europe, with average SAP rating 51 (Shorrock and Utley, 2003). Therefore, action in this area is evidently needed if both social and environmental sustainability is to be achieved.

Being aware of all this, the author has become more concerned with energy efficiency in housing and possible impact caused on the environment. His main concern and focus area has become 'energy conservation' and 'why it is vital in our environment'. During the past twenty-five years energy for heating buildings has been relatively low-priced, mainly with the effect of utility privatisation on prices and designers felt able to work without taking energy conservation into account. However this situation has now started to change due to increasing price and potential shortage of world oil and therefore designers will have to show careful consideration not only to building regulations, which prescribe a minimum standard, but also to other factors in design, which will also reduce energy consumption. Energy conservation is important for many reasons, such as economic, environmental and social (see appendix B).

Before 1973, little action was taken towards energy conservation. With the rapid increase on energy prices in 1970s, international attention has been given to an energy conservative way of life. The problem of energy use and availability is common to a greater or lesser extent throughout the world. While the industrialised nations depend heavily upon fossil fuels for their industrial processes, the developing nations also desire to increase their technological capabilities and thus the use of energy in its various forms. In the last fifty years, there has been a tremendous increase in world energy use, partly as a result of the availability of easily extractable fossil fuels (coal, gas and oil) and awareness of the limited nature of these reserves existed since 1970s. Although it is unlikely that the world will completely run out of fossil fuels in the next millennium, the majority of easily extractable reserves are located in a small part of the world and the prices due to increase (see 'World Energy Use' section in chapter 1 for more details).

Nowadays, fossil fuels are too costly to be burned; they should be used wisely, not wastefully or/and again not for the purpose of cooling, heating, etc. It must be stressed that the world's fossil fuel energy is limited by geological conditions. We are living in a period where energy demands must be reduced through any means available. These should also include; conservation of energy, employment of renewable energy, energy-conscious planning and design of buildings. In this stage, it could be said that the renewable energy sources should be the primary energy sources of 21st Century, as being a free source of energy (derived from solar radiation, including direct use of solar energy for heating or electricity and indirect forms such as energy from the wind, waves, etc.) and thereby reducing the associated environmental impact on our very environment in worldwide (Boyle, 1996).

Solar energy is a renewable resource, which can easily be a plentiful contribution to heating and lighting in buildings and has an important role in sustainable development in our environment. There is plenty of sunshine available and if only properly controlled, can help to reduce energy use in buildings. This energy is also a non-polluting source and therefore its effective utilisation helps to reduce emissions of carbon dioxide and other gases resulting from the use of fossil fuels. Every building has certain amount of its heating requirements met by solar energy. Sunlight passing through windows is a source of heat; however most buildings are not specifically designed to utilise this solar energy. The value of passive solar heating is enhanced by proper building insulation. A well-insulated building requires less energy for heating; and thus passive solar features can meet much of the heating load.

Actions to improve housing energy efficiency could result in great energy savings, both for cooling and especially for heating. Among all efforts to improve energy efficiency, application of thermal insulation in building envelope components (i.e. ceilings, walls, floors and glazing) is the most effective and important factor. In addition to reduction in space heating and cooling costs on a long-term basis, other benefits such as occupant's comfort and smaller capacity requirements for heating and cooling systems would be achieved. Due to considerable savings in operating costs and initial costs, insulation pays back its investment in a short period of time. It is a well-known fact that solar energy as an important and non-polluting renewable energy source can make a vast contribution to energy savings, which can again limit environmental damage, conserve fossil fuel reserves and save money.

With the UN Framework Convention on Climate Change in 1992, UK has committed to reducing the emission of the basket of six greenhouse gases with carbon dioxide being the most significant to 12.5% lower than the 1990 levels by 2010. Energy consumed by the building stock approaches 50% of the total energy consumption as oppose to transport being 28%. Furthermore energy used only in domestic building sector is responsible for about 30% of overall carbon dioxide emission and considerably is a major contributor to the global warming. Over the 25 years period (1973 - 1998), despite the increase mentioned above, the total energy consumed within a home by the average UK household fell by about a tenth (Shorrock and Walters, 1998). Now this fall is mostly attributable to a decline in the average number of people per household, to an increase in insulation and draught proofing as new homes are built and existing dwellings are improved, and to the introduction of more energy efficient heating systems.

2. Scope of the Problem

Today, if we were to analyse current conditions and energy standards of UK housing stock, we would easily conclude that there are potentials for energy efficiency improvements, particularly in the private sector. According to the English House Condition Survey (EHCS) Reports published in 1998 and 2003, there are considerable scope for improvements in the energy efficiency and thermal performance of the existing housing stock. The vast majority of existing housing has an average SAP rating of 51, which falls well below modern building regulation and energy standards (Shorrock and Utley, 2003).

In the UK, local authorities can only have a little influence on the private sector, which accounts for the majority of the stock, and this therefore remains a great challenge for the government, whilst there is no enforced legislation of energy standards in the private sector. Consequently, this research has focused on the privately rented properties within this sector that also accounts for about 15% of the total housing stock and demonstrates one of the worst conditions of housing standards in the country (Revell and Leather, 2000).

Furthermore, the UK has a reputation for poorly heated homes, low indoor temperatures and a general preference for sweaters over building insulation especially when compared to other European countries and therefore experiences higher levels of inequality and poverty (Stephens, et. al., 2002). Although there has been a rapid growth in central heating and greatly improved heating standards over the last two decades, low levels of insulation remains a problem.

Moreover, revised building regulations will only affect new housing and therefore legislation for energy efficiency improvements in existing housing should be properly enforced. Accordingly, standards need to be progressively raised and more effectively supervised. Even so, it is clear that regulations on their own will not be sufficient to achieve a really substantial improvement in the overall environmental performance of dwellings. They will need to be supplemented and reinforced by stronger policy direction, and a more proactive programme to increase public and professional awareness of the objectives and the potential for improvement.

3. Actions to tackle Existing Problems

The main mechanisms currently in place for addressing energy efficiency in homes are briefly explained below:

The Energy Efficiency Standards of Performance (EESoP), the precursor of Energy Efficiency Commitment (EEC), was introduced as a mechanism to assist in delivery of climate change policy, whereas Warm Front was initially more socially based to promote affordable warmth.

The Home Energy Conservation Act (HECA) requires Local Authorities to plan to improve the energy efficiency of housing in their area by 30% on a baseline of 1995 by 2010.

Energy efficiency measures also form part of energy security; the performance and innovation unit (PIU) report on energy policy has been published emphasising energy efficiency as a key strand of future energy policy. The report recommends an improvement target for home energy efficiency of 10% by 2010 and a further 20% by 2020.

The Government's Decent Homes standard is a four-part definition. Social housing providers are required to identify all homes that do not meet these standards and propose a plan to bring them up to standard by 2005.

Links between cold homes and ill-health are well established. The Health Act addressed the organisation of health care in the UK, such that the emphasis now falls on Primary Care Trusts (PCTs) to deliver local care working through the network of health professionals (HMSO, 1999).

The UK Quality of Life headline indicators include poverty, health, housing and climate change and give a snapshot of the state of the country as a result of measures and events for sustainable development (HMSO, 1999).

4. Research Hypothesis

The broad question driving this research is:

Can the UK meet its domestic sector goal to reduce carbon dioxide emissions to 20% below 1990 levels by 2010?

To do so, will improving energy efficiency and reducing carbon dioxide emissions within privately rented sector actually help to deliver positive results and achieve long-term sustainability in the domestic sector?

This research attempts to answer the primary question by taking into consideration the secondary question, which is investigating potentials for energy efficiency improvements and reduction of carbon dioxide emissions in the privately rented sector. It is important to emphasise that the aim of this study is to determine potentials for improving energy efficiency and reducing carbon dioxide emissions in existing housing, particularly in the private sector.

5. Research Aims and Objectives

- To provide a database of the current conditions and energy standards of privately rented properties.
- To investigate potentials for energy efficiency improvements and reduction of carbon dioxide emissions in the privately rented sector.
- To evaluate and review energy and environmental assessment methods, and their applications in terms of energy efficiency and carbon index (CI).
- To identify a way of cost effective modifications to dwelling base designs which can improve energy efficiency within privately rented properties.
- To develop case study results that can be used by landlords/landladies to encourage energy conservation.
- To promote general recommendations for immediate energy savings throughout privately rented properties analysed with supplementary documentation enclosed within feedback reports compiled.

6. Research Methodology

The work for this research has investigated the potential for energy efficiency in privately rented properties within Sheffield. The research methodology was as follows:

Current conditions of these properties including the efficiency of space and water heating systems in use were examined.

SAP ratings of these dwellings with respect to CO_2 emissions were calculated.

Reductions of carbon dioxide emissions due to modifications conducted to base designs were identified and compared to the current situation of the properties and therefore necessary energy efficiency improvements were suggested in order to optimise energy use and CO_2 emission consumed accordingly.

Additional to SAP ratings and CO_2 emissions calculated; total costs of energy use for space and water heating, natural ventilation and heat loss in these properties were also examined.

245 properties have been studied; existing conditions (with relevant SAP rating), total costs of energy use (both for space and water heating), CO_2 emissions, effective air change in the property (natural ventilation) and heat loss parameters have been determined.

Furthermore, the research has also been followed up by the comparison between results obtained from Stelrad Software (Home Assessment Rating Procedure) and SAP Calculation Program (version 9.53).

7. Thesis Structure

This section provides a summary guide to this thesis. This thesis consists of eight sections including chapters and appendices, which can be summarised as follows:

Introduction

This section contains the introduction, which gives a background to the issues in this area. It also includes a descriptive introduction to the scope of the problem, aims and objectives, methodology and the thesis structure.

Chapter 1. Energy and the Environment

This chapter outlines energy use and the environment on the whole and looks at the history of energy use and alternative energy sources in the UK. Renewable energy has also been reviewed in order to comprehend why it is necessary to replace fossil fuels. Moreover, this chapter considers the action that is currently being taken both internationally and in the UK to tackle the effects, which our energy use has on our environment.

Chapter 2. Housing Typology in the UK

This chapter reviews the typology of existing UK housing and examines the profile of the stock by type, age and region to determine influences that will affect building designers when tackling issues regarding energy efficiency improvements and carbon dioxide emissions in existing stock. In this chapter, energy efficient house design and benefits for its occupants have also been reviewed.

Chapter 3. Energy and Environmental Assessment Methods for Buildings in the UK

This chapter reviews the main existing energy and environmental assessment methods for buildings in the UK and presents a comparison chart to assist users choosing the appropriate method for the building energy study and environmental impact assessment. Furthermore, the importance of using existing assessment methods and why they should be integrated within building design and thermal performance analysis has also been discussed.

Chapter 4. Energy Consumption in Domestic Buildings

This chapter outlines the pattern of domestic sector energy use and determines potential improvements in this sector to help the UK meet its international commitment. In this chapter, embodied energy of materials and energy efficiency basics have been reviewed. This chapter also talks about the Home Energy Conservation Act 1995 and examines complications experienced by local authorities in meeting 30% improvement rate in domestic energy efficiency by 2010. Moreover, the UK government's Home Information Pack, which is due to be introduced, has been considered as well.

Chapter 5. Case Studies within Private Housing Sector in Sheffield

This chapter presents case study analysis carried out in privately rented properties within Sheffield and assesses energy efficiency standards of these dwellings. Calculations of CO_2 emissions and SAP ratings have been included and modifications to basic designs with respect to other energy efficiency measures have also been examined. In addition, case study results have been supported with potential energy efficiency improvements suggested.

Conclusion

Conclusions are drawn and further recommendations are specified regarding the case study analysis undertaken in privately rented properties within Sheffield. Furthermore, in this section, the UK's domestic sector goal to reduce carbon dioxide emissions, the main greenhouse gas, to 20% below 1990 levels by 2010 and to deliver the required standards have also been discussed with respect to the current conditions and energy standards of these privately rented dwellings analysed.

Several papers were published as part of the research and these papers are included in appendix C. A list of all the appendices is given below:

Appendix A. Questionnaire, SAP and Feedback Report

Appendix B. Greenhouse Gases and Energy Conservation

Appendix C. Publications

1 Energy and the Environment

1.1 Introduction

This research study is aimed at energy efficiency in housing and potential improvements in existing housing in the UK. This chapter outlines energy use and the environment on the whole and additionally looks at the history of energy use and alternative energy sources in the UK. Renewable energy is also reviewed in order to understand why it is essential to replace fossil fuels. Moreover, this chapter considers the action that is currently being taken both internationally and in the UK to tackle the effects, which our energy use impacts on our environment.

Energy plays a central role in human life and therefore its demand and use is increasing continuously as the world population increases. Energy sustains life and provides the facility that is certainly needed in people's lives. Today, the world is facing various environmental problems, which have come to the public consciousness. Many of these are largely the result of large-scale fuel use. One of the most significant problems appears to be that of 'global warming', a gradual increase in the global averaged air temperature at the earth's surface. The majority of scientists now believe that global warming is probably taking place, at a rate of around 0.3°C per decade, and that it is caused by increases in the concentration of so-called 'greenhouse gases' in the atmosphere (Houghton, et al., 1990 and 1992).

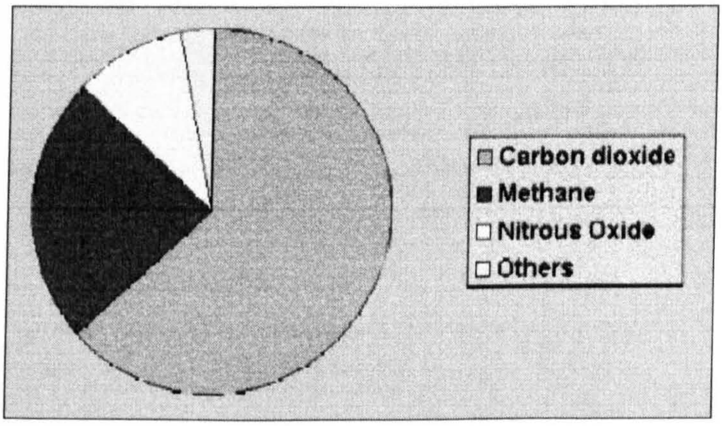
Despite the latest draft report from the UN Inter-Governmental Panel on Climate Change (IPCC) stating that the burning of fossil fuels has contributed substantially to the observed warming over the last 50 years, there is still a lobby that believes that there is still no definitive answer to the question as to weather the current episode of global warming is being driven by human activity or is a fluctuation due to natural causes. However, there is widespread evidence that changes in the earth's climate are occurring at a rate almost unprecedented. It is the wide scale evidence of anomalous climatic events coupled with the rate at which they are occurring that has convinced the IPCC scientists that the finger of blame points to human activities rather than natural causes (for further details, see appendix B).

1.2 Global Warming and the Greenhouse Effect

There are four main gases that cause global warming: Carbon dioxide (CO_2), methane (CH_4), the chlorofluorocarbons (CFCs) and nitrous oxide (N_2O). Carbon dioxide's warming contribution is about 50%, whereas the contribution of methane, the CFCs and nitrous oxide are approximately 18%, 14% and 6% respectively. The shockingly large contribution of these latter gases is due the fact that methane is 25 times more effective than CO_2 as a greenhouse gas, the chlorofluorocarbons up to 10,000 times and nitrous oxide 150 times. In contrast, carbon dioxide is more important due to the fact that it is integrally bound up with the carbon cycle and our use of fossil fuels (Harland, 1995).

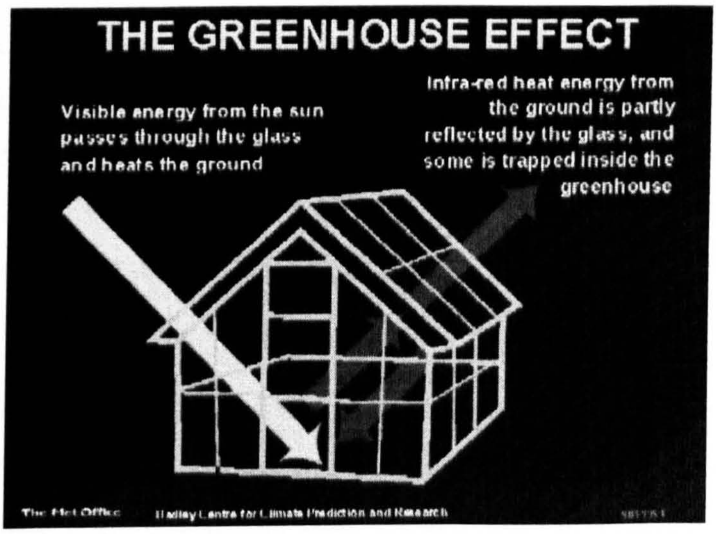
The scientific evidence is growing that man-made greenhouse gas emissions are having a noticeable effect on the earth's climate. CO_2 has played a significant role in moderating the increase of the amount of the sun's energy falling on the earth since the beginning of life. Globally, seven of the ten warmest years on record were in the 1990's. In the future, the earth's climate could warm by as much as 3°C over the next 100 years (see figure 1.1). We are in a danger of destroying this delicate natural balance by exhausting even increasing quantities in to the atmosphere and the results could be catastrophic. During the energy crisis in 1970s, the concern was with our diminishing reserves of gas, oil and coal. However today, the concern is to reduce CO_2 emission, which reaches the atmosphere. For more information on 'list of greenhouse gases' and 'how to compare the relative climate effects of greenhouse gases', see appendix B.

Figure 1.1: Relative Warming Effect of Current Emissions of Greenhouse Gases over next 100 years. (Met Office 2001)



A balance between energy coming in from the sun in the form of visible radiation (sunlight) and energy constantly being emitted from the surface of the earth to space determines the temperature of the earth. The energy coming in from the sun can go through the atmosphere almost unchanged and warm the earth; however the infrared radiation emanating from the earth's surface is partly absorbed by some gases in the atmosphere and re-emitted downwards. This further warms the surface of the earth and the lower atmosphere. The gases that play a big role in this naturally are mainly water vapour and carbon dioxide. An analogy is made with the effect of a greenhouse, which allows sunshine to penetrate the glass that in turn keeps the heat in, hence the greenhouse effect (see figure 1.2) (DEFRA, 2000).

Figure 1.2: The Greenhouse Effect. (Met Office 2001)



Without this natural greenhouse effect, the earth would be over 30°C cooler and would be too cold to be habitable. Nevertheless as greenhouse gas concentrations increase well above their natural levels, the additional warming that will take place could threaten the future sustainability of the planet. For further information about scientific and technical review on climate research (2000/1), visit www.met-office.gov.uk.

1.3 World Energy Use

1.3.1 Background

Today, modern societies and particularly industrial societies are entirely dependent upon the use of large quantities of energy, which are mostly in the form of fossil fuels. Energy is regarded as essential for the growing, distribution and preparation of foods, used for construction, manufacturing, communication and the organisation of other various activities. World's energy use review is always useful in order to understand the modern use of energy in our time. Mankind has used wood fires to keep warm, to provide light and to cook food for over a million years. Fire was also used to extract and work metals, fire clay pots and bricks. Yet again, animals were used for traction in agriculture and wind was used to power ships in the Mediterranean for over six thousand years ago. The power of wind and water were the source of energy used in mills and for many centuries natural forces, such as wind and water have been the main source of providing energy for transportation and production. These energy sources are still predominant in many parts of the less industrialised world.

It was the industrial revolution, which had crucial impact on changes in energy use and introduced the increase in dependence on fossil fuels. After the steam engine was invented, which was burning coal and coke fuels; water mills, which were running water as the power source, were replaced. Throughout the revolution coal and iron ores were plentiful and therefore, crude techniques and inefficient energy use were engaged in industrial processes, despite adverse environmental effects, which were not fully appreciated. Towards the end of the nineteenth and early twentieth century, the electricity and the internal combustion engine, oil and gas as additional fuels were developed. Energy was supplied directly from combustion of oil or gas in engines or from electricity generated from burning coal, oil and gas or from hydroelectric plant (Boyles, 1996).

The widespread distribution networks of electricity began in countries in the mid-twentieth century and progressed rapidly to the point that it was almost available universally. Industrial culture became entirely dependent on fossil fuel with the opening of major oil fields in the Middle East and North Africa. After the Second World War, nuclear sources of electricity were introduced as an additional energy source and fossil fuels were still seen as inexpensive and plentiful. The use of these fuels was mostly inefficient whilst their environmental effects were still largely ignored. In the twentieth century, manufacturing has continued to increase, but is no longer the largest sector of the economy. Services, particularly communications and information processing, have become dominant activities, accompanied by developments in support technologies.

Since the late 1960's there has been a growing recognition of the environmental impact of industrial societies, and especially of the burning of fossil fuels. With the oil crises in 1970's, there has been a significant growth in new techniques for making more efficient use of energy and providing energy from renewable sources. Major reductions in fuel use are now seen as technically possible, simply through care and attention to the energy aspects of the design of buildings, equipment and industrial processes, and many other methods. The understanding of energy efficiency was only beginning to be applied in 1990's; however, economic constraints have been a major difficulty.

Interest in renewable energy has been growing steadily over the past twenty-five years and today only few observers would perceive a future without renewables contributing to world energy demand. Yet again, recent studies indicate that renewable energy will make a substantial contribution to global energy supplies in the longer term. Increased concerns about the environment, particularly the impacts of conventional energy systems on global warming has revitalised interest in renewable energy technologies, which has little or no net emissions of polluting gases and is widely seen as part of the solution. Furthermore, interest in non-conventional energy sources, new and renewable energy, also arises from the recognition that the commercial forms of energy in popular use today such as liquid and gaseous hydrocarbons and solid forms of fossil fuels-represent limited and eventually exhaustible resources of energy (Boyle, 1996).

1.3.2 Energy Consumption

Modern societies, particularly industrial societies, are now largely dependent upon the use of large quantities of energy from fossil fuels. In 1992, the estimated total world consumption of primary energy (in all forms) was approximately 400EJ per year, equivalent to some 9500 million tonnes of oil equivalent (mtoe) per year. Assuming, a world population of about 5300 million, this gives an annual average world-fuel-use equivalent to about 1.8 tonnes of oil per person per year. This is equivalent to about 470 imperial gallons of oil per person per year (Boyle, 1996).

The magnitude of the energy problem that may face future generations can be illustrated by the following calculation: the world's population stood at approximately 5 billion people, in 1990. The best UN estimates population trend show it continuing to increase to around 8 billion by 2025, but stabilising towards the end of the next century at somewhere between 10 and 12 billion people. Most of that increase will be in the less developed countries (LDCs). Fuels are used at an average rate in the developed countries, which is more than six times that in the LDCs (see table 1.1).

Table 1.1: Increase in Energy Use expected as a result of Population Increases. (Boyle 1996)

Year	Population	Total Energy Use		Energy Use Per Person	
	(Billion)	*(EJ/y)*	*(TW)**	*(GJ/y)*	*(KW)*
1990 (dev)	1.2	284	9.0	237	7.5
1990 (ldc)	4.1	142	4.5	35	1.1
1990 (world)	5.3	426	13.5	80	2.5
2025 (dev)	1.4	167	5.3	120	3.8
2025 (ldc)	6.8	473	15.0	69	2.2
2025 (world)	8.2	640	20.3	78	2.5

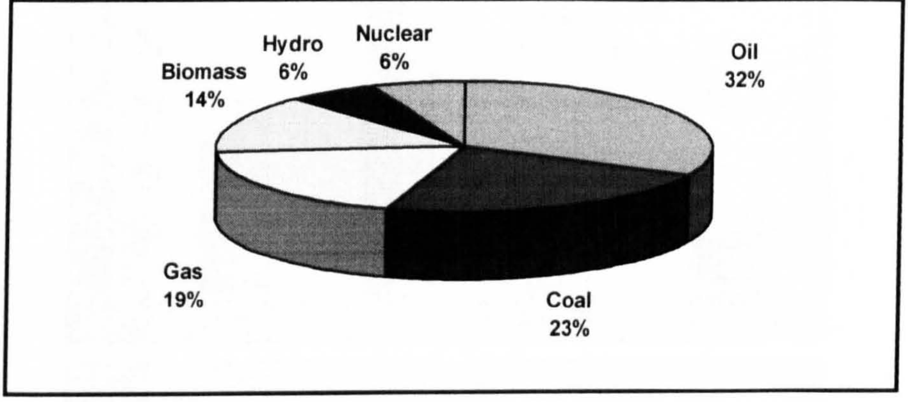
Note: *: Equivalent Continuous Power, dev: Developed Countries, ldc: Less Developed Countries

It can be seen that the developed countries use nearly twice as much fuel as the LDCs, despite the fact that they have less than a third of their population. Given the expected population increase, there is still a rise of 50% in the overall level of global energy use.

A breakdown of world primary energy consumption by source in 1992 is shown on table 1.2: Oil is the dominant fuel, contributing some 32%, followed by coal at 23%. Coal was once the dominant world fuel, but is now losing ground rapidly to oil and gas, which has a 19% share. Hydroelectricity and nuclear are much less used, at around 6% each, with biomass at about 14% (DTI, 1995).

Table 1.2: Estimated Annual Energy Consumption, 1992. (Boyle 1996)

Oil	Coal	Gas	Biomass	Hydro	Nuclear
32%	23%	19%	14%	6%	6%

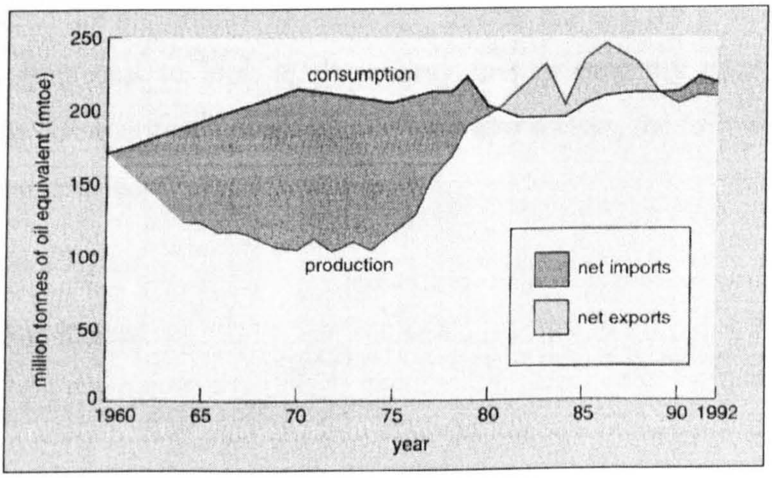


1.4 Energy Use in the UK

1.4.1 Background

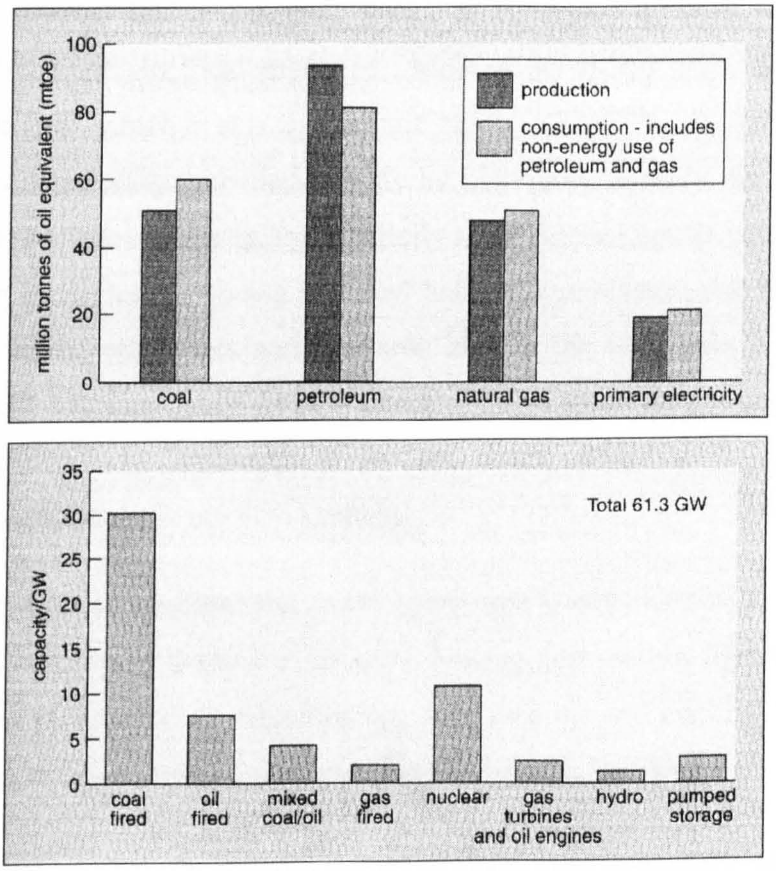
The UK has substantial energy resources, including large reserves of coal, oil and gas, which make it self-sufficient. Figure 1.3 below, shows UK energy production and consumption between 1960 and 1992.

Figure 1.3: UK Energy Production and Consumption, 1960-1992. (DTI 1993)



Gas and oil are known as primary sources and all made major contributions to UK energy consumption in 1992, as shown in figure 1.4. Additionally, electricity from hydro and nuclear plants is known as primary electricity sources, while electricity generated by burning primary fuels is known as secondary electricity sources (Boyle, 1996).

Figure 1.4: Production and Consumption of Primary Fuels in the UK in 1992. (DTI 1993)



1.4.2 Potential Renewable Energy Use

To understand the importance of renewable energy use and the problem of present use of fuels, it is best to look at the energy that is currently used in industrial societies. If the UK energy use was to be divided into sectors, the following four main sectors can be identified:

- Transport Sector
- Domestic Sector
- Commercial and Institutional Sector
- Industrial Sector

Energy in UK transport sector is dominated by road transport and this accounts for about 80% of energy used in this sector, which again is mainly consumed by private cars. The main reason for using fossil fuels, particularly oil for transport purposes is that they are inexpensive, easily stored in vehicles, widely available and has high energy density.

The main energy use in domestic sector is for space heating, water heating, cooking, lighting and electrical appliances. Most of the energy used, around 85%, is for low-grade heat, which is at a temperature below about 80°C, for space and water heating. This is generally provided directly by high-grade sources, by burning fuels directly, or much less efficiently, by electricity from thermal power plants. There are now so many examples of housing with low heating requirements that the heat given off cooking, lights, appliances and the body heat of the occupants is sufficient to supply virtually all their space heating needs. This is again why energy efficiency housing is particularly important, as we are facing global warming and other environmental problems in our environment.

The commercial and institutional sector energy use is quite similar to the domestic sector, which is currently dominated by space heating, followed by lighting, electrical appliances and equipment, air conditioning, water heating and cooking. Then again, the energy use in this sector differentiates from building to building.

The industrial sector varies both within and between countries. Generally the largest category of end use energy is process heat, often at high temperatures, as in the iron and steel or chemical industries. In this sector the principle approaches to improved efficiency start with shifts from more to less energy intensive industries; more efficient motors, drives and controls; more careful use of energy-intensive materials such as aluminium; shortened process routes, which replace a larger number of energy consumption stages by a direct pathway to the end product; yield improvements on given process routes; technical changes to raise process efficiencies; and greater use of integrated energy technologies such as CHP and heat recovery schemes (Boyle, 1996).

1.5 Environmental Problems

The main environmental problems currently loom in the public consciousness are briefly described below:

1.5.1 Acid Rain

This is another side effect of burning fossil fuels. Acid rain is a term, which is used to describe a variety of processes that might more accurately be referred to as acidic deposition. Natural rainfall is slightly acidic due to dissolved carbon dioxide, picked up in the atmosphere. Organisms and ecosystems all over the planet have adapted to the slightly acidic nature of normal rain, and thus it poses no environmental problems. It is an increase in the acidity of rain, caused by human activities such as the combustion of fossil fuels, which again has turned acid rain into a problem. Highly acidic rain can damage or destroy aquatic life, forests, crops and buildings, as well as posing a threat to human health.

There are basically two ways of reducing acid rain:

- Emission control technologies can be attached to smokestacks at power plants and other industries, removing the acid gases before they are emitted into the atmosphere.
- Another alternative is to burn less high sulphur fossil fuel. Switching to alternative sources of energy, or improving the efficiency of our energy consuming technologies can accomplish this.

Ultimately, the most effective methods of reducing acid rain are renewable energy and energy efficiency. Renewable energy technologies such as solar and wind energy can produce electricity without any emissions of sulphur dioxide or nitrous oxides and additionally both have the added benefit that also result in reduced emissions of carbon dioxide, the greenhouse gas most responsible for global warming (Houghton, et, al., 1992).

1.5.2 Oil Pollution

Power stations and oil refineries can cause significant visual intrusions and produce significant smells and other effluent locally. Although the transportation of oil is generally a safe industry, the scale of it and the size of the tankers; means that when accidents do occur, they have a large net effect on the environment. For example, in 1989 in Alaska, USA, about 40 million litres of crude oil spilled into the ocean from the supertanker 'Exxon Valdez', which caused massive environmental damage (clean up cost over US$2 billion) (http://www.uneptie.org).

1.5.3 Environmental Sustainability and Climate Change

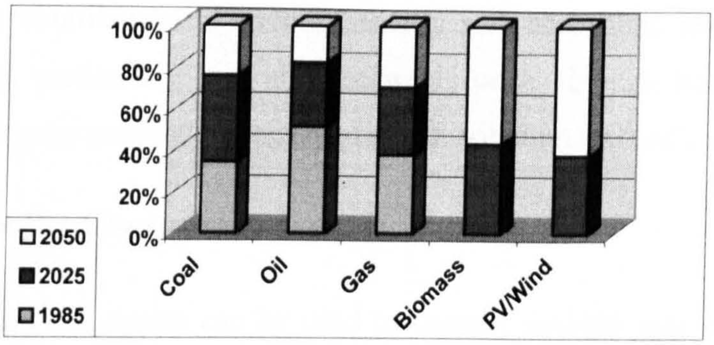
The continual man-made emissions of 'Greenhouse Gases' are resulting in global atmospheric warming, local climate changes and sea-level rise with the prospect of consequent serious environmental, social and economic impacts. The most comprehensive scientific assessment of climate change was conducted by Working Group I of the Inter-Governmental Panel on Climate Change, which is organized jointly by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). For more information on Global Warming and the Climate Change, see section 1.2.

1.6 Renewable Energy

Renewable energy is the term used to cover the energy flow, which occurs repeatedly in the environment and can be harnessed for human benefit. International Energy Agency statistics forecast that by the middle of the 21st century, renewable energy sources could account for three-fifths of the market for fuels used directly and two-fifths of the market for fuels used directly, (see table 1.3). It is widely accepted within the international scientific community.

Table 1.3: Direct Fuel-Use for the Renewable-Intensive Global Energy Scenario. (Johansson 1997)

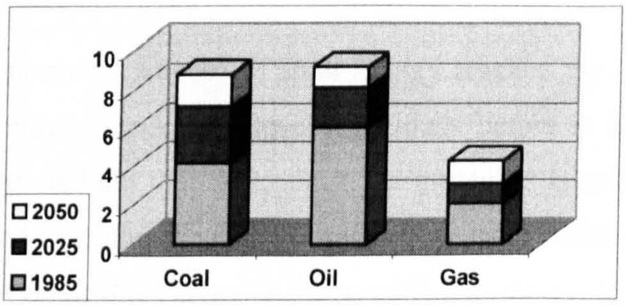
	1985	2025	2050
Coal	34.85	41.82	23.64
Oil	51.81	30.91	17.28
Gas	38.18	32.73	29.09
Biomass	0	43.64	56.36
PV/Wind	0	38.18	61.82



Making a transition to a 'renewable-intensive' energy economy would provide environmental and other benefits not measured in standard economic accounts. Recent studies indicate that by 2025 global carbon dioxide emissions would be reduced to 75% of their 1985 levels, provided energy efficiency and renewables are both pursued aggressively (see table 1.4). Renewable energy is expected to be competitive with conventional energy; such benefits could be achieved at no additional cost (Johansson, 1997).

Table 1.4: World per capita Emissions of CO_2 for Renewable-Intensive Global Energy Scenario. (Johansson 1997)

	1985	2025	2050
Coal	4.16	2.94	1.62
Oil	6.02	2.06	1.03
Gas	2.06	1.03	1.18



The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, in June 1992, addressed the challenges of achieving worldwide sustainable development. The goal of sustainable development cannot be realised without major changes in the world's energy system. Accordingly, 'Agenda 21', which was adopted by UNCED, called for 'new policies or programs, as appropriate, to increase the contribution of environmentally safe and sound and cost-effective energy systems, particularly new and renewable once, through less polluting and more efficient energy production, transmission, distribution and use'.

1.7 Passive Solar Energy

Many different techniques can be used to convert sunlight into useful forms of energy. Active and passive solar energy technologies are generally used for space conditioning (heating and cooling), while solar electric technologies such as photovoltaic cells convert sunlight into electricity. Although the distinction between active and passive solar is blurred, the use of integral building components to capture the sun's energy is considered passive solar. Active solar technologies are generally add-on features, which utilise mechanical means to distribute captured solar energy. An example of active solar energy is a solar hot water heater, while passive solar features may be as simple as south facing windows. Passive solar features can be used to heat and cool buildings, as well as provide light. The best time to incorporate passive solar technologies into a building is during the initial design. These features can often be included in new buildings without significantly adding to construction costs, while providing energy savings of up to 40%. Designing buildings to capture the ambient energy of the sun through passive solar features is one of the least expensive and most environmentally friendly methods of providing for our energy needs (Jefferson, et al., 1991).

Each year, an enormous amount of solar energy reaches the earth's atmosphere. Much of this is reflected back into space by clouds before it reaches the planet's surface. 99% of the sunlight that does reach the ground is converted into heat (the other 1% is captured by plants through photosynthesis) and radiated back into space. If only a small fraction of this energy could be captured, the world's energy demands could be met (EMRC, 1990). The capture of solar energy by passive solar technologies has almost no negative impact on the environment. Passive solar energy gives off no air or water emissions and therefore does not contribute to any of the environmental problems such as acid rain and global warming. The sun is an infinite and free source of energy, which is 'renewable' and will never become depleted like fossil fuels. There is nothing new about using the sun's energy to heat our living spaces; humankind has used passive solar techniques for thousands of years. In many countries, inexpensive and plentiful fossil fuels have led to the abandonment of passive solar energy. Rediscovering passive solar energy and incorporating technological advances can go a long way towards creating a more sustainable energy future.

Direct solar gain, increased thermal mass and attached sunspaces are the most common features of passive solar heating. Direct solar gain, the main source of passive solar heat, is accomplished by capturing the sun's energy through large areas of south facing windows. Window glass is virtually transparent to incoming solar radiation. When sunlight strikes the interior of a building, it is converted into heat, which is not as readily transmitted back through the glass, thus resulting in a heat gain inside the house. Window glass, however, is generally not a good insulator, and increased solar heat gain during the day can be offset by loss of heat through windows at night. New high efficiency, triple glazed windows with special coatings have recently been developed that have such a high insulation value that they are net producers of heat even when facing north in the winter (Howes and Fainberg, 1991).

Solar cooling on the other hand may sound impractical but there are a variety of ways in which the sun's energy, although indirectly, can be used to cool the interior of buildings. The two most common methods of passive solar cooling are the use of vegetation (trees and vines) and natural ventilation (wind). An example of painting buildings a light colour to reflect sunlight and keep them cool is also often considered to be a passive solar construction technique.

Daylighting is the use of sunlight to replace electric lighting in a building. There is no such technology at the current time capable of storing sunlight for release at a later time. Daylighting is therefore most valuable in applications such as office buildings where most of the lighting demand occurs during the day. Windows provide light for the perimeter of buildings while atria, light-shelves and light-pipes, can transmit daylight into the interior of buildings. In combination with electronic 'photo-sensor' controls, which adjust electric lights according to light levels, daylighting features can drastically reduce the amount of electricity required to light a building. The use of daylighting has often been seen as contradictory to the need for keeping a building cool in the summer. Sunshine streaming through a window provides daylight, but is also a source of heat. While this heat is valuable in the winter, it can make buildings unbearably hot in the summer. An example of new window technologies such as films, which let in light but not heat, and 'smart windows' whose transparency can be adjusted by an electric current, have helped to reconcile the need for both light, and heat in buildings.

Passive solar energy has the potential to supply a large proportion of energy needs for a properly designed building such as house. The best opportunity for using passive solar features is in new construction. Before the proliferation of fossil fuels, architects usually designed buildings to utilise available solar energy for heating, cooling and lighting. Recent advances in technology and building materials have greatly expanded the available tools for architects to work with. Passive solar energy, while often seen as 'low-technology', represents in many cases, the cleanest and least expensive possible source of useful energy for buildings (ICLEI, 1993).

1.8 Agenda on Climate Change

1.8.1 The International Framework on Climate Change

In response to increasing concerns about climate change, the United Nations Framework Convention on Climate Change was agreed at the Earth Summit in Rio de Janeiro in 1992. Under the Convention, all developed countries agreed to aim to return their greenhouse gas emissions to 1990 levels by 2000.

It was then quickly recognised that the Convention commitments could only be a first step in the international response to climate change. Climate prediction models showed that deeper cuts in emissions would be needed to prevent serious interference with the climate. The Kyoto Protocol was designed to address this issue and was agreed in December 1997. Accordingly, developed countries agreed to targets, which will reduce their overall emissions of a basket of six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by 5.2% below 1990 levels over the period 2008 - 2012. This was the first time these targets would be legally binding and differentiated between Parties to the Convention.

Under the Kyoto Protocol; the European Union (EU) agreed to an 8% cut in greenhouse gas emissions and under a burden sharing agreement amongst its member states, the United States (US) agreed to a 7% cut, Japan agreed to a 6%, Russia and the Ukraine to return to 1990 levels, and Australia was allowed an 8% increase.

1.8.2 The UK's Climate Change Programme

Following the Kyoto Protocol, the UK agreed to a 12.5% cut in greenhouse gas emissions below 1990 levels by 2008 - 2012. The Government and the devolved administrations also have a domestic goal to reduce the UK's emissions of carbon dioxide, the main greenhouse gas, by 20% below 1990 levels by 2010. The UK will continue to be committed to working at international level to encourage global responsibility and action, not only in relation to climate change, but also more widely in terms of the environmental impact of energy generation and use.

In November 2000, the government with the devolved administrations published the UK Climate Change Programme aimed at meeting the UK's Kyoto target and moving towards its domestic goal. The programme sets out a far-reaching strategy for tackling climate change in the UK. It aims to ensure that the UK moves towards a more sustainable, low carbon economy. It puts in place policies that indicate clear signals about the changes that need to be made in the longer term and outlines a variety of measures that will deliver cut in emissions from all sectors of the economy for the remainder of this decade and beyond.

The UK's programme is a significant contribution to the global response to climate change and the government estimates the package of measures included in the programme could cut the UK's greenhouse gas emissions to 23% below 1990 levels in 2010, or 19% in carbon dioxide alone. The government also believes that there will be clear benefits for the UK by moving beyond its Kyoto target towards its domestic goal. Consultation on the programme has revealed that many businesses agree that taking early action and starting the transition to a low carbon economy will bring financial and economic gains. The programme includes a flexible, cost effective set of policies and measures that will help to achieve these objectives, safeguard the UK's competitiveness and also deliver wider benefits for the environment and society (DETR, 2000).

On the other hand, the Utilities Act 2000 has contributed to the government's environmental objectives in a number of ways. It has introduced a power to place an obligation on companies to increase the proportion of electricity generated from renewable sources. It has transferred from the Office of Gas and Electricity Markets (OFGEM) to the government the power to set energy saving targets by encouraging consumers to take up energy efficiency improvements. It has also set the framework for the government to issue guidance to the Regulatory Authority on its environmental and social policies to which the Authority must have regard in making its decisions (DEFRA, 2000).

1.9 Conclusion

Today, global warming is one of the most serious environmental problems the world faces. Floods, storms and droughts in the UK and across the world show clearly how vulnerable the countries are to climate extremes and how high the human, environmental and economic costs can be. As most of the scientists believe today, the climate change is now inevitable, but the worst effects can be avoided if the world acts now to reduce greenhouse gas emissions. Although it is now generally understood that the extreme weather patterns are probably due to global warming caused by increased carbon dioxide emissions to the atmosphere, there is no real consensus on how to tackle the problem and reduce emissions. With the media attention to environmental concerns, people are becoming increasingly conscious of the fact that their lifestyle is affecting the earth's very natural resources and environment. This approach also creates a considerable challenge for the energy policy and should be based on integrated economic, environmental and social policies to ensure that energy resources and use of these resources are sustainable now and for generations to come.

This chapter has looked at energy use and the environment on the whole and environmental concerns rose due to global warming and carbon dioxide emissions. The recent IPCC report has stated that to stabilise the concentrations of CO_2 emissions in the atmosphere at the necessary level, a reduction in emissions due to human activity in the order of over 60% will be required. Accordingly, buildings have been identified as a major source of carbon dioxide emissions and therefore a major contributor to global warming. In the UK, energy consumed by the building stock approaches 50% of the total while transport is responsible for 28% and predicted to rise significantly. Domestic energy use represents a large proportion of total national energy use and has risen from 25% of the total in 1970 to 30% in 2001. Clearly, housing energy consumption is a major contributor to global warming and has become one of the key elements of improving energy efficiency and reducing CO_2 emission in the country.

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2 Housing Typology in the UK

2.1 Background

The development of UK housing history began shortly before the Conquest during Norman occupation. First dwellings were showing Norman influence. This continued with Roman and Saxon times. Roman occupation of Britain had little permanent effect on native architecture. Today, in the UK, most of the existing housing stock background goes back to early 1850s. Many domestic buildings were designed during the remainder of the nineteenth century. The early eighteenth century was the time of rapid social change and the British population was growing at a furious pace through the nineteenth century.

2.2 Housing Typology

UK housing can be categorized under four main house types, which are listed below:

1. Purpose-Built Flats
    - Purpose-Built High-Rise Flat
    - Purpose-Built Low-Rise Flat
    - Converted Flat
2. Bungalows
3. Detached Houses
    - Detached House
    - Semi-Detached House
4. Terraced Houses
    - Large Terrace House
    - Medium Terrace House
    - Small Terrace House

2.2.1 Purpose-Built Flat

A flat in a built block that includes cases where there is only one flat with independent access in a building which is also used for non-domestic purposes. A built flat, which is in a block at least 6 stories high is a High-Rise Flat (see figure 2.1) and in a block less than 6 stories high is a Low-Rise Flat (see figure 2.2).

A flat resulting from the conversion of a house (generally other house types) or former non-residential building which includes buildings converted into a flat as well as commercial premises (typically corner shops) is a Converted Flat (see figure 2.3).

Figure 2.1: High-Rise Flats. (DOE 1996)

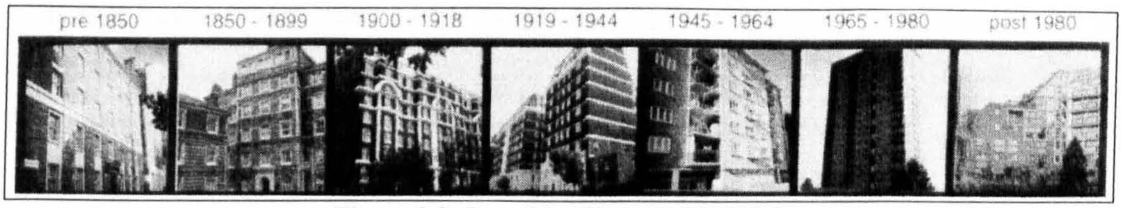


Figure 2.2: Low-Rise Flats. (DOE 1996)

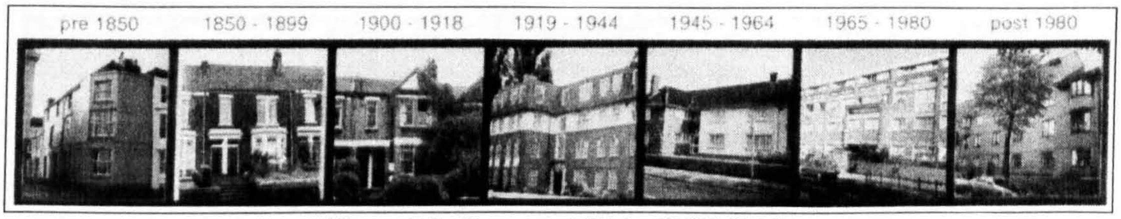
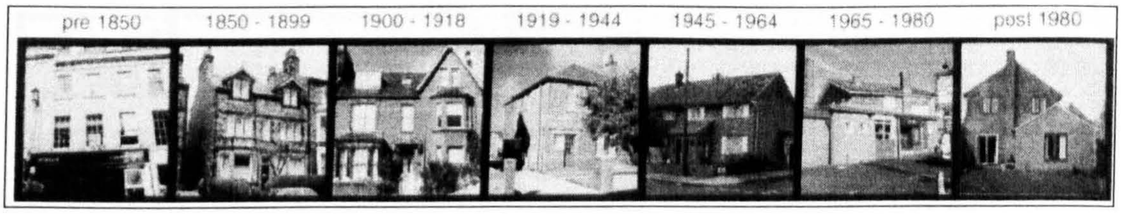


Figure 2.3: Converted Flats. (DOE 1996)



2.2.2 Bungalow

It is a house with all of the habitable accommodation on one floor. Excludes chalet bungalows and bungalows with habitable loft conversions, which are treated as houses. The name stems from the Indian word "bangla" or "of Bengal" and it was a relatively common house type in India.

Bungalows were particularly popular in Scotland. Partly this may have been smaller and Scottish house sizes have traditionally been smaller than those in

England, Wales and Northern Ireland (Department of the Environment, 1996). Basically, it can be seen as a flat with a garden.

Figure 2.4: Bungalows. (DOE 1996)

2.2.3 Detached House

It is a house where none of the habitable structure is joined to another building other than garages, etc (see figure 2.5). There is a type of detached house, Semi-Detached House, which is attached to one other house (see figure 2.6).

Figure 2.5: Detached Houses. (DOE 1996)

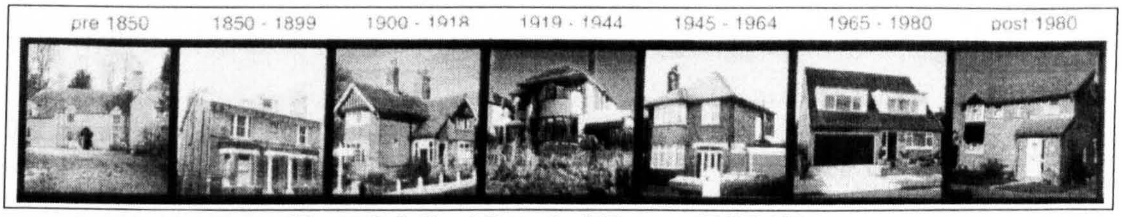
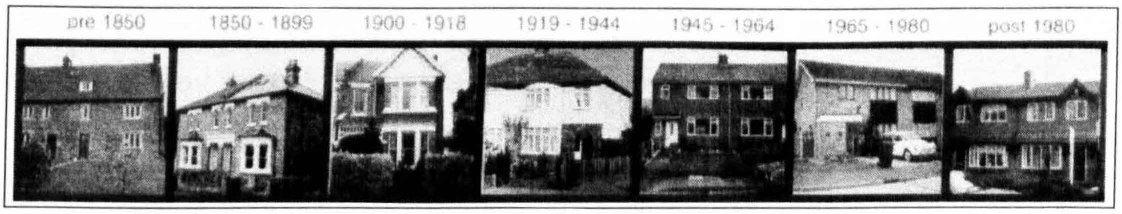


Figure 2.6: Semi-Detached Houses. (DOE 1996)



2.2.4 Terraced House

It is a house forming part of a block where at least one house is attached to two or more other houses. In the UK, especially at the beginning of the nineteenth century, terrace houses were the most common middle class urban house type. There are Small Terraced Houses, which are relatively small size compare to the large ones (see figure 2.7) and Medium/Large Terraced Houses, which are with fairly large size compare to the small ones (see figure 2.8).

Figure 2.7: Small Terraced Houses. (DOE 1996)

Figure 2.8: Medium/Large Terraced Houses. (DOE 1996)

Today, in the UK as well as in the world, the development of a more sustainable, ecological built environment is one of the major challenges for architects. Sustainable buildings are increasing and becoming more important every day. Therefore, energy efficient housing should also be included under the main housing typology in view of the fact that it has become a significant part of future housing scheme in the UK (see following section 2.2.5 for more information about energy efficient house design).

2.2.5 Energy Efficient House Design

It is the recent house design scheme that has the environmental concerns added to the design and also has major impact on world's approach to energy efficiency. An energy efficient house has many benefits for its habitants:

- The house is warmer in winter in general.
- The house has affordable fuel bills even for families on low incomes.
- The house minimises condensation possibility due to reduced heat loss via high insulation and better ventilation.
- The house is healthy, designed to have a long life and lower maintenance costs.
- The house reduces environmental pollution (e.g. carbon dioxide emissions) and this way has less impact on environment.

Figure 2.9: An Example of Energy Efficient House Design, 'The Integer House', which was developed at BRE Garston in 1998. (http://www.bre.co.uk 2001)

2.3 Existing Housing and the Profile of the Stock

According to the National Statistics and Regional Trends carried out in years 1991 and 1994, there were 24,248,000 total existing number of dwellings in the UK (Office for National Statistics, Regional Trends, 1996). The number of dwellings with reference to each individually country – in England: 20,219,000, in Wales: 1,219,000, in Northern Ireland: 600,000, and in Scotland: 2,210,000.

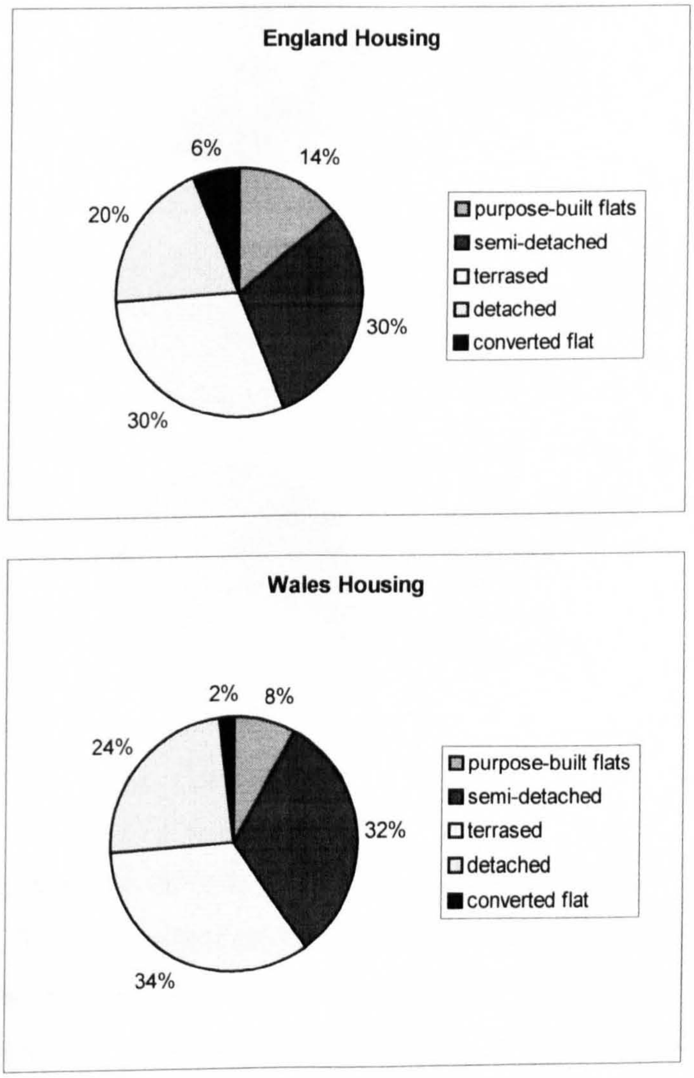
Table 2.1: Total Housing Stock in the UK, 1981 - 1994.
(Office for National Statistics, Regional Trends 1996)

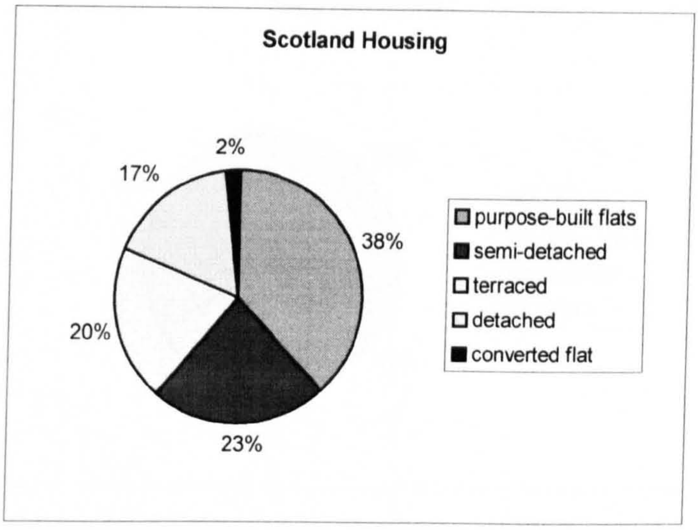
Country	1981 (000,s)	1986 (000,s)	1991 (000,s)	1992 (000,s)	1993 (000,s)	1994 (000,s)	Increase 1981-1994 (%)	Rates Per 1,000 Population 1994
England	18,025	18,883	19,788	19,927	20,070	20,219	12.2	425
Wales	1,089	1,128	1,191	1,201	1,210	1,219	11.9	418
Northern Ireland	502	540	573	580	590	600	19.5	366
Scotland	1,970	2,050	2,160	2,175	2,193	2,210	12.2	431

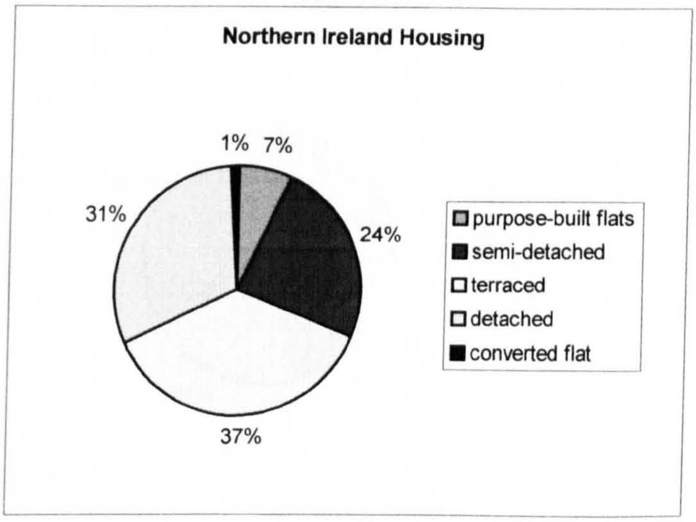
Furthermore, in England, there were some 20.4 million dwellings in 1996 (Department of the Environment, 1998). The stock has increased by 649,000 dwellings since 1991, some 696,000 dwellings have been added and some 130,000 have been lost. Of those dwellings added, 19,000 were through conversion and/or changes of use from non-residential to residential accommodation. The remaining dwellings were new built and almost all the new built has been for owner occupation or for register social landlords.

The housing typology profile varies within the UK. Figures 2.10 and 2.11 below illustrate the composition of the housing stock within the UK by type and age:

Figure 2.10: UK Housing Stock by Type, 1991/1993. (DOE 1996)

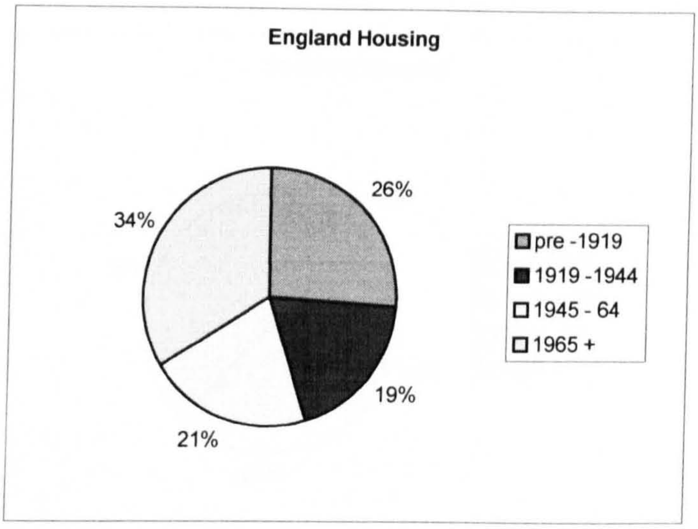


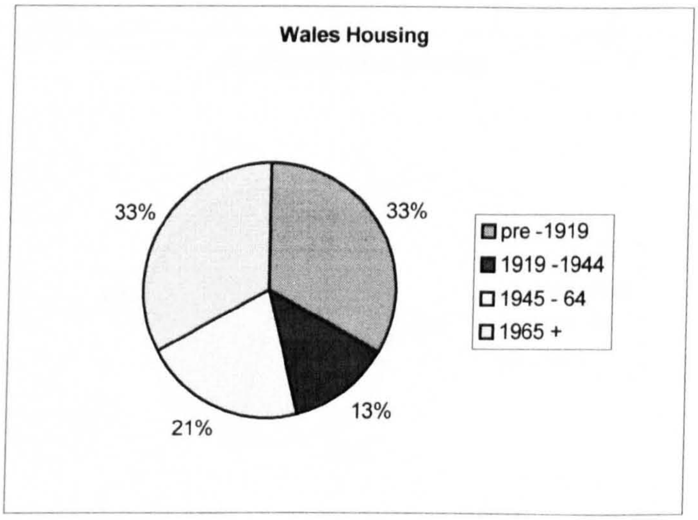


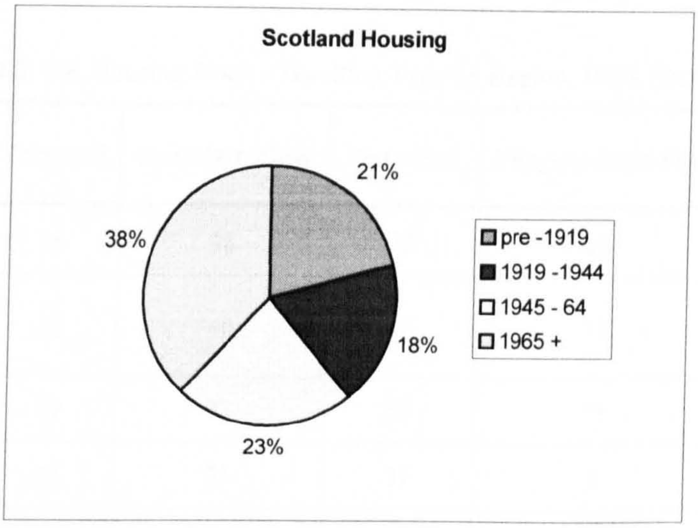


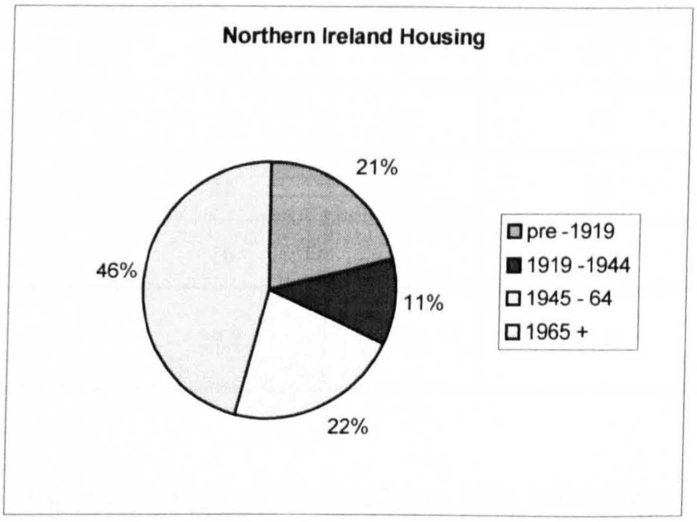
As it can be seen above, there are significant differences in the profile of houses by type in the UK. Both in England and Wales, semi-detached and terraced houses are the most common types of dwelling. In England, semi-detached and terraced houses are each accounting for 30% of the stock. In Wales, terraced houses are accounting for 34% and semi-detached houses are accounting for 32% of the stock. In Scotland, the stock profile is substantially different compare to England and Wales. Only 60% of dwellings are houses. Semi-detached houses are the most common type and accounting for 23% of all the dwellings. In Northern Ireland dwelling stock is more similar to that in England and Wales, with relatively few flats (8%, of which the majority are purpose-built). Terraced dwellings are the most common (37%), followed by detached houses (31%) and semi-detached houses (24%) (Leather and Morrison, 1997).

Figure 2.11: UK Housing Stock by Age, 1991/1993. (DOE 1996)









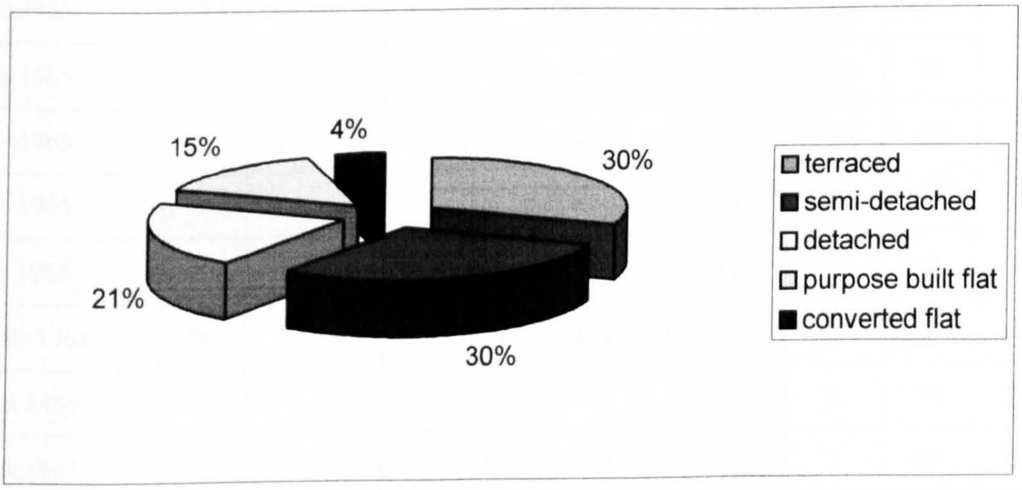
Then again, if we look at the profile of houses by age, we could easily see that, there are considerable differences in dwelling stock. Both in England and Wales almost half of the housing stock was built before 1944 with 26% and 33% respectively built before 1919. 34% of the dwellings stock in England was built after 1965 and in addition, in Wales, recently built houses are accounting for 33% of all the dwellings. Scotland's housing stock is slightly newer on average, however in Northern Ireland the stock is much more recent, with only 32% built before 1944 (Leather and Morrison, 1997).

The recent statistics of the housing stock in England by dwelling type is also given below:

Table 2.2: UK Housing Stock – Dwelling Type by Region, 1996. (DOE 1998)

Government Office Region	**Terraced**	**Semi-Detached**	**Detached**	**Purpose-Built Flat**	**Converted Flat**
North East	36	38	12	13	2
Yorkshire and the Humber	30	40	15	11	3
North West	37	33	17	11	2
East Midlands	25	35	31	8	2
West Midlands	29	34	21	13	3
South West	28	27	29	11	4
East of England	28	29	27	12	3
South East	28	26	28	11	6
London	32	16	5	37	11
England (dwellings %)	**30.5**	**29.8**	**20.5**	**14.9**	**4.3**

Figure 2.12: England Dwelling Types, 1996. (DOE 1996)



2.4 Conclusion

When focused on English housing stock, the highest profiles of houses by type are terraced and semi-detached houses accounting for 30% of all the dwellings. In addition, 45% of housing stock was built after 1944, which can also be seen as almost the half of all the dwellings is relatively recent (DOE, 1998). The table below is showing the relationship between dwelling age, tenure, type and energy rating (SAP):

Table 2.3: England Dwelling Types, 1996. (DOE 1998)

Dwelling Age	**Tenure**			**Type**	**Energy Rating (SAP)**			
	OO	***LA / HA***	***PR***		***Mean***	***Min***	***Max***	***<10 (%)***
Post 1980	OO			Terraced	56	21	72	0
Post 1980	OO			Semi-detached	46	18	63	2
Post 1980		LA / HA		Terraced	47	16	88	0
Post 1980		LA / HA		Semi-detached	47	16	88	0
1965-80	OO			Terraced	47	-13	70	2
1965-80	OO			Semi-detached	46	-20	68	1
1965-80		LA / HA		Terraced	43	-3	69	1
1965-80		LA / HA		Semi-detached	32	-14	62	7
Pre 1965	OO			Terraced	36	-23	71	5
Pre 1965		LA / HA		Semi-detached	28	-36	60	11
Pre 1965		LA / HA		Terraced	33	-19	65	8
Pre 1965			PR	Terraced	24	-19	56	18
Pre 1965			PR	Semi-detached	13	-38	47	40
1850-1964	OO			Semi-detached	33	-27	69	5
Post 1964			PR	Terraced	31	3	54	12
Post 1964			PR	Semi-detached	31	3	54	12

Note: The minimum and maximum values in the EHCS sample represent statically the range covered, on average, by over 99% of dwellings in the national stock of each type.
Categories listed and shaded are below average SAP rating (35).
Owner Occupied: OO, Local Authority / Housing Association: LA / HA, Private Rented: PR

As the table 2.3 shows, there is a variation in the overall energy efficiency (SAP ratings) between terraced and semi-detached houses in 1991. In general, the age of these dwelling types is the dominant influence together with tenure playing an important but secondary role. Moreover, the table is not only showing the mean SAP rating for terraced and semi-detached houses, but also showing the distribution from the worst to the best by age and tenure. The final column gives the percentage of dwellings in each group which have SAP ratings less than 10 and thereby fall within the worst of the existing stock.

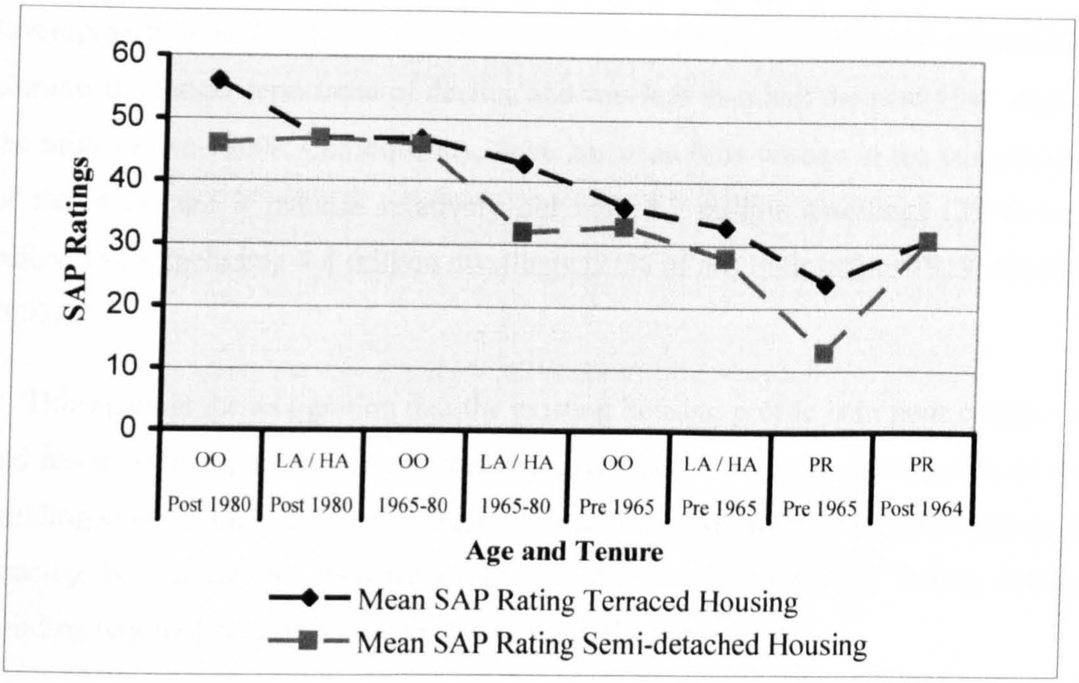
Therefore, in order to understand the frequency distribution of SAP ratings by dwelling age and tenure, see table 2.4 below:

Table 2.4: Comparison between Terraced and Semi-Detached Housing in England, 1996. (Generated 2000)

Terraced Housing			**Semi-Detached Housing**		
Dwelling Age	**Tenure**	**Mean SAP Rating**	**Dwelling Age**	**Tenure**	**Mean SAP Rating**
Post 1980	OO	56	Post 1980	OO	46
Post 1980	LA / HA	47	Post 1980	LA / HA	47
1965-80	OO	47	1965-80	OO	46
1965-80	LA / HA	43	1965-80	LA / HA	32
Pre 1965	OO	36	1850-1964	OO	33
Pre 1965	LA / HA	33	Pre 1965	LA / HA	28
Pre 1965	PR	24	Pre 1965	PR	13
Post 1964	PR	31	Post 1964	PR	31

Note: Categories listed and shaded are below average SAP rating (35).
Owner Occupied: OO, Local Authority / Housing Association: LA / HA, Private Rented: PR

Figure 2.13: Frequency distribution of SAP Ratings by Age and Tenure of two main House Types in England, 1996. (Generated 2000)



To conclude, it could be said that for all tenures on both housing types, the dwelling age and form are the important factors (see figure 2.13). These factors also determine the heat loss through the building envelope. As the English House Condition Survey (EHCS) explains, in England, many older buildings have been upgraded by the addition of roof and wall insulation (DOE, 1998). Besides, since 1964, building regulations also require progressively higher insulation standards for all new housing.

Overall, the age of the dwelling is the dominant influence together with tenure playing an important but secondary role (see both table 2.3 and figure 2.13). Both the table and figure show how the dwelling groups fall neatly into three blocks corresponding to the age bands 'post 1980', '1965-1980' and 'pre 1965'. There are only four exceptions to this rule, which can be explained by owner occupied properties rising into a higher SAP rating block or dwellings from the rented sectors slipping into a lower SAP rating block. Also within each block there is a fairly clear pattern of owner occupied properties being slightly more efficient than those owned by local authorities or housing associations, with private rented dwellings coming a poor third. Moreover, SAP ratings frequency distributed on figure 2.13 shows that terraced houses are being superior to semi-detached houses.

Furthermore, to summarise, there are 21.1 million dwellings in England with an increase of 800 thousand since 1996 and most additions were provided by new-build (averaging around 150 thousand each year) although the level of new construction continued a longer term trend of decline and was less than half the post-1945 high of the mid- to late-1960s. Consequently, there has been little change in the composition of the stock and it remains relatively old with 8.1 million dwellings (39%) built before 1945, including 4.4 million dwellings (21% of all) built before 1919 (ODPM, 2003).

This again is the recognition that the existing housing profile is in poor conditions and has a large impact on the environment given that it occupies the majority of the building stock in the country. It is therefore a serious concern and that more and more housing is causing the increase of carbon dioxide emission and falling behind building required standards, which should make the actual point.

This chapter has reviewed the housing typology in the UK and looked at the conditions of the existing housing stock to determine the influences which will affect building designers when tackling issues concerning energy efficiency improvements and carbon dioxide emissions in these dwellings. In addition, undertaken improvements within the last decade, and how poor the conditions were across different types of dwellings, households and areas have also been summarised. There is more and more revised data being published every five years by the Office of the Deputy Prime Minister (ODPM) on housing conditions and undertaken improvements.

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3 Energy and Environmental Assessment Methods for Buildings in the UK

3.1 Background

As a global matter, environmental issues and good building design have also been increasingly important in the UK for the last twenty years. Therefore, in order to accomplish good building design that could contribute considerably to reducing pollution and improving the built environment, building energy and environmental assessment methods have been developed. These assessment methods for buildings identify criteria for a range of issues also concerning the global, national and indoor environments. Furthermore, using these methods can help to achieve the following:

- To provide recognition for buildings, which are friendlier to the global environment than normal practice and therefore, help to simulate a market for them.
- To improve the indoor environment quality and occupants' health.
- To raise awareness of the dominant role which buildings play in global warming through the greenhouse effect; in production of acid rain, through the burning of fossil fuels for energy; and in depletion of the ozone layer.
- To reduce today's long-term impact that buildings have on the global environment.
- To reduce energy consumption, thus CO_2 emissions caused by buildings, and encourage savings of energy.
- To provide a common set of targets and standards and accordingly avoid the false claims of environmental friendliness.
- To encourage designers to achieve environmentally eco-sensitive and low energy building designs.

3.2 Existing Energy and Environmental Assessment Methods

In the UK, there are nine main methods that have been developed since early 1980s. Some of these methods are relatively in use today and have also been added to the building regulations to improve the building energy usage and increase the efficiency in the country.

The main building energy and environmental assessment methods including simulation tools, which have been developed since 1980's are listed below:

1. BREDEM
2. SAP
3. Environmental Standard - BREEAM
4. NHER
5. MNV STARPOINT
6. ENVEST
7. The Toolkit – The Office Toolkit
8. APACHE
9. TAS

3.2.1 BREDEM

The Building Research Establishment Domestic Energy Model provides a framework for calculation of energy use in buildings. It is an energy model developed in 1980s by the Building Research Establishment and adopted by the Energy Efficiency Office of the Department of Energy and the Department of the Environment to estimate energy costs and potential savings in housing. This model assesses the energy use in occupied dwellings and shows that the physical characteristics of a dwelling and the lifestyles of the occupants are about equally important in determining energy consumption.

Building Research Establishment Domestic Energy Model exists in a number of standardised versions, which differs in technical detail and in the precise requirements for data related to particular application. Some versions are designed to be implemented as computer programs while others are defined in such a way that do not require the use of a computer. The latest version is a particular development which is suitable for calculating SAP ratings in both new and existing dwellings, which can also be separated as one of main energy and environmental assessment methods in the list given above.

BREDEM is designed to be easy to use to provide reliable results and as well as based on practical experience gained through measurements made in many occupied buildings.

The main aims of this scheme are:

- To identify the various uses of energy in dwellings.
- To estimate the annual requirement for each use.

When space-heating requirements are calculated, all the physical details of the dwelling, the heating system, internal and external temperatures and the living pattern of its occupants are all taken in to account. Other energy uses are estimated from average consumptions derived from surveys, which are also appropriate to the composition and activities of household.

Figure 3.1: Various Uses of Energy in Dwellings. (BRE 1988)

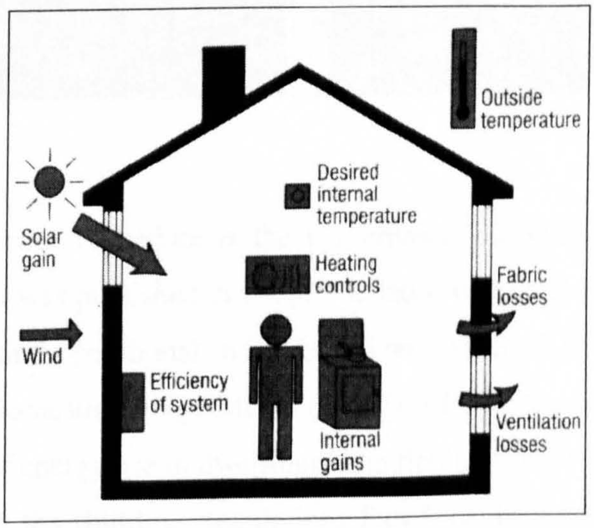


Figure 3.2: Comparison of Predicted and Actual Fuel Consumptions in Different House Types. (BRE 1988)

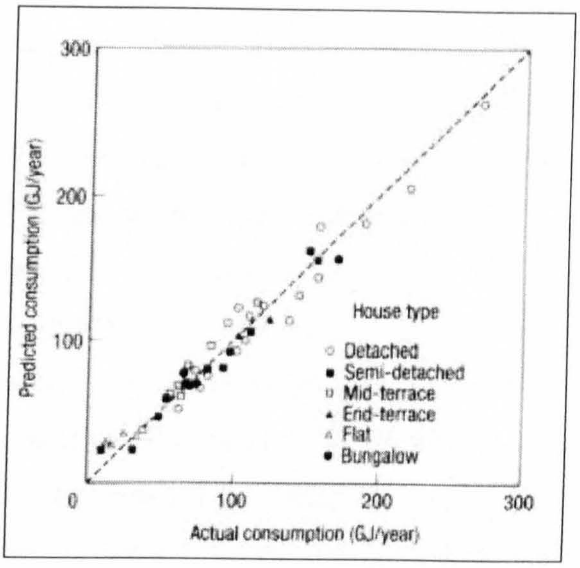


Figure 3.3: Example House; Before and After Refurbishment. (BRE 1988)

3.2.2 SAP

Standard Assessment Procedure is the Government's standard system for home energy rating, which was published in 1993. The latest edition is SAP 2001, published in December 2001 and operational in the UK. The SAP used to calculate the rating based on the BRE Domestic Energy Model (BREDEM), which provides a framework for the calculation of energy use in dwellings. The first edition (1993) was included as one means to satisfy the Building Regulations Part L Domestic Buildings since July 1995. The latest edition (2001), on the other hand, calculates the Carbon Index (CI) which can also demonstrate compliance with Approved Document L1 (England and

Wales) and Technical Part J (Scotland). Standard Assessment Procedure provides a manual guide for energy rating of dwellings and to energy efficiency in buildings. This manual guide describes the Government's SAP for producing an energy rating for a dwelling, which is based on calculated annual energy cost for space and water heating. The rating is normalised for floor area and therefore the size of the dwelling does not strongly affect the result, which was presented on a scale of 1 – 100: the higher the number, the better the standard (SAP 1993). This rating has been changed in the latest edition (SAP 2001) to a scale from 1 – 120 with an additional scale of 0.0 – 10.0 for the Carbon Index, which is based on the annual CO_2 emissions associated with space and water heating. The method of calculating the rating is set out in the form of a worksheet, accompanied by series of tables (see appendix A for more information). Therefore, by completing the numbered boxes in the worksheet, using the data in tables as indicated, the SAP calculations can be made. In addition, there is a computer program approved for SAP calculations by the Building Research Establishment that could also be applicable, such as used in this research (see chapter 5 for more details).

The rating obtained for the SAP rating depends on range of factors that contribute to energy efficiency such as:

- Thermal insulation of the building fabric.
- Efficiency and control of the heating system.
- Ventilation characteristics of the dwelling.
- Solar gain features of the building.
- The price of fuel used for space and water heating.

The rating is not affected by factors that depend on the individual characteristics of the household inhabits in the building such as:

- Household size and composition.
- The ownership and efficiency of particular domestic electric appliances.
- Individual heating patterns and temperatures.
- The geographical location of the dwelling.

3.2.3 Environmental Standard – BREEAM

Environmental Standard, 'Homes for a Greener World', is the first revision of BREEAM Version 3/91 for new homes. It uses the experience gained in operating BREEAM/New Homes and replaces and reflects the increase in knowledge and understanding of early issues since it launched in 1991. BREEAM/New Homes was resulted from joint research between BRE and Municipal Mutual Insurance Ltd. It is one of the series of five assessment methods developed for different type of buildings. There are other series developed such as Version 1/93: An Environmental Assessment for New Offices, Version 2/91: An Environmental Assessment for New Superstores and Supermarkets, Version 4/93: An Environmental Assessment for Existing Offices, Version 5/93: An Environmental Assessment for New Industrial Units.

BREEAM, the Building Research Establishment's Environmental Assessment Method, was developed by ECD Energy and Environment with the UK Building Research Establishment and introduced in 1990. One of its most important aims is to provide guidance on ways of minimising the adverse effect of buildings on the global and local environments while promoting a healthy and comfortable indoor environment for inhabitants. This assessment method, which is carried out at the design stage, is based on readily available and generally accepted information. As it is stated in one of 'Building Research Establishment Reports', the method identifies and credits designs where specific targets are met. It is not expected that any single design will be met all of the target requirements.

The main aims of this scheme are:

- To distinguish dwellings of reduced environmental impact in the marketplace,
- To encourage best environmental practice in building design, operation, management and maintenance,
- To establish criteria and standards going beyond those required by law and regulation,
- To increase awareness of owners, occupants, designers and operators of the benefit of environmentally sensitive buildings.

Since its launch in 1990, BREEAM has become the UK industry standard for specifying and benchmarking the environmental performance of buildings.

3.2.4 NHER

The National Home Energy Rating is a policy tool for Authorities and Housing Associations, which calculates the energy performance of dwellings. It is the first scheme to receive full governmental approval for the delivery of SAP. The method is designed in 1990 by the Building Research Establishment in the function of a comprehensive system for evaluating the energy efficiency of housing stock. In addition to SAP rating, it also delivers accurate running cost rating, CO_2 emission, building fabric rating, and condensation analysis.

The NHER has three steps towards establishing and implementing an energy policy:

- Step 1- *A Stock Profile* – Step 1 sets the energy performance of the stock of 0 (poor) to 10 (excellent) and is based on the total annual running cost.

Figure 3.4: Energy Performance based on a Scale of 0 (very poor) to 10 (very efficient). (Energy Advisory Services 1994)

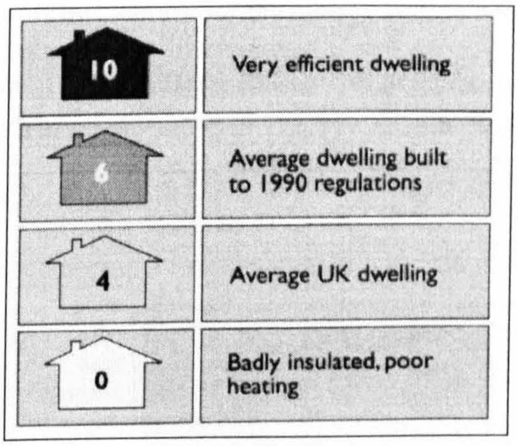
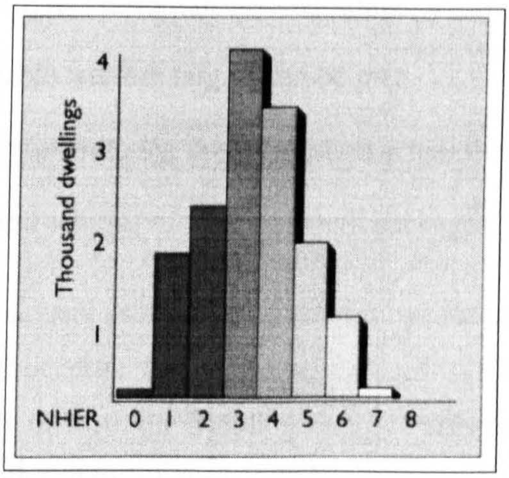
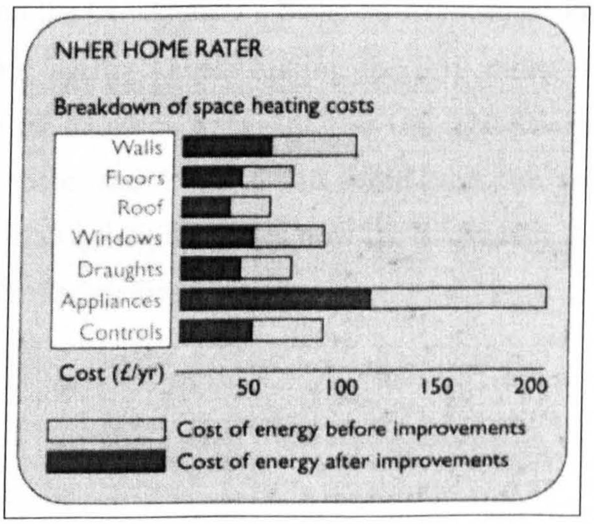


Figure 3.5: Example of Dwelling's Stock Profile generated by the Stock Profiler Software. (Energy Advisory Services 1994)



- Step 2- *Priorities and Targets* – Once an 'NHER Stock Profile' is obtained, following priorities and targets could be used:
    - ❑ Identify priority estates or house types – those with the worst energy performance will often show the best return on investment.
    - ❑ Establish targets for refurbishment, e.g. an NHER of over 6.0.
    - ❑ Establish overall policy goals e.g. all dwellings should have an NHER of 4.0 or over by the year 2000.
- Step 3- *Implementation* – Once the goals of the energy policy are established, the practicalities of implementing the energy policy needs to be addressed.

Figure 3.6: Example of NHER's Home Rating with Breakdown Costs and Savings; Before and After Refurbishment. (Energy Advisory Services 1994)



The main aims of this scheme are:

- To aid energy efficient design of new buildings.
- To check affordable warmth targets can be met.
- To calculate accurate running costs based on actual living patterns if known.
- To detail costs and savings of refurbishment packages.

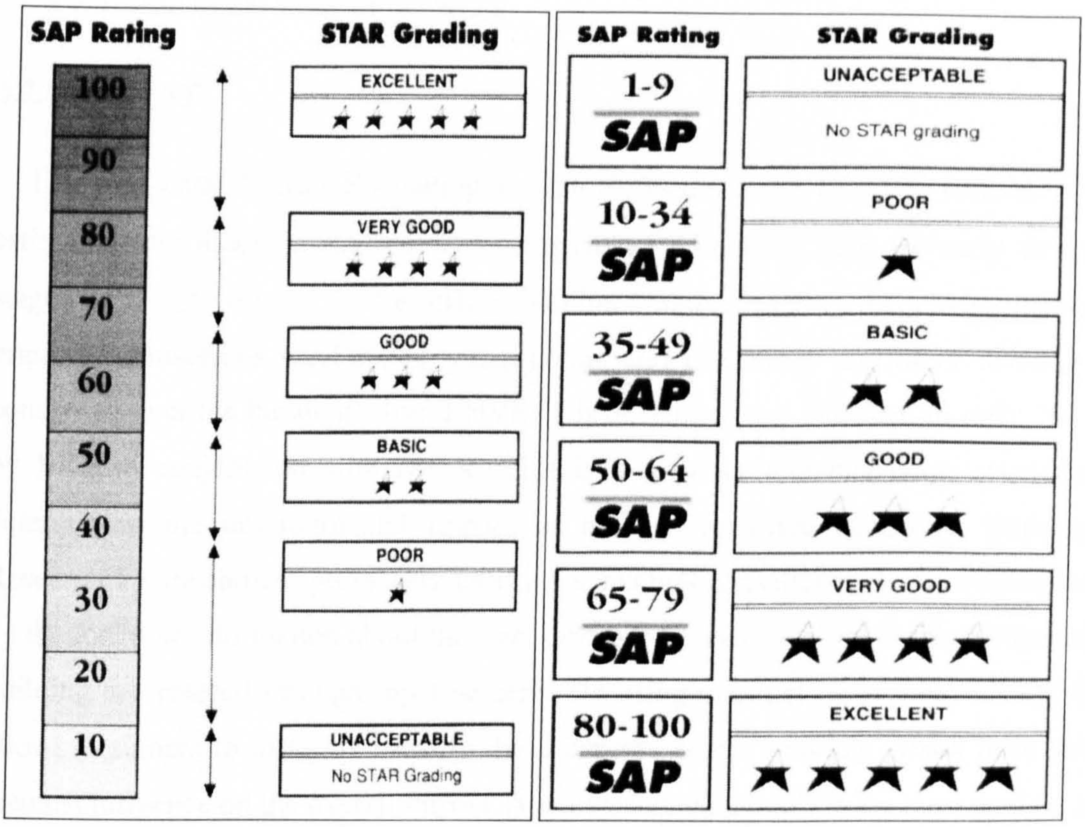
The software delivers many useful indices and ratings including; the Government's Standard Assessment Procedure Rating on a scale of 1-100, the National Home Energy Rating on a scale of 1-10, the Building Energy Performance Index (BEPI), the total CO_2 Emissions produced by a house.

3.2.5 MNV STARPOINT

MNV STARPOINT, Home Energy Labelling, is an essential aid to achieving the needs and requirements set by the Government and the Housing Corporation, which is launched in 1990. It aims to assess existing energy efficient standards in housing, identify priority action areas and cost-effective improvements and tests the extent to which these improvements can raise the rating and reduce carbon dioxide emissions and heating bills.

MNV STARPOINT is computer software and its products and consultancy services are based on the Government's Standard Assessment Procedure. It has been given to issue Home Energy Labels bearing the SAP rating, which illustrates the energy efficiency of the house on a scale of 1 to 100. The Star grading operates with ONE STAR being poor and FIVE STAR excellent. The unique 'STARPOINT Conversion Table' given below illustrates how the SAP rating 1 to 100 is converted into the ONE to FIVE star grading.

Figure 3.7: STARPOINT Conversion Table for Dwellings' Energy Efficiency. (MVN Starpoint Ltd 1993)



SAP Rating	STAR Grading
1-9 SAP	UNACCEPTABLE No STAR grading
10-34 SAP	POOR ★
35-49 SAP	BASIC ★★
50-64 SAP	GOOD ★★★
65-79 SAP	VERY GOOD ★★★★
80-100 SAP	EXCELLENT ★★★★★

In addition, a home energy label requires a home energy survey, which is simply the collection of the information necessary to estimate the cost of the energy needed to heat a house and hot water, based on a standard, national heating pattern and typical occupancy. The energy survey normally lasts less than 30 minutes. It collects information such as dimensions of the property, how it is constructed, insulated and ventilated, and what type of heating system and controls are installed. A home energy label provides an energy efficiency rating to the property not to the lighting and appliances.

The main aims of this scheme are:

- To improve home energy rating of the house.
- To help reducing harmful CO_2 emissions in the environment.
- To save household money on house's heating bills.
- To improve the comfort conditions in the house and therefore make the house feel warmer.

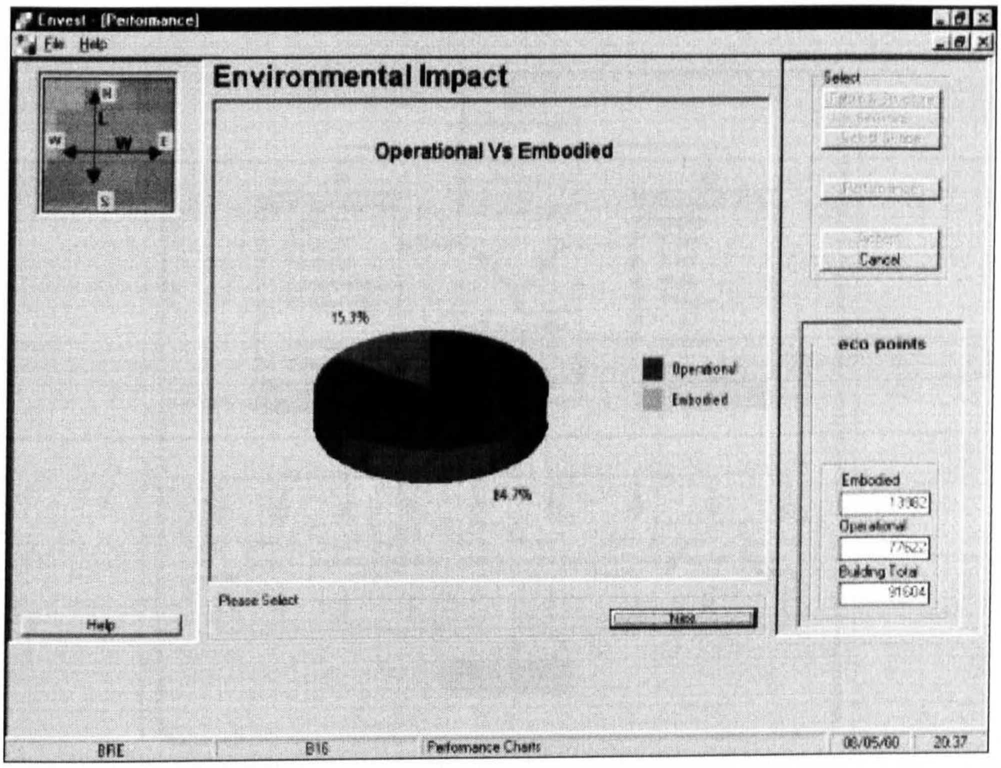
- To reduce maintenance costs.
- To add to the value of the house.

3.2.6 ENVEST

Environmental Impact Estimating Design Software is the first UK software for estimating the lifecycle environmental impacts of a building from the early design stage. The first version is for office buildings and considers the environmental impacts of materials used during construction and the energy and other resources consumed over the building's life. ENVEST is developed and launched in early 2000 by BRE in conjunction with DETR. This is a software tool that helps specifiers determining the environmental impact of their construction decisions. Building Research Establishment previously used it for internal consultancy. Data is provided by the tool and information about the size, fabric and service options for the proposed building are entered through input screens. By using minimal input data, ENVEST allows designers to instantly identify those aspects of the building, which have the greatest influence on the overall impact. All environmental impacts are measured on a single points scale called 'Ecopoints' allowing the designer to compare different designs and specifications directly. 100 Ecopoints are equivalent to the environmental impact caused by one UK citizen in one year. It is extremely easy to use; the simplicity of the software belies the wealth of research data on materials, impacts and weightings that underpin its calculations.

In addition, the software has pre-selected default values set on a typical office building specifications which can also be edited by the user. Total life cycle environmental impact of the building in Ecopoints is also allowing designers to make direct comparisons between different designs and specifications. These are displayed both numerically and in graphic form. The graphs include total life cycle environmental performance of the study building, and environmental impacts comparison between the study building and a previously save building.

Figure 3.8: ENVEST, Environmental Impact Estimating Design Software. (ENVEST BRE 2000)

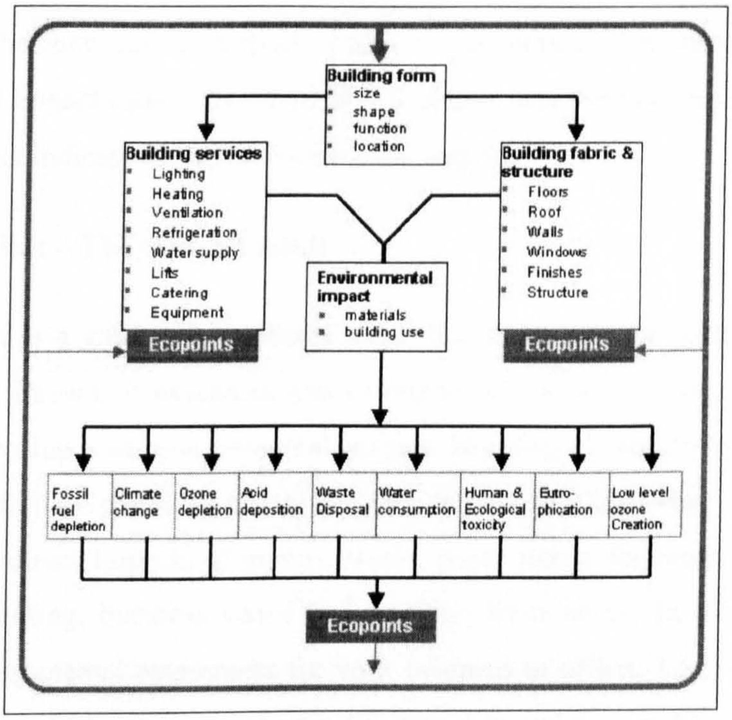


Embodied 13982
Operational 77622
Building Total 91604

The key benefits for users of this software are:

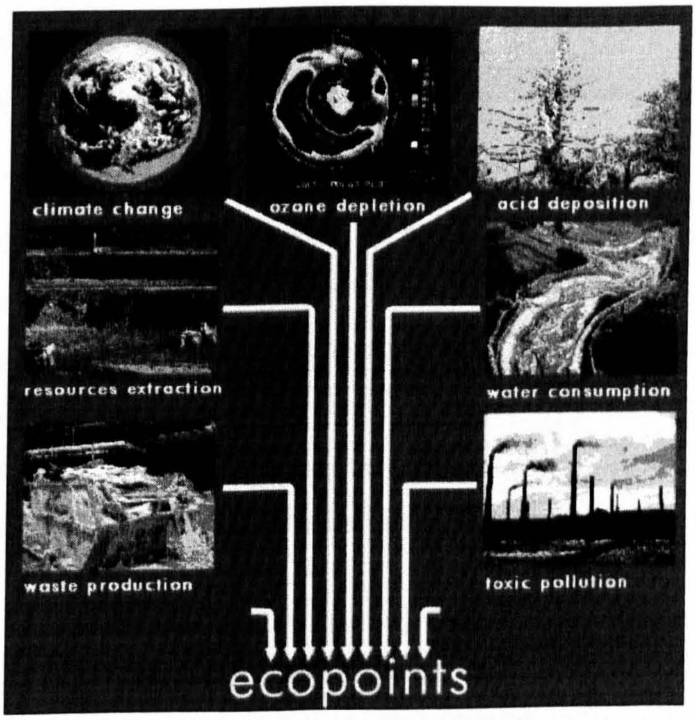
- Optimises the building form for least environmental impact.
- Informs choice on main construction materials.
- Enables the environmental impacts of construction and building operation to be balanced over the life of the building.
- Gives comparisons for different buildings and specifications.
- Graphically illustrates the environmental credentials of various design options to clients.

Figure 3.9: Schematic Sketch of the Method to derive the Ecopints for a Building Design. (ENVEST BRE 2000)



The environmental impacts of construction encompass a wide range of issues, including climate change, mineral extraction, ozone depletion and waste generation. Assessing such different issues in combination requires subjective judgements about their relative importance.

Figure 3.10: ENVEST, Ecopoints. (ENVEST BRE 2000)



Moreover, ENVEST also has great potential to be used as a benchmarking tool. UK Ecopoints are derived by adding together the score for each issue, calculated by multiplying the normalised impact with its percentage weighting. The annual environmental impact caused by a typical UK citizen therefore creates 100 Ecopoints. More Ecopoints indicate higher environmental impact.

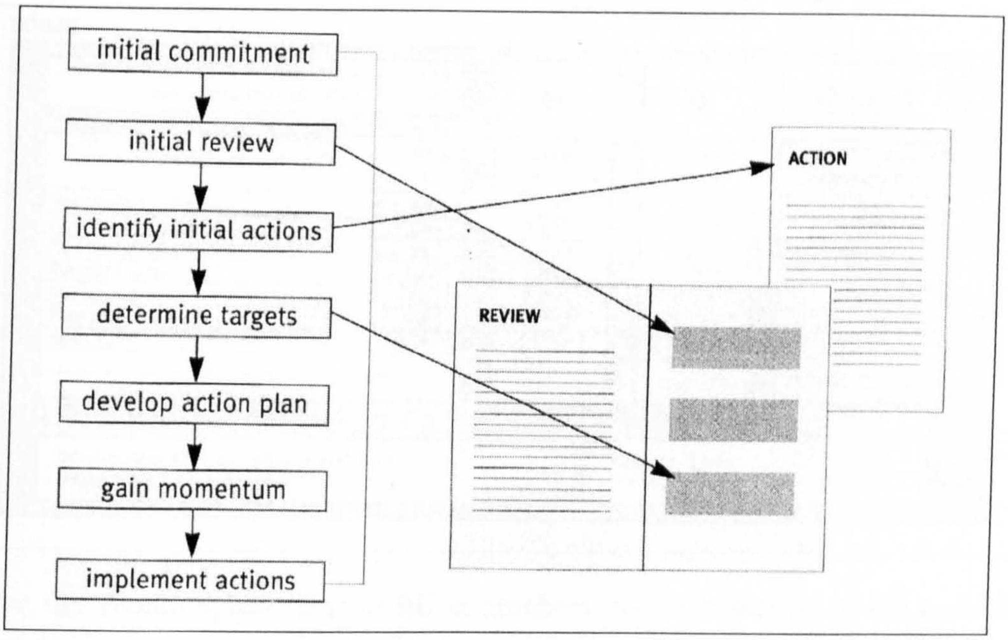
3.2.7 The Toolkit – The Office Toolkit

The Toolkit is a guide for facilities and office managers for reducing costs and environmental impact. It examines and evaluates all the aspects of an office-based business, which have an environmental impact. Building Research Establishment in partnership with PA Consulting Group has prepared the Toolkit in late 1995. This tool is not just the direct impacts of energy, water, paper usage and waste management, but also commuting, business travel and working from home. In all, it provides a complete environmental assessment for your business or office. The Toolkit consists of spreadsheets, which are supplied on a 3.5-inch disk and require Microsoft Excel or Lotus 1-2-3 software. It is designed to help the busy facilities, building or office manager to improve environmental performances and save money. Existing users of the Toolkit found that it takes only a few days (typically five days for a 150 person office) to get the point where they were achieving significant results. Some large organisations have managers responsible for a group of smaller offices such as local sales offices and bank branches, which can easily use the Toolkit as well. Therefore it can be said that it is also applicable to the small businessman, with one or several offices.

The focus of the Toolkit is the office and everything that is based upon it. It includes commuting, business travel and home working as well as the more direct impacts of energy, water, paper usage and waste management. In addition, the Toolkit includes the environmental impacts of a building based business such as the impacts caused by generating the powered used. Within the office, small kitchens, laboratories, workshops and computer rooms are also included and this can also be applied to most warehouses and shops.

Furthermore, the Toolkit also covers health and safety topics that can be included within the spreadsheet if required. Initial benefits may be up to 20% if not previously taken any environmental initiatives, however, after a little more effort and time it should enable to extract more benefits and then to develop a process of continuous improvement, gaining 5 - 10% every year.

Figure 3.11: Recommended Approach to Using the Toolkit. (The Office Toolkit BRE & PA Consulting Group 1995)

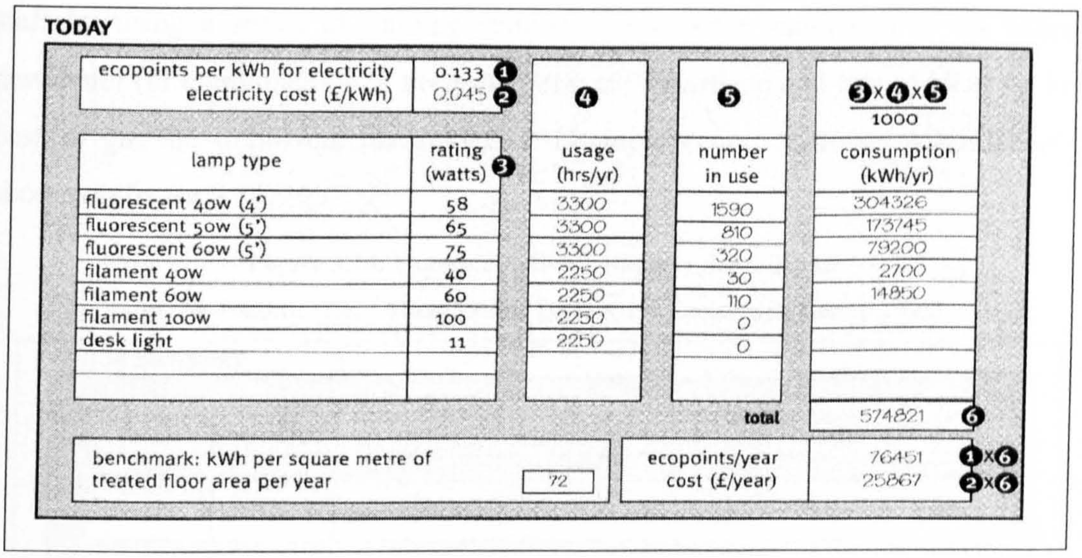


As the figure 3.11 has shown, the first step is to establish an initial commitment. The key decision makers in the business should support the aims of the initial review, and all staff should be aware of what is about to happen. It may have been that other people should be involved from several parts of the organisation, or even from several organisations. In order to maximise the gain and make it worthwhile, following steps should be considered when using the Toolkit:

- If you are a tenant, then you need to involve the landlord. Only he can commit to significant changes in the building and how it is operated - for example the building probably has a centrally controlled central heating system, and waste will be collected centrally.
- If you are the landlord, then you may want to get all the tenants involved. Everyone has something to gain, and you can use this approach to develop business relationships.
- If you run a branch office of a large organisation, then office supplies and energy may be purchased centrally.

- If you are responsible for the facilities or environmental management in an organisation with a number of sites, then you will want to involve local managers.

Figure 3.12: Example Toolkit Spreadheet Completed. (The Office Toolkit BRE & PA Consulting Group 1995)



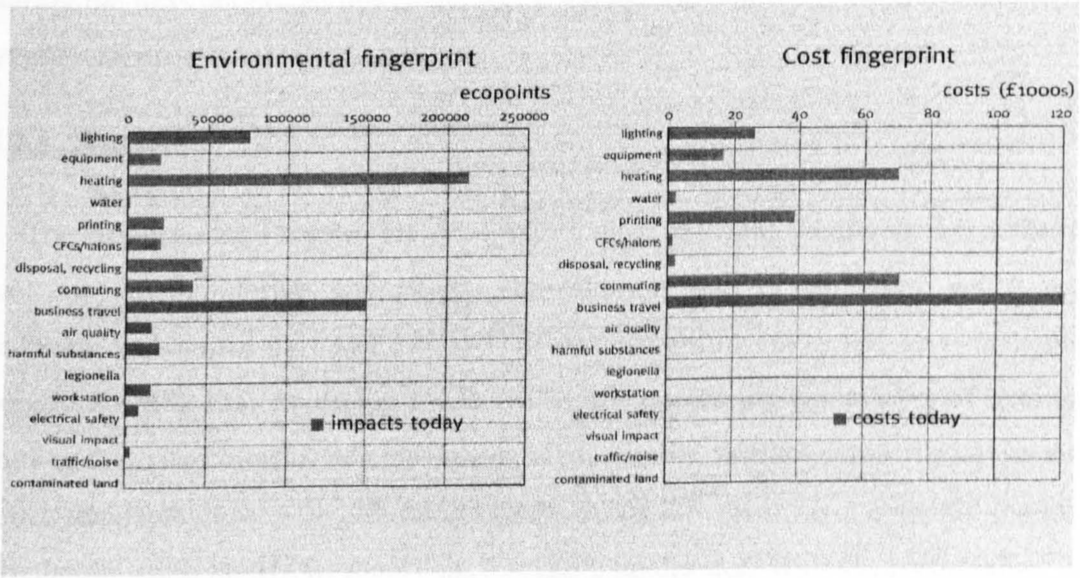
TODAY

ecopoints per kWh for electricity	0.133 ❶			
electricity cost (£/kWh)	0.045 ❷	❹	❺	❸x❹x❺ 1000
lamp type	rating (watts) ❸	usage (hrs/yr)	number in use	consumption (kWh/yr)
fluorescent 40w (4')	58	3300	1590	304326
fluorescent 50w (5')	65	3300	810	173745
fluorescent 60w (5')	75	3300	320	79200
filament 40w	40	2250	30	2700
filament 60w	60	2250	110	14850
filament 100w	100	2250	0	
desk light	11	2250	0	
			total	574821 ❻

benchmark: kWh per square metre of treated floor area per year	72	ecopoints/year	76451 ❶x❻
		cost (£/year)	25867 ❷x❻

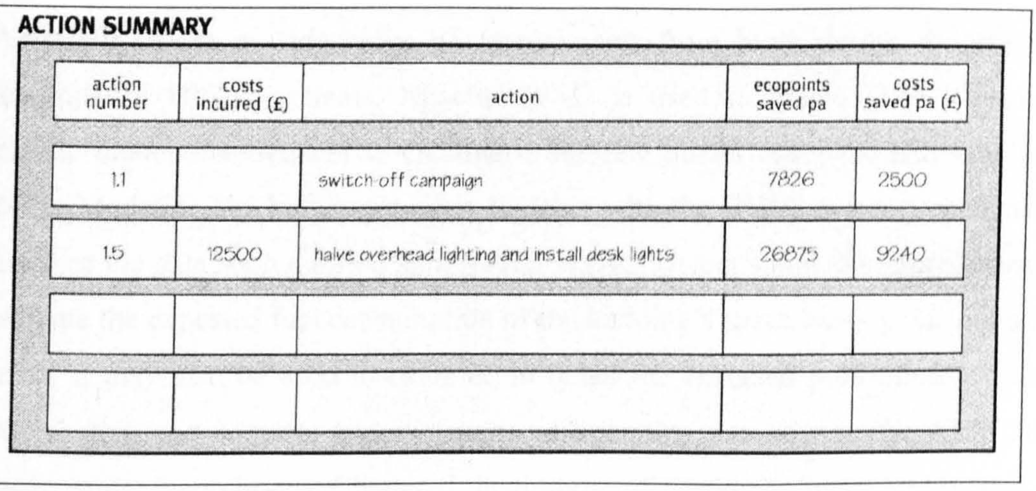
Use the Toolkit spreadsheet to fill in numbers, for each section of the review, as displayed on example spreadsheet of figure 3.12 above and enter guidance notes to help estimate numbers where the facts are not readily available. From these numbers, the Ecopoints (the environmental impact) and the running costs calculations will be performed automatically by the Toolkit programme.

Figure 3.13: Example Environmental Impact and Running Cost Chart on the Toolkit. (The Office Toolkit BRE & PA Consulting Group 1995)



The key to a successful environmental programme is gaining momentum. Most of the early actions involve everyone in the office changing their behaviour; particularly in switching off lights and office equipment. A carefully planned communication programme is needed to ensure that everyone gets the message and gets involved. Once the major environmental impacts are discovered, convey these impacts to all staff by using a series of training seminars or a poster campaign or an internal newsletter (or combinations of these) to generate discussion and lots of ideas on how best to get the improvements achieved. Example action summary spreadsheet is shown on figure 3.14.

Figure 3.14: Example Action Summary Spreadsheet of the Toolkit. (The Office Toolkit BRE & PA Consulting Group 1995)



ACTION SUMMARY

action number	costs incurred (£)	action	ecopoints saved pa	costs saved pa (£)
1.1		switch-off campaign	7826	2500
1.5	12500	halve overhead lighting and install desk lights	26875	9240

At the end of the implementation period, the actions should be reviewed in order to know what has been achieved, where things could be improved and what to tackle during the next period. At this stage, it is a second cycle of the process to continuous improvement.

3.2.8 APACHE

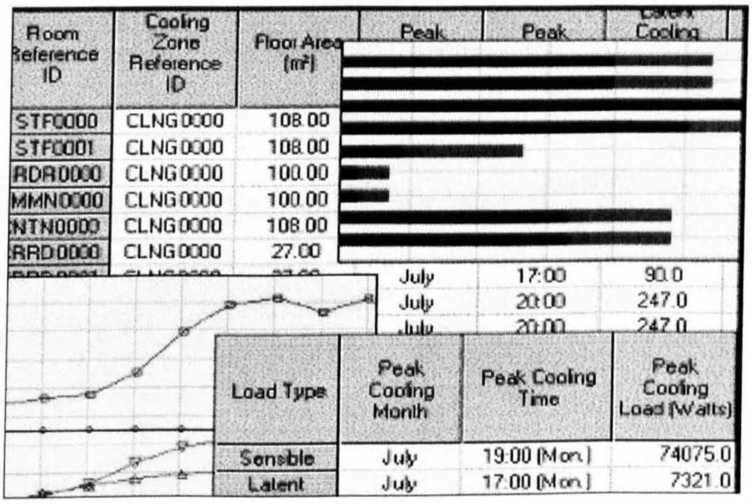
The Applications Program for Air-Conditioning and Heat Engineers is a software tool for thermal design and energy simulation related to buildings, which was originally developed by Facet Ltd in 1981 and bought by Integrated Environmental Solutions (IES) Ltd. In design mode, APACHE covers the calculation of heating, cooling and latent room loads, the sizing of room units, internal comfort analysis and codes/standards checks. In simulation mode, APACHE performs a dynamic thermal simulation using hourly weather data. Linked modules deal with the performance of

HVAC plant and natural ventilation. APACHE is a component of the IES Virtual Environment (see figure 3.15), an integrated computing environment encompassing a wide range of tasks in building design such as listed below:

- Thermal design (heating, cooling and latent load calculations).
- Equipment sizing.
- Codes and standards checks.
- Dynamic building thermal performance analysis.
- Systems and controls performance.
- Energy use.

APACHE covers a wide range of requirements from basic design to detailed simulations of HVAC systems. Apache-HVAC is used to create HVAC system schematic models, subsequent to creating a building model using the IES building modeller ModelIT. The building models together with the HVAC system schematics are used as the data source for APsim. APsim HVAC system simulation may be used to estimate the expected fuel consumption of the building's space heating and cooling systems. It may also be used to examine in detail the expected performance of an HVAC system and controls under a range of operating conditions. The APACHE software suite incorporates Chartered Institution of Building Services Engineers (CIBSE) facilities for performing fabric analysis; heat loss and heat gain calculations and thermal simulation.

Figure 3.15: APACHE – Thermal Design and Energy Simulation Sotware. (APACHE IES Ltd 2000)



Room Reference ID	Cooling Zone Reference ID	Floor Area (m²)
STF0000	CLNG0000	108.00
STF0001	CLNG0000	108.00
RDR0000	CLNG0000	100.00
MMN0000	CLNG0000	100.00
NTN0000	CLNG0000	108.00
RRD0000	CLNG0000	27.00

Peak	Peak	Cooling
July	17:00	90.0
July	20:00	247.0
July	20:00	247.0

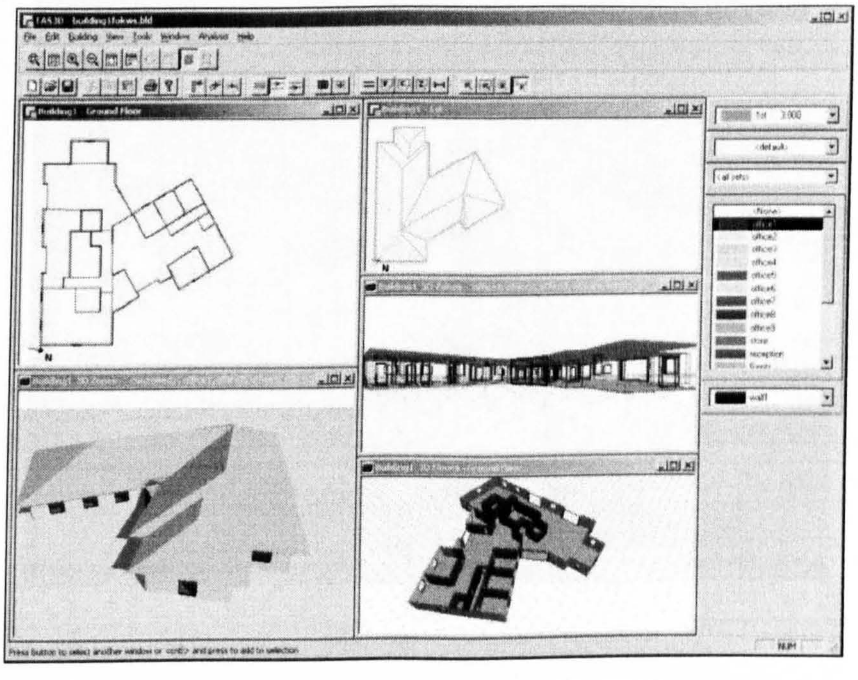
Load Type	Peak Cooling Month	Peak Cooling Time	Peak Cooling Load (Watts)
Sensible	July	19:00 (Mon.)	74075.0
Latent	July	17:00 (Mon.)	7321.0

Geometrical models may alternatively be entered using facilities within the Virtual Environment. Input of data relating to materials, occupancy, internal gains, climate, air movement and systems is managed via graphical interfaces and supported by extensive databases. APACHE presents a wide range of outputs in tabular and graphical form.

3.2.9 TAS

Thermal Analysis Software is a suite of computer software products, which simulate the dynamic thermal performance of buildings and their systems. Environmental Design Solutions Limited (EDSL) was formed in 1989 to commercially develop TAS. The main module is TAS Building Designer, which performs dynamic building simulation with integrated natural and forced airflow. As a secondary module, it has 3D graphics based geometry input that includes a CAD link. TAS Systems is a HVAC systems/controls simulator, which may be directly coupled with the building simulator. It performs automatic airflow and plant sizing and total energy demand. The third module, TAS Ambiens, is a robust and simple to use 2D CFD package which produces a cross section of microclimate variation in a space. TAS is a complete solution for the thermal simulation of new or existing buildings, allowing design professionals to compare alternative heating/cooling strategies and façade design for comfort, equipment sizing and energy demand.

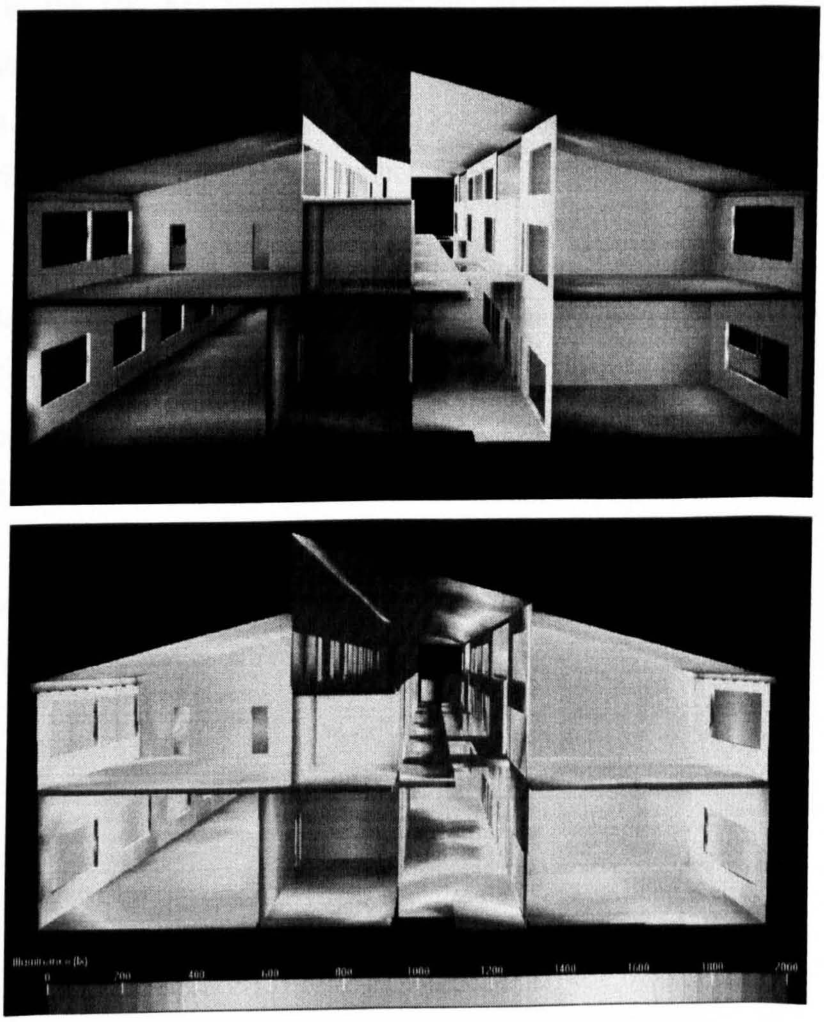
Figure 3.16: TAS – 3D Modeller, a Thermal/Energy Analysis Module. (TAS EDSL Ltd 1999)



It is also a very responsive and accurate tool for concept development while being a powerful design tool for the optimisation of a buildings environmental, energy and comfort performance. With TAS 3D Modeller (see figure 3.16), rendered 3D views that display comprehensive shading can be created and even calculate sunshine penetration through the interior of the building between spaces.

Construction materials and glazing types can be allocated from the comprehensive databases included in the software. These have their dynamic response automatically calculated in the model. The occupation of the building is represented by a calendar, with different day types having varying schedules of use. The final ingredient that brings the building model to life is the climate data used to drive the simulation. TAS has access to over 2,500 recorded weather sites worldwide. The data consists of hourly values for solar, temperature, humidity and wind speed and direction.

Figure 3.17: Lighting Simulation and Luminance Lux Levels with TAS. (TAS EDSL Ltd 1999)



TAS exports the various constructions and glazing types with their original TAS colours and these can be edited within Lightscape to enhance the appearance of the building's interior finishes. The sky conditions can be specified and the building can be located anywhere in the world for any date and time. From this, the lighting simulation is completed and a photo-realistic model of the whole building is created. The model can be viewed from any position and used to generate fly-through animations. Day lighting analysis can be performed on the rendered model to determine the daylight levels on any of the internal surfaces. In addition, luminance lux levels can also be displayed numerically with contour lines or via colour mapped images representing lux level banding as shown on figure 3.17.

3.3 Summary

In this chapter, existing energy and environmental assessment methods for buildings in the UK has been reviewed and compared in order to assist people choosing the right method for the building energy study and environmental impact assessment. As stated earlier in the chapter, tool and techniques looked at are the main energy rating and environmental impact analysis methods currently used in the country.

The following comparison shown on table 3.1 has not been prepared to justify that there is only one method to be used, which would be the best method for the purpose, but to describe each method in more detail and therefore help users make decisions easier. As it can be seen, each method has its unique way of assessment, some may even cover issues that others may not, and therefore it is worthwhile to use more than one method. Architects, designers, environmental/energy consulting firms, authorities/clients, quantity surveyors, and research universities presently use these methods.

Table 3.1: Comaprison of Existing Energy and Environmental Assessment Methods for Buildings in the UK. (Generated 2001)

COMPARISON ISSUES	BREDEM	SAP	BREEAM	NHER	STARPOINT	ENVEST	TOOLKIT	APACHE	TAS
Produces an energy rating for a dwelling	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable for calculating SAP ratings	Yes	Yes	No	Yes	Yes	No	No	No	No
Provides a framework for calculation of energy use in buildings	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Estimates energy costs and potential savings in housing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
When calculating energy costs, takes into account thermal insulation of the building envelope as well as the efficiency and control of the heating and hot water systems and the ventilation characteristics of the dwelling	No	Yes	No	Yes	No	Yes	No	Yes	Yes
Estimates the solar gain features of the building and the price of fuel used for space and water heating	No	Yes	No	Yes	Yes	No	No	Yes	Yes
Includes energy used for lighting and appliances	No	No	No	No	No	No	Yes	Yes	No
Consists of a worksheet that calculates the space and water heating energy requirement of a dwelling, and a rating that is based on fuel costs rather than primary energy use or CO_2 emissions	No	Yes	No	Yes	Yes	No	Yes	Yes	No
Provides simple means of reliably estimating the energy efficiency performance of dwellings	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Enables the levels of energy efficiency in buildings to be compared.	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Additionally taking into account CO_2 emissions resulting from energy use in dwellings; CFC and HCFC (hydro chlorofluorocarbon) emissions; natural resources and recycled materials; storage of recyclable materials; water economy; the ecological value of the site; ventilation; volatile organic pollutants of indoor origin; wood preservatives; man-made mineral fibres; asbestos and lead; lighting; smoke alarms; storage of hazardous substances	No	No	Yes	Yes	Yes	Yes	No	Yes	No

COMPARISON ISSUES	BREDEM	SAP	BREEAM	NHER	STARPOINT	ENVEST	TOOLKIT	APACHE	TAS
Provides guidance on ways of minimising the adverse effect of buildings on the global and local environments while promoting a healthy and comfortable indoor environment for inhabitants	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Based on readily available and generally accepted information - establish criteria and standards going beyond those required by law and regulation	No	No	Yes	No	No	Yes	No	No	No
Covers issues such as global, local and indoor	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Provides a common rating for the new and existing buildings and offers greater flexibility in benchmarking building portfolios	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Encourages greater use of public transport and cycling, while discouraging the use of private cars for commuting	No	No	Yes	No	No	No	Yes	No	No
Provides the environmental assessment of materials as a major addition, green guide to specification and an environmental profiling system for building materials and components	No	No	Yes	No	No	Yes	No	Yes	No
Produces a simple scale rating for material's life expectancy and recyclability	No	No	Yes	No	No	Yes	No	Yes	No
Provides applicable ratings in both new and existing dwellings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Software based program	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

To summarise, it is suggested that using more than one method at a time would help achieving better results as some of these energy and environmental assessment methods cover whole range of issues considering energy rating and environmental impact assessment of a building.

3.4 Conclusion

As widely known, there is more than twenty years of research background that has produced broad understanding of the implications of the energy use and helped increasing the number of energy efficiency strategies and technologies with significant potential for energy savings in the UK. Building energy and environmental assessment methods described in this chapter are designed and developed to assess energy consumption of buildings and building designs against a range of environmental issues covering impacts on the environment.

These methods are not only covering a large part in research background achieved, but also playing an essential role in increasing awareness of the importance of energy efficiency in buildings today and encouraging energy conscious building design throughout the country. In addition, some of these main assessment methods, such as SAP and NHER, have been added to the building regulations to improve energy efficiency in buildings and reduce carbon dioxide emissions caused by existing building stock. Nevertheless these strategies and technologies have not been effectively transferred to the building design community, as recent studies suggested that the profile of the existing housing stock has remained with little change since 1996, which has already been stated in chapter 2 (ODPM, 2003).

Against this background, my research advocates that more emphasis should be paid to encouraging property developers to design energy conscious buildings and property owners to implement energy efficiency improvements in existing buildings. Today, while being one of the most important issues, sustainable development is forever on the agenda and therefore this knowledge gap should be rapidly bridged. Moreover, the building regulations and associated policies could be more effective and efficient in this matter and the use of energy ratings should enable decision makers to take energy efficiency into account on a rational basis when designing new dwellings or refurbishing existing ones. For building professionals, ratings can be used as a design tool to optimise energy efficient building design.

3.5 References

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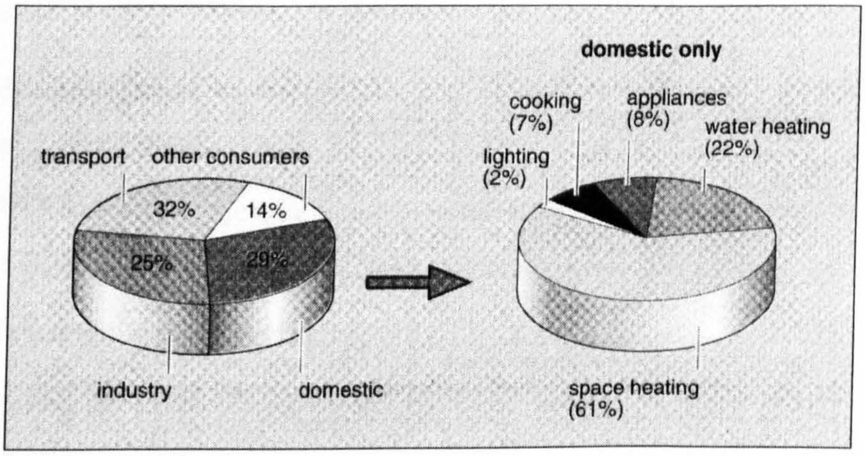
4 Energy Consumption in Domestic Buildings

4.1 Introduction

All societies including both developed and less developed countries are dependent on energy for their existence. Today, the consumption of energy is costly and degrades the environment and therefore its use should be reduced. In the UK, the domestic sector is one of the main consumers of energy and accounted for 29% of the total primary energy consumption in the country (see figure 4.1).

In view of the fact that buildings (both domestic and commercial buildings) accounted for the largest proportion of UK's energy consumption, they should be considered as one of the highest priorities when it comes to reducing the overall energy consumption in the country and meeting required targets. According to the statistics, the UK domestic sector energy consumption has increased by 32% since 1970 and by 19% since 1990. In addition, since 1990 factors affecting domestic energy consumption such as the number of households has increased by 10%, population has increased by 4% and household disposable income has increased by 30% (DTI, 2002).

Figure 4.1: Breakdown of UK Energy Consumption and Domestic Only Energy Use. (Shorrock and Walters 1998)



Environmental damage caused by carbon dioxide emitted during energy use, combined with the more basic issue of cost has made energy conservation the central theme of sustainable development. In this chapter, energy consumption in domestic buildings and strategies for energy efficiency design have been reviewed for the purposes for identifying the domestic sector energy use and the drivers of energy consumption in this sector, which can eventually help bring down the energy being consumed.

4.2 Domestic Sector Energy Use

Today in the UK, almost 30% of the carbon dioxide produced is being caused directly or indirectly by the use of energy in dwellings (see figure 4.1) and as a result, it is clear to state that the way we use energy is extremely inefficient. If all energy efficiency measures outlined in this research were to be carried out the amount of CO_2 produced could have been reduced by 60 - 80%. Moreover, if we were also to change our lifestyle and use renewable energy sources we could reduce the CO_2 emissions even further.

Services and systems installed within dwellings use energy to create a comfortable, safe, healthy and productive environment. These services and systems are as follows:

- Space Heating
- Water Heating
- Lighting
- Cooking
- Other Appliances

Each dwelling should be considered as a total system (see table 4.1) and by doing so, the way energy is being used can be studied and therefore the ways we can reduce CO_2 emissions can also be worked out. The following steps can help save energy and therefore carbon dioxide emissions can be reduced in each dwelling:

- Choosing the sources of energy emitting the least amount of carbon dioxide.
- Finding the most efficient ways of using energy in heating systems, lighting and other appliances.
- Conserving the heat in dwellings through draught proofing, ventilation control and insulation.

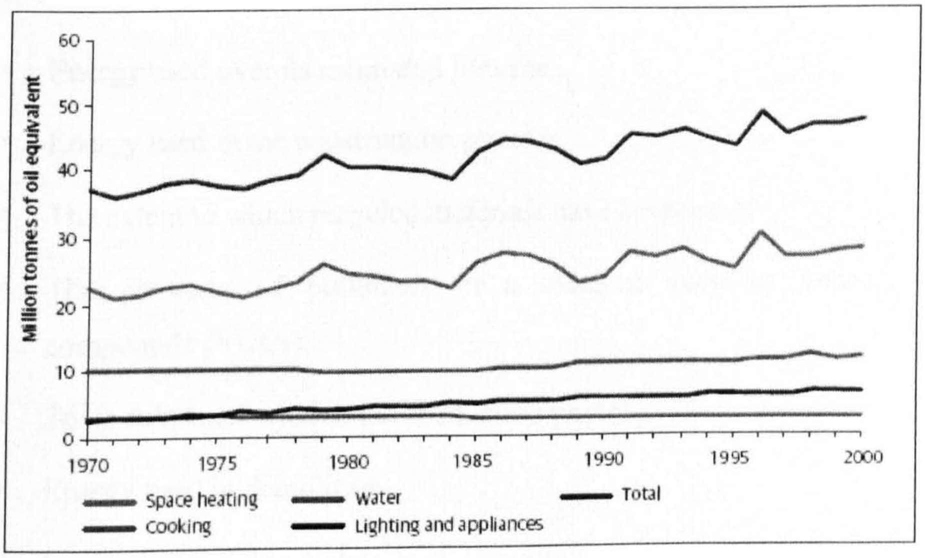
The main issue is not improving the overall energy efficiency of a dwelling but the resources that can be directed to the task and how far to go with each measure to achieve the efficiency levels.

Table 4.1: Dwelling as a Total System. (Action Energy 2002)

Input (sources of energy)		Use (and misuse)		Output (loss)
Fossil Fuel	Gas	Space Heating		Draught, Ventilation
	Oil	Water Heating		Hot Flue Gases
	Coal	Lighting		Heat Loss through:
Electricity		Electricity		Walls and Windows
Biomass:	Wood	Appliances:	Cooking	Roof
Solar Energy:	Passive	Solar Energy:	Washing	Floor
	Active	Human Metabolism		Waste Warm Water
Food				

The majority of energy consumed in the domestic sector is for space heating, which accounted for 58% of all delivered energy consumed in 2000 (see figure 4.2). Space heating in any year is largely dependent on outside temperatures, which explains the year-to-year fluctuations, although increases in internal temperatures, the growth in central heating and the increased number of households have all contributed to the increase over the period 1970 to 2000, despite the increased presence of insulation. The other major areas of energy consumption in the domestic sector are for heating water, for lighting and appliances and for cooking. Between 1970 and 2000, energy consumption in lighting and appliances increased by 157%, while energy use in cooking has fallen by 16% (DTI, 2002).

Figure 4.2: Domestic Final Energy Consumption by End Use, 1970 to 2000. (Shorrock and Utley 2003)



The fall in energy consumption in cooking is partly explained by a change in lifestyle. More convenience foods are now consumed and people eat out more frequently than in the past. The average person in 2000 spent £7.36 per person per week on food and drink consumed out of the house. In addition, excluding alcoholic drink, expenditure on eating out has increased by 13% in real terms since 1994, whilst household food and non-alcoholic drink purchases fell by 2% (DTI, 2002).

Space and water heating require heat, which is produced by converting the chemical energy in gas, oil or coal to thermal energy by combustion in a heating appliance. The remaining services require electricity, which can also be used to provide space and water heating, however is somewhat costly. In the UK, the majority of electricity is produced in power stations from steam or gas turbines driven by the combustion of fossil fuels. Smaller quantities are generated from nuclear power and renewable energy sources (see chapter 1).

4.3 Embodied Energy and Materials

When considering energy consumption in buildings, it is important that not only the energy consumed during the life of a building has to be considered, but also the extent to energy involved in the extraction, manufacture and transportation of building materials should be taking into account. This is known as the 'embodied energy' and directly relates to the gross carbon intensity of a material. The overall environmental credentials of a building are affected by a number of factors, which are as follows:

- Energy used over its estimated lifetime.
- Energy used in the construction process.
- The extent to which recycled materials have been used.
- The presence of pollutants in a material such as volatile organic compounds (VOCs).
- Toxic substance used in the production process.
- Energy used in demolition.
- Level of recyclable materials at demolition.

- Materials used in refurbishment.

Currently, it is known that a building consumes much more energy during its lifetime than is involved in extraction, manufacture and transportation. However, it is usually the case that the embodied energy will be significant fraction of the total, as buildings become more energy efficient. As seen earlier in this chapter, domestic buildings account for almost 30% of the total primary energy consumption in the UK and therefore the embodied energy of a dwelling has to be considered in achieving best results in overall energy efficiency.

4.4 Energy Efficiency Basics

In housing, energy efficiency means using less energy for heating, cooling, and lighting. It also means buying energy saving appliances and equipment for use in a house. An important concept for energy efficiency in housing is the building envelope, which is everything that separates the interior of the dwelling from the outdoor environment: Doors, windows, walls, foundation, roof and insulation. All the components of the building envelope need to work together to keep a dwelling warm in the winter and cool in the summer. Insulation, for instance, will be less effective if the roof, walls and ceiling allow air to leak in or allow moisture to collect in the insulation.

Various approaches can help improve the building envelope, such as wall insulation can reduce heat loss through walls by up to 80% and draught stripping badly fitted windows and doors can also reduce heat loss. In addition double-glazing increases comfort and reduces condensation. Even low-emissivity glass further enhances these benefits and can significantly improve a dwelling's energy efficiency.

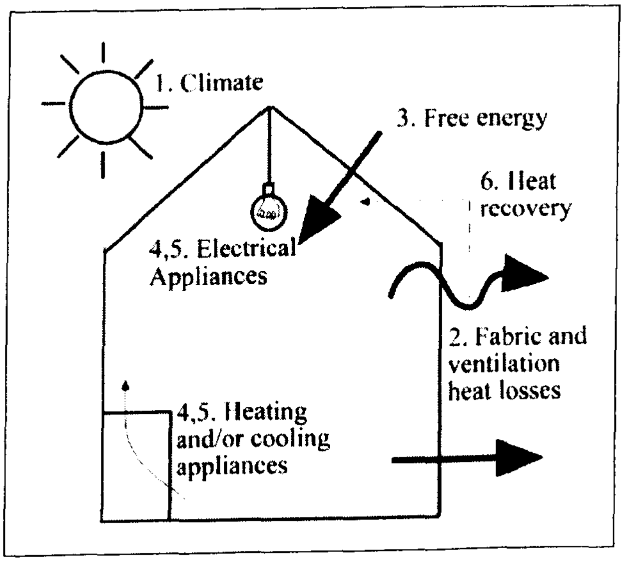
Heating and cooling systems typically use the most energy in the domestic sector. In housing, the addition of efficient controls, like a programmable thermostat, can significantly reduce the energy use of these systems. Some dwellings can also use zone heating and cooling systems, which reduce heating and cooling in the unused areas of a house.

Both heating water more efficiently and reducing hot water use can reduce the energy consumed to heat water. A wide variety of fixtures, such as low-flow showerheads and faucet aerators, can also reduce hot water use. In a house, an older water heater can be replaced with a newer, more energy-efficient one, and the water heater and hot water pipes can be insulated to minimise heat loss.

Today, most common appliances and electronic devices are available in energy-efficient models, from washing machines and refrigerators to copiers and computers. Several energy-efficient lighting options, such as compact fluorescent light bulbs, are also available. There are ways to determine how energy efficient a dwelling really is and, if needed, what improvements can be made. Homeowners can conduct simple energy audits on their homes or have professional audits done.

Energy efficiency standards in a house could be more desirable to the occupants than an equivalent higher energy consuming dwellings. In addition, the maintenance costs are reduced due to less energy consuming devises installed and the effect is seen as an immediate reduction in gas and electricity bills. However, the reductions in bills are often not as large as predicted. This is because the dwelling occupants use the opportunity for lower fuel bills to obtain an improvement in thermal comfort conditions. It is well known fact that homes can be better heated yet still have lower fuel bills. Improvements in temperatures also have an effect on health (Action Energy, 2002).

Figure 4.3: Energy Efficiency Basics. (Action Energy 2002)



There is a well known approach, which is to first reduce the demand for energy then make use of natural energy flows and finally supply energy that is needed in an efficient and well controlled manner (see figure 4.3). The order to energy efficiency is therefore:

1. Site and orientate the house in a microclimate by choosing an appropriate site or using landscaping techniques to modify the climate.
2. Minimise fabric and ventilation heat loss rates.
3. Optimise any free sources of energy such as solar gains, daylight or natural ventilation.
4. Select the energy consuming plant to be as energy efficient as possible.
5. Control the energy consuming plant so that it operates only when required and to the level required.
6. Recover waste energy where viable.

4.5 Reducing Energy Consumption

While there are a number of important dimensions to the concept of sustainability, it is largely used in reference to sustaining the balance and health of the environment; the greatest threat to our environment today being climate change associated with emissions of greenhouse gases. Under the Kyoto Protocol, the European Community agreed to an 8% cut in greenhouse gas emissions and under a burden sharing agreement amongst its member states, the UK agreed a cut of 12.5%. Both the UK government and the devolved administrations also have a domestic goal to cut the emissions of carbon dioxide, the main greenhouse gas, to 20% below 1990 levels by 2010 (DETR, 2000). It is accordingly believed that there will be clear benefits for the UK by moving beyond its Kyoto target towards its domestic goal. Taking early action and starting the transition to a low carbon economy will therefore bring financial and economic gains. The UK's Climate Change Programme includes a flexible, cost effective set of policies and measures that will help to achieve these objectives that will safeguard the UK's competitiveness and that will also deliver wider benefits for the environment and society.

Achieving emissions reductions associated with energy use in the domestic sector will inevitably mean reducing energy consumption. This itself must be considered as a significant challenge given that the domestic energy sector is a growing market (both gas and electricity consumption in the domestic sector has grown by 8 - 10% over the last 5 years (DTI, 2002)) and perhaps most importantly, a competitive supply market where unit prices have been steadily falling; reducing the incentive and economic benefits of energy efficiency. The methods used by the UK government can be broadly categorised as fiscal, legislative and technical, and briefly explained below:

4.5.1 Fiscal

Taxation can be used to penalize the use of energy or reward the purchase of energy saving devices. The 'Climate Change Levy' (CCL) is a major new energy-related tax that came into operation in 2001. It is an energy tax, which applied to the business and public sectors and aimed to discourage energy use by increasing the cost of fuels. Moreover, it makes purchases of energy saving devises and systems more cost effective. Some fuels are exempt from the levy such as renewable energy and combined heat and power (CHP) output.

Taxation is a punitive method of encouraging energy efficiency but there is also enchased capital tax allowance available for energy efficiency equipment such as CHP systems, efficient boilers, pipe insulation, variables speed drives and low energy lighting systems. These enhanced allowances allow the full cost of the devices to be written off over one year instead of over approximately eight years, which is normal for most capital items.

4.5.2 Legislation

Conservation of fuel and power is included within the building regulations, which are enforceable by law. In the past the regulations have concentrated on reducing the space heating energy use of buildings, however, it now includes lighting, ventilation and air-conditioning with an excepted tightening of standards in future years.

4.5.3 Technical

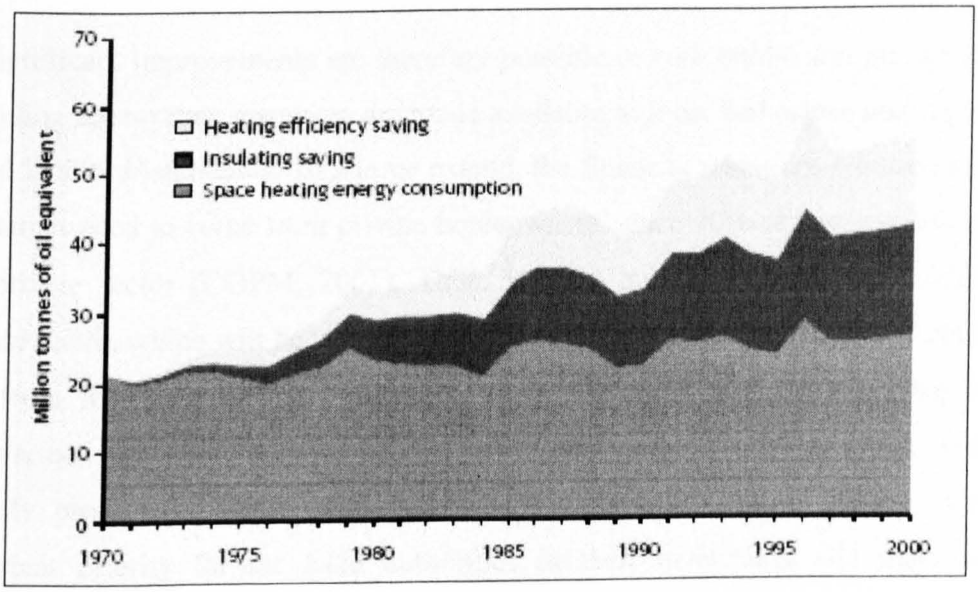
There are a number of improved technologies that can be used to reduce energy consumption and CO_2 output whilst maintaining existing levels of thermal comfort, ventilation and lighting.

Renewable energy sources, such as wind, solar, biomass and hydroelectric power stations, can be used to displace fossil fuel and nuclear generation. Currently, renewables are not cost competitive when compared to fossil fuel generated electricity and are often rejected due to environmental concerns.

Energy efficiency basics can generally achieve cost effective energy savings as great as 40 - 60% in existing housing with poor fabric and services. These savings can be achieved often at little or no extra cost if energy efficiency techniques are integrated during refurbishment or at the design stage.

As an example, savings due to better insulation and heating efficiency is shown on figure 4.4 over the period 1970 to 2000. The combined savings from insulation and heating efficiency improvements reduced domestic space heating energy consumption to about 48% in 2000. It is calculated that without insulation energy consumption would have been 59% higher by 2000 (DTI, 2002).

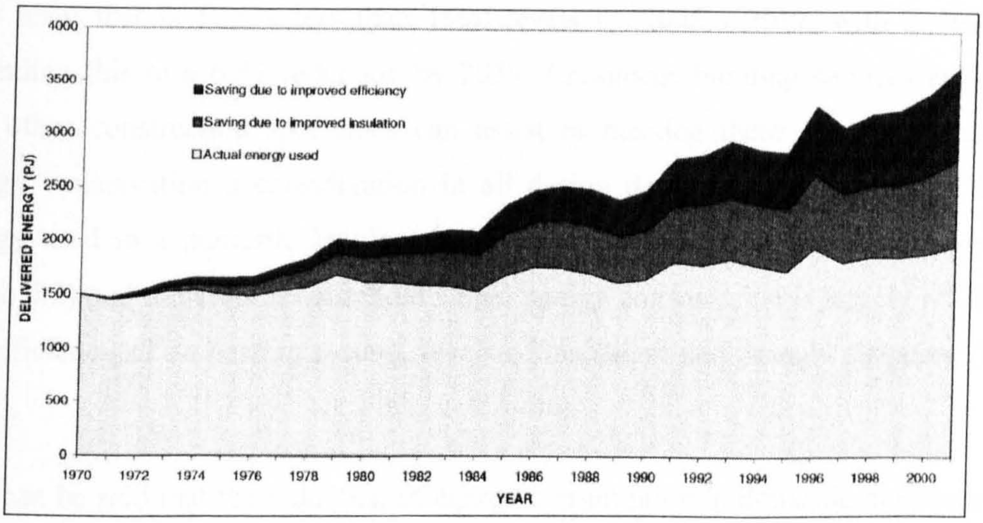
Figure 4.4: Savings due to Better Insulation and Heating Efficiency, 1970 to 2000. (Shorrock and Utley 2003)



4.6 Home Energy Conservation Act 1995

The Home Energy Conservation Act (HECA) 1995 set a target of 30% improvement in domestic energy efficiency to be achieved by 2010. It came into effect from April 1996 and required every UK local authority with housing responsibilities – 'Energy Conservation Authorities' – to prepare, publish and submit to the Secretary of State an energy conservation report identifying practicable and cost-effective measures to significantly improve the energy efficiency of all residential dwellings in their area; and to report on progress made in implementing the measures.

Figure 4.5: The Effect of Energy Efficiency Improvements on Energy Consumption. (Shorrock and Utley 2003)



Significant improvements are therefore possible in both public and private sector, providing appropriate resources are made available to local authorities and registered social landlord/landladies. To a large extend, the financial resources required to meet this target need to come from private homeowners, since 70% of housing belongs to the private sector (ODPM, 2001). There is local authority investment within the private sector, which will be targeted primarily at low income and other households at risk from fuel poverty and undertaken as part of local authority's private sector renewal activity. There are also sources of external grants available, which could be actively promoted by the local authority. Furthermore, energy efficiency is an important priority for the local authorities in their investment and maintenance strategies for public sector and therefore they will continue to support measures that help the provision of affordable heating to all households.

4.7 Conclusion

Given the value of energy efficiency basics and techniques to producing better buildings and reducing environmental impact, it is the duty of professionals in the construction industry to recommend energy efficiency solutions whenever alternative choices occur. This must also be supported with increasing legislation by government; in recognition of the importance of energy issues have introduced legislation that aims to reduce building energy consumption.

The UK government's target is to reduce greenhouse gas emissions in the country to a level that is 12.5% less than 1990 levels by 2008 - 2012, with a desire of extending this to a 60% reduction by 2050. Architects, building services engineers and other construction specialists can assist in meeting these targets by making energy conservation a consideration in all design decisions. Additionally, 83% of energy used in a domestic building is consumed for space and water heating (see figure 4.2) and therefore a household's total energy consumption is largely related to the efficiency of its heating system, levels of insulation and draught stripping (DTI, 2002).

It can be said that the reduction of energy consumption in domestic buildings and consequently the effective refurbishment of dwellings for energy efficiency relies on improvements in these key areas. Energy efficiency improvements in existing housing stock have made an impact on energy consumption since 1970 and it has been calculated that without these improvements, energy consumption would have been 46% higher by 2001 (see figure 4.5) (Shorrock and Utley, 2003). However, opportunities to make much greater improvements to energy efficiency and therefore to reducing energy consumption still remain.

This chapter outlines energy consumption in domestic buildings and determines potential improvements in this sector to help the UK meet its international commitment. If energy efficiency improvements in domestic sector were to be accelerated both by professionals and the government, overall carbon dioxide emissions could be radically reduced. Thus, improving energy efficiency and reducing CO_2 emissions in this sector is not only going to help the country achieve its target, but also tackle vital issues, such as fuel poverty, non decent homes, excess winter deaths, etc. This will also raise awareness in sustainable and energy efficient building design in the UK.

Furthermore, sustainable design has become an important issue and to achieve this there must be a significant reduction in CO_2 emissions and the amount of energy consumed in buildings. The following chapter focuses on case studies carried out within private housing sector that examines energy related problems and determines potential improvements for energy efficiency in the domestic sector.

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5 Case Studies within Private Housing Sector in Sheffield

5.1 Background

As previously explained in this thesis, the UK is committed to reducing the emission of six greenhouse gases with carbon dioxide being the most significant to 12.5% lower than the 1990 levels by 2010. In addition to this commitment, the UK government has also indicated that it has an aim of further reducing the emissions with an eventual target of 20% below the 1990 levels by 2010 (see chapter 1 for more information about the UK's Climate Change Programme).

In the UK, energy consumed by the building stock approaches 50% of the total while transport is responsible for 28% and predicted to rise significantly. Moreover, energy consumption for energy use in the domestic sector is responsible for about 30% of overall CO_2 emissions and is a major contributor to global warming (see chapter 4 for more information). Today, the domestic sector energy consumption has become one of the key drivers to improving energy efficiency and reducing carbon dioxide emissions in the country, which is again the main focus area of this research.

This research has begun with building confidence and relationship with landlords/landladies through the Housing Services at the University of Sheffield. The main idea behind this was to find ways to contact people in charge (property owners) directly rather than the occupiers. In this case, it was the privately rented accommodation and particularly the university–controlled properties targeted. The question to answer is; '**how can we encourage property owners to implement necessary energy efficiency improvements, while there is no effective legislation in place to tackle energy related issues**'. This has already been a great challenge for the government as there are no effective solutions in place and therefore it is a crucial barrier where again this research has focused on (scope of the problem).

In order to bring an alternative solution to the problem and encourage further improvements in privately rented properties, the author has decided to take the first step to reach across a barrier by contacting the authority, which has supported privately rented property owners and help to market their properties locally. In this case, this authority is the University of Sheffield, Housing Services that currently controls and checks dwellings registered both under the university private housing and private landlord schemes, which is also recognised by the City Council. For the majority of the property owners, their properties are considered as 'affordable and decent homes', due to the fact that they are registered with the university housing scheme and inspections are undertaken on a yearly basis; however mostly covering fire regulations and security issues rather than energy efficiency measures. As a result, this remains a great challenge to be tackled.

The author has attended a meeting with the housing officer in Housing Services and explained both the research aims and objectives (see following section 5.2), and justified the outcomes. The housing officer has not only found the project interesting, but also helpful for developing further strategies, such as considering energy efficiency measures in university private housing requirements. Furthermore, housing services has a yearly meeting with the property owners of registered dwellings under the university private housing scheme. The author has taken this opportunity to attend this event to meet landlords/landladies who are able to action when essential improvements are necessary. The main purpose of attending this annual meeting was to build up confidence with property owners and explain the forthcoming project briefly.

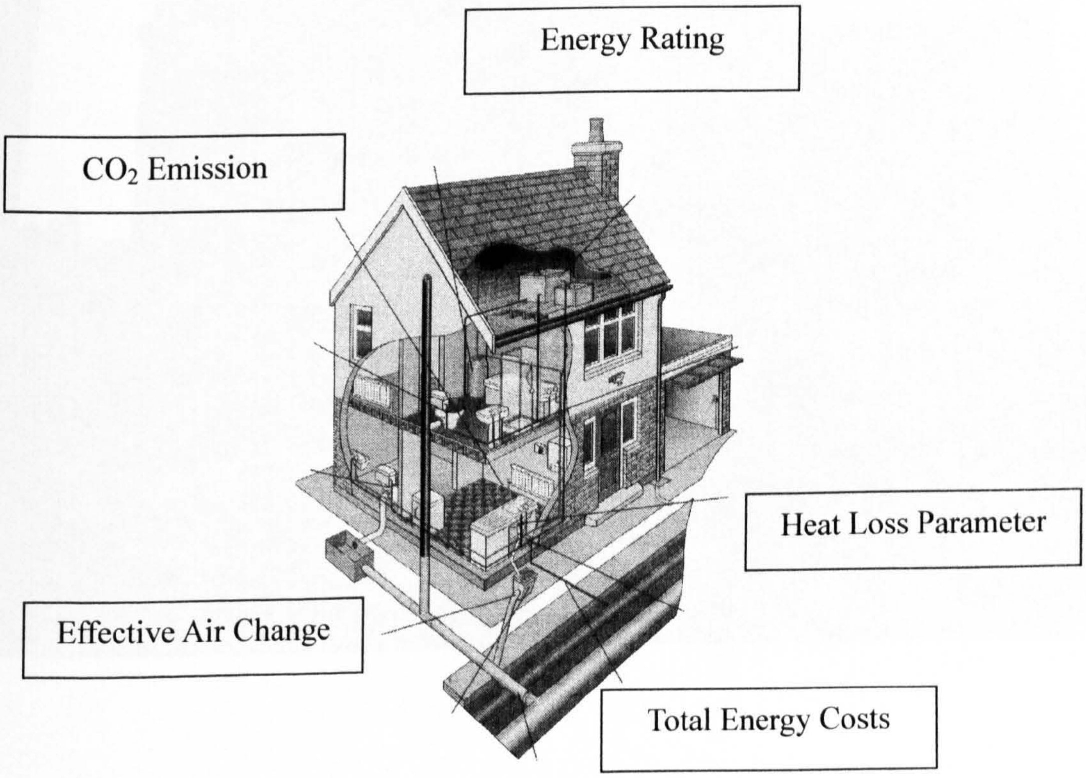
After a successful meeting, the author prepared a questionnaire to be sent out together with housing services support letter in their annual mail shot. It was not feasible to carry out more detailed site surveys in each property due to the time limit and obtain permission to access each property. Therefore the questionnaire designed strategically not only aimed to gain knowledge about each individual property, but also collect the necessary initial data crucial for the case study analysis in this research. 615 questionnaires were sent out and as a result, overall respond rate of 30% achieved as opposed to average feedback rate in most questionnaire-based surveys (generally it doesn't exceed 5%), which can therefore be considered as a highly successful survey.

One of the reasons why the response rate was relatively high could be contributed to the fact that by meeting directly with landlords/landladies confidence was established between the researcher and the owners. Feedback gained from 245 properties covering all essential data required for the case study analysis in this research. With the initial data collected, it was decided to carry out SAP calculations, total energy consumption analysis and predictions of carbon dioxide emissions in each property. This will then help to draw conclusions for the research studied accordingly. Furthermore, SAP calculations were used because it is currently part of Building Regulations and quoted in English House Conditions Survey, which makes the results of this research directly compatible with other published information.

The main criteria examined are:

- House Conditions (SAP Rating).
- Cost of Energy Use (Both for Space and Water Heating).
- Carbon Dioxide Emission.
- Effective Air Change in the Property (Natural Ventilation).
- Heat Loss Parameter (HLP).

Figure 5.1: Criteria Examined Versus Energy Use Areas in a House. (Generated 2002)

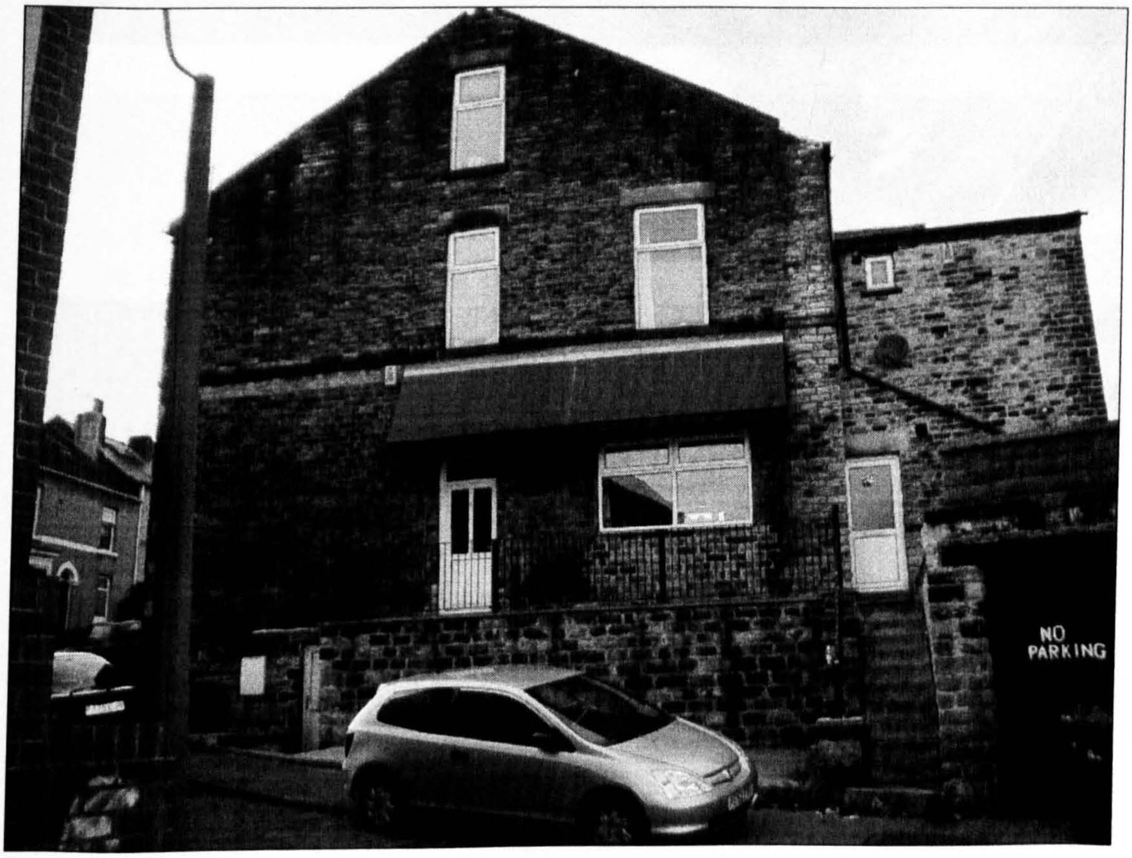


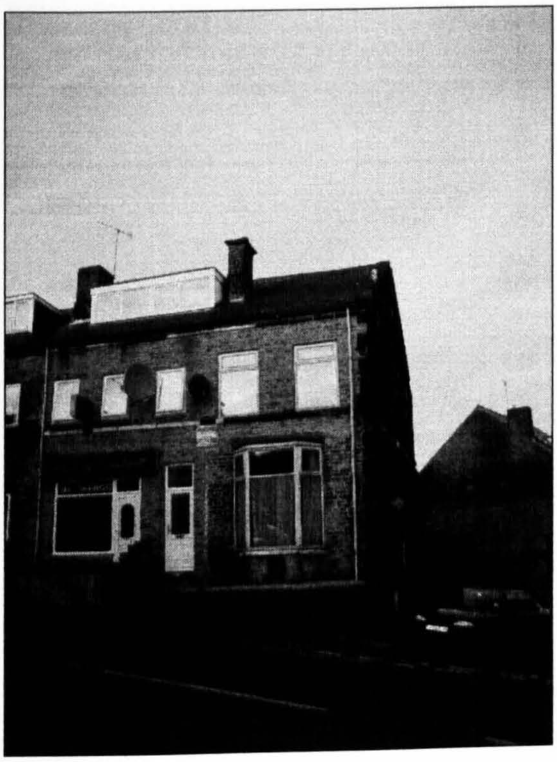
In addition, each of the 245 properties had external site survey completed in order to gather the following information:

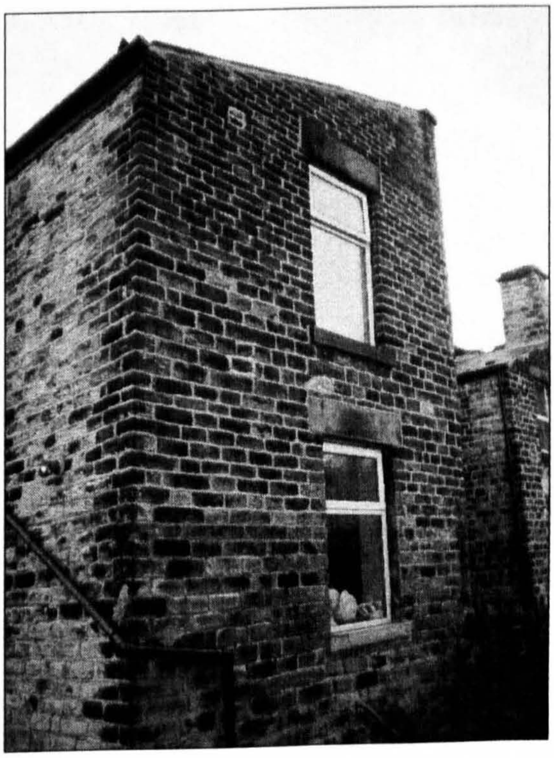
- Scaled Floor Plans
- Dwelling Elevations
- Orientations
- Openings

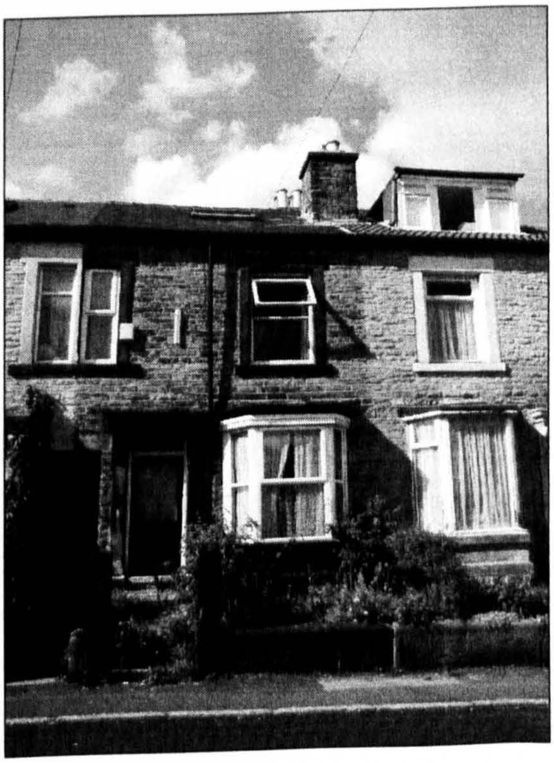
Measures, such as property floor plans were obtained by using Edina Digimap online services (http://edina.ac.uk/digimap/). The information produced in this study relates to areas in the city of Sheffield (S1, S2, S3, S6, S7, S8, S10, S11), which are close to the university campus and mainly rented by the university students, staff and other professionals.

Figure 5.2: Sample Property Elevetaions. (Generated 2003)









The above photos (figure 5.2) were taken in order to gather information on both dwelling elevations and openings. Each dwelling in figure 5.2 was photographed in a way of an example showing the variations in property types. This survey then continued with obtaining scaled floor plans (see figure 5.3) through Edina Digimap software (internet based) and supported by questionnaires (see figure 5.4) received from landlord/landladies containing information about the age, type and other relevant value of the property.

The data collected were imperative for both examining dwelling conditions for energy standards and calculating energy ratings for each individual property. This then will be used for compiling home conditions reports (feedback reports) for those property owners requested feedback on current situation of their properties (116 property feedbacks requested from over 60 landlords/landladies).

Figure 5.3: Sample Property Floor Plans. (Edina Digimap 2003)

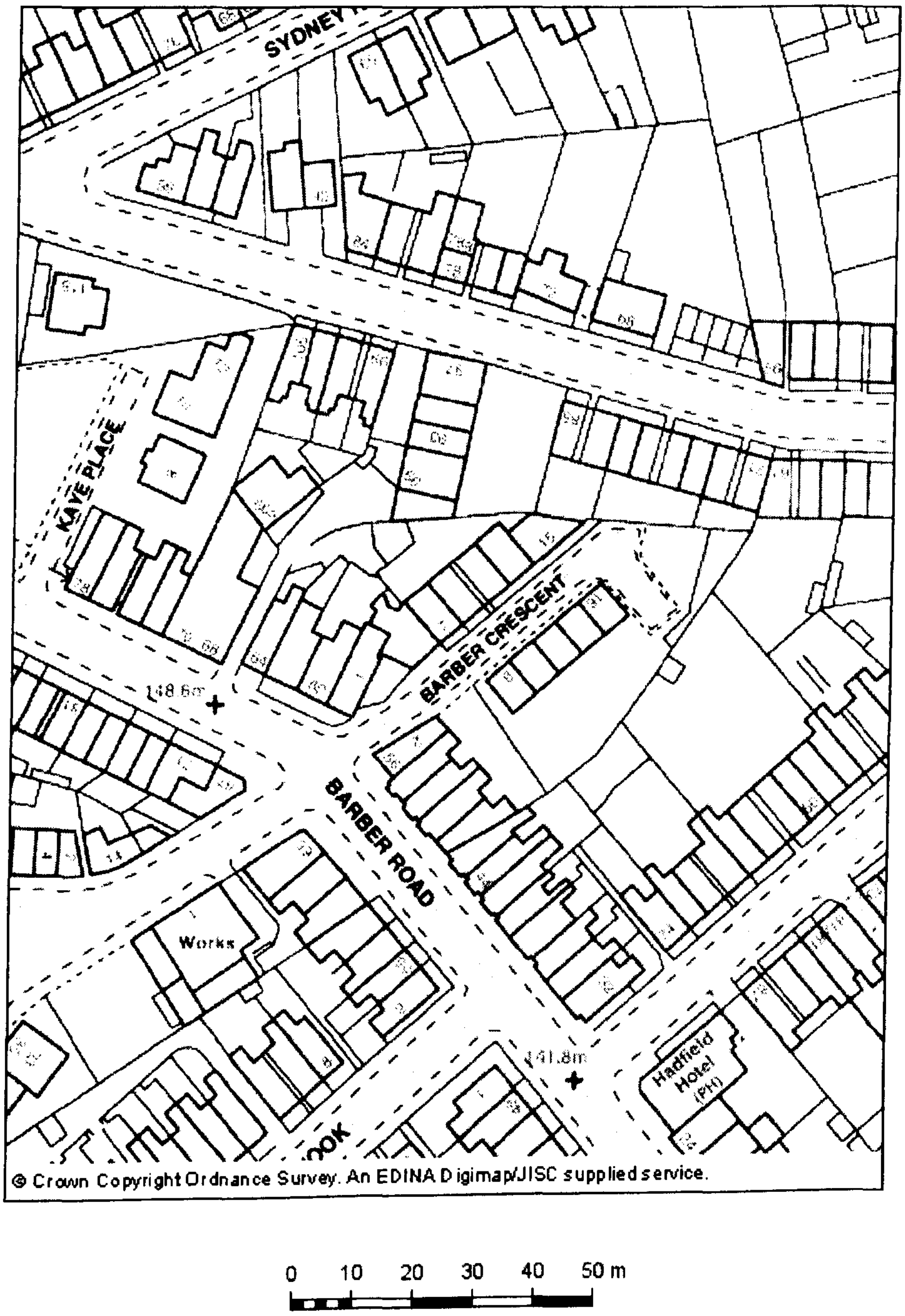


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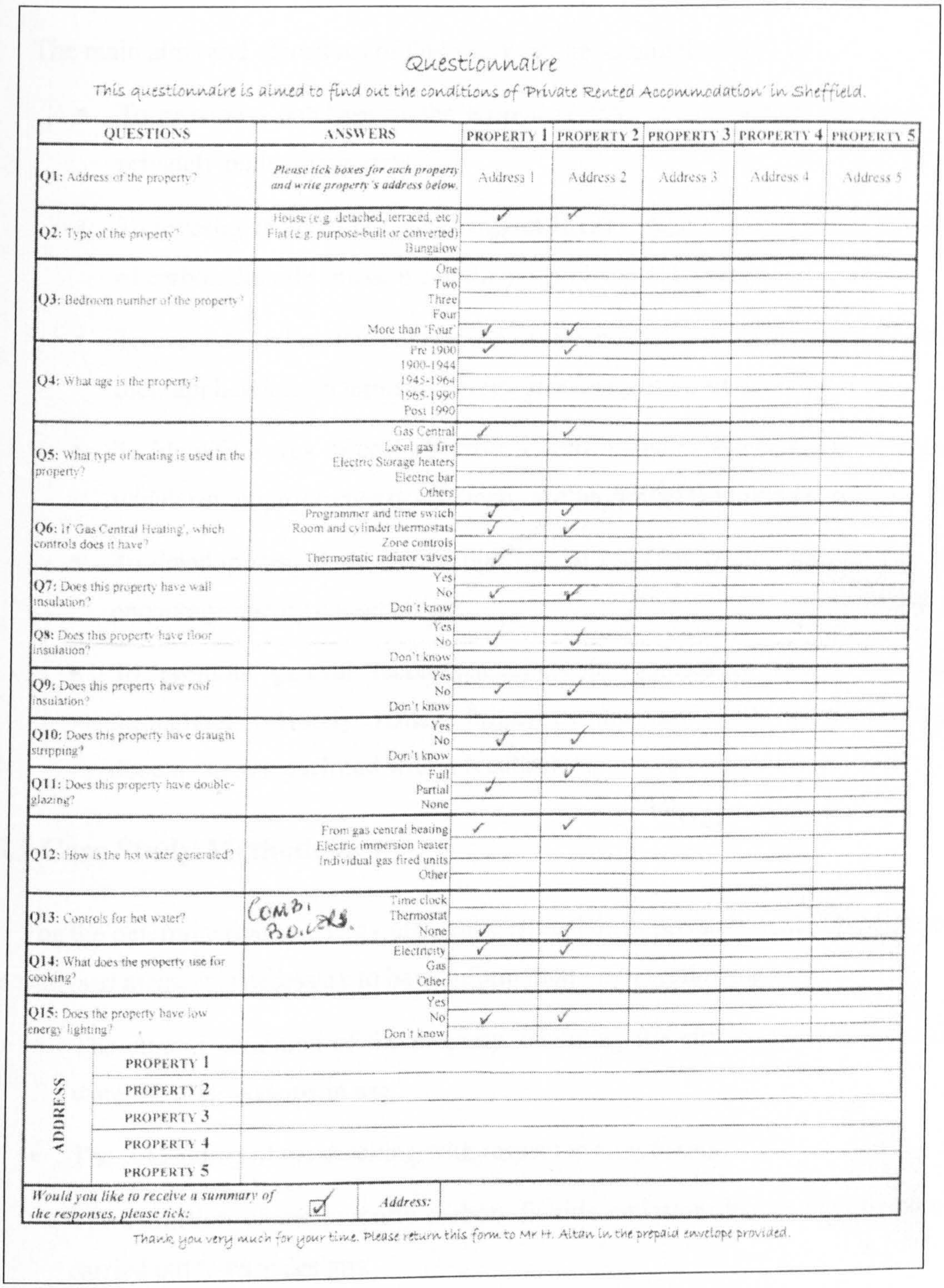
Figure 5.4: Sample Questionnaire Received. (Generated 2003)



Questionnaire

This questionnaire is aimed to find out the conditions of 'Private Rented Accommodation' in Sheffield.

QUESTIONS		ANSWERS	PROPERTY 1	PROPERTY 2	PROPERTY 3	PROPERTY 4	PROPERTY 5
Q1: Address of the property?		*Please tick boxes for each property and write property's address below.*	Address 1	Address 2	Address 3	Address 4	Address 5
Q2: Type of the property?		House (e.g. detached, terraced, etc.)	✓	✓			
		Flat (e.g. purpose-built or converted)					
		Bungalow					
Q3: Bedroom number of the property?		One					
		Two					
		Three					
		Four					
		More than 'Four'	✓	✓			
Q4: What age is the property?		Pre 1900	✓	✓			
		1900-1944					
		1945-1964					
		1965-1990					
		Post 1990					
Q5: What type of heating is used in the property?		Gas Central	✓	✓			
		Local gas fire					
		Electric Storage heaters					
		Electric bar					
		Others					
Q6: If 'Gas Central Heating', which controls does it have?		Programmer and time switch	✓	✓			
		Room and cylinder thermostats	✓	✓			
		Zone controls					
		Thermostatic radiator valves	✓	✓			
Q7: Does this property have wall insulation?		Yes					
		No	✓	✓			
		Don't know					
Q8: Does this property have floor insulation?		Yes					
		No	✓	✓			
		Don't know					
Q9: Does this property have roof insulation?		Yes					
		No	✓	✓			
		Don't know					
Q10: Does this property have draught stripping?		Yes					
		No	✓	✓			
		Don't know					
Q11: Does this property have double-glazing?		Full		✓			
		Partial	✓				
		None					
Q12: How is the hot water generated?		From gas central heating	✓	✓			
		Electric immersion heater					
		Individual gas fired units					
		Other					
Q13: Controls for hot water?	COMBI BOILERS.	Time clock					
		Thermostat					
		None	✓	✓			
Q14: What does the property use for cooking?		Electricity	✓	✓			
		Gas					
		Other					
Q15: Does the property have low energy lighting?		Yes					
		No	✓	✓			
		Don't know					
ADDRESS	**PROPERTY 1**						
	PROPERTY 2						
	PROPERTY 3						
	PROPERTY 4						
	PROPERTY 5						

Would you like to receive a summary of the responses, please tick: ☑ *Address:*

Thank you very much for your time. Please return this form to Mr H. Altan in the prepaid envelope provided.

The questionnaire-based survey has been strategically prepared to obtain data concerning property type, age, number of bedrooms, space heating used and controls (if applicable), wall/floor/roof installation, draught stripping, double glazing, hot water source and controls (if applicable), cooking source and low energy lighting in these dwellings.

5.2 Case Study Aims and Objectives

The main aims and objectives of this study can be summarised as:

- To provide a database of the current conditions and energy standards of privately rented properties.
- To investigate potentials for energy efficiency improvements and reduction of carbon dioxide emissions in the privately rented sector.
- To evaluate and review energy and environmental assessment methods, and their applications in terms of energy efficiency and carbon index (CI).
- To identify a way of cost effective modifications to dwelling base designs which can improve energy efficiency within privately rented properties.
- To develop case study results that can be used by landlords/landladies to encourage energy conservation.
- To promote general recommendations for immediate energy savings throughout privately rented properties analysed with supplementary documentation enclosed within feedback reports compiled.

5.3 Case Study Methodology

For the determination of energy efficiency potentials in privately rented properties in analysed areas, it is necessary to have information on the following:

- The current condition of the property, including the efficiency of space and water heating systems in use.
- The SAP rating of the dwelling with respect to CO_2 output.
- The reduction of the property carbon dioxide emission due to modification carried out to base designs.

5.4 Case Study Analysis and Results

With all measures obtained, the author has started to examine each dwelling for energy standards and calculate energy ratings with the use of available software, such as Stelrad's and Energy Design Advice Scheme's (EDAS) (both BRE approved) SAP calculation programs. For each questionnaire received, analysis carried out and comprehensive current situation reports compiled (Home Condition Reports) for future references, in this case for potential energy efficiency improvements in privately rented properties. Reports compiled also contain conditions of the property as well as current energy (SAP) ratings and predicted carbon dioxide (CO_2) emissions.

Furthermore, property owners were asked if they were interested in receiving summary reports on their properties. This request was accepted by property owners covering 116 properties. As a result, feedback reports compiled to demonstrate the current conditions of each individual property and potential energy efficiency improvements in these dwellings, and ultimately encourage property owners to act on it.

Overall findings from the case studies undertaken in this research are as follows:

- Average SAP rating is 61.
- 58% of these properties are above 60 SAP rating.
- Only 10% are above 70 SAP rating.
- 5% are below 50 SAP rating.
- For all analysed properties required average SAP rating is 80 or above and therefore these properties have failed to meet current standards required by the building regulations. Nevertheless, about 60% of these dwellings are considered as 'affordable and decent homes' in terms of university requirements.
- The average SAP rating for this type of property (EHCS) is 49 (ODPM, 2003); therefore these properties are better than the average for this sector.

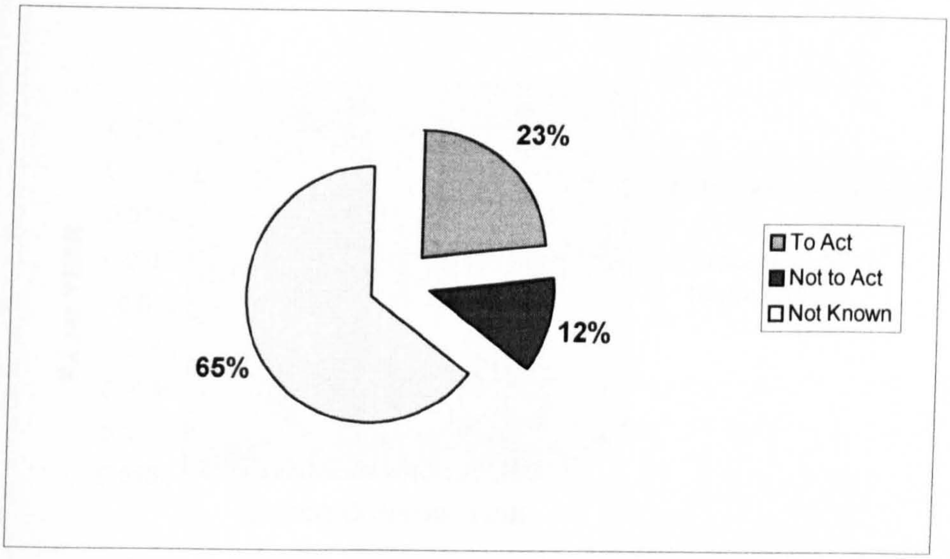
Moreover, the author has met the housing officer to discuss the research findings and share the information compiled for future recommendations accordingly. Each report composed also included a short questionnaire, as means to find out how likely the property owners were to implement the suggested improvements. To enhance the idea of encouraging further developments, they have been informed about the government's plan on introducing 'Home Information Pack' and possible SAP rating for an energy efficient house within existing housing stock.

As from the questionnaire-based survey conducted, only 24 percent of the response received stated the following:

- 56% of these property owners are either likely to implement improvements suggested or already undertaken possible improvements.
- 44% of these property owners are not likely to carry out improvements suggested via feedback reports.

On the other hand, the majority of the property owners (76 percent) are considered as 'action unknown' due to no such response as yet received in terms of this research time scale. Further to the results obtained regarding the implementation of energy efficiency improvements in those properties, it can be said that the 23% of landlords/landladies are voluntarily willing to carry out the necessary improvements (as the majority of them have submitted supplementary sheets justifying improvements already undertaken and further actions to be implemented; a sample letter can be viewed in appendix A) in order to increase energy standards of their properties. As a result, current SAP rating of these properties increased by about 22% (equivalent to 14 in number).

Figure 5.5: Overall Results for Actions to Implement Energy Efficiency Improvements within Privately Rented Properties Analysed. (Generated 2003)



It can be concluded that the 12% are not willing to undertake such improvements for energy efficiency potentials in their dwellings. This can be seen as a crucial barrier, since there is no enforced legislation in place. On the other hand, the majority of the property owners' actions are unknown with no predicted reason and therefore this barrier remains a great challenge for the energy efficiency improvement programme in the country.

Table 5.1: Predicted Energy Savings within Properties Examined. (Generated 2003)

Sector	Energy (PJ)	Notes
Yorkshire and the Humber Region	19.743 *	10% of Total Privately Rented
Properties Analysed	0.019743	0.1% of Total Region
Properties After Improvement	0.0187572	5% Reduction of Total Regional

* Regional Energy Statistics taken from the Domestic Energy Fact File 2003 (Shorrock and Utley, 2003) and English House Conditions Survey 2001 (ODPM, 2003).

Table 5.1 shows the latest total energy use recorded (2001) for Yorkshire and the Humberside region, and predicted energy use for both before and after improvements carried out within privately rented properties analysed. Please also note that the energy statistics for these properties are predicted analysis containing theoretical improvements undertaken. Yet, property owners have also stated that they are willing to action voluntarily. Considering the number of properties in this region (241,000), privately rented dwellings analysed covers 0.1% of the total and therefore energy use for this portion can be estimated as 0.1% of the latest total energy consumption recorded in 2001.

Figure 5.6: Estimated Energy Savings After Improvements. (Generated 2003)

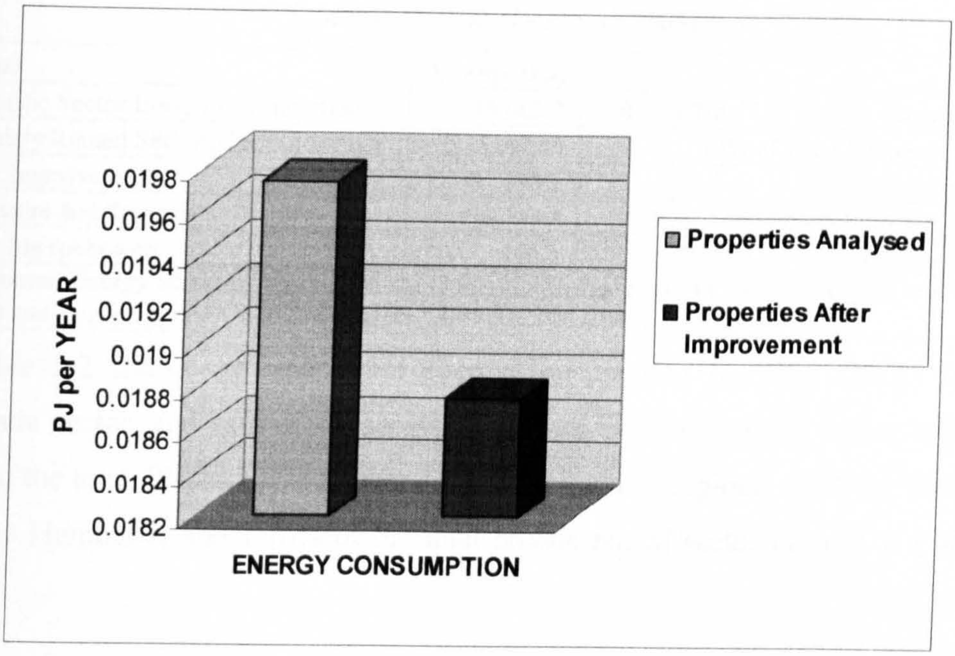


Figure 5.6 shows the reduction in energy consumption through energy efficiency improvements undertaken theoretically (although voluntary action stated) within privately rented properties analysed. Rates on this chart are estimated figures; calculated by means of both data generated (see table 5.1) and obtained from the Domestic Energy Fact File 2003 (Shorrock and Utley, 2003) and English House Conditions Survey 2001 (ODPM, 2003) statistics.

Please also note that the privately rented regional stock for Yorkshire and the Humber is about 10% of the total private rented sector in the UK (ODPM, 2003). With the improvements carried out theoretically from the 23% action can result in current average SAP rating increased by about 5% (equal to 3, in number to 64), which is also equivalent to 5% reductions on energy consumption within these privately rented properties.

Within properties analysed, although the reduction rate is 5% through theoretical improvements, regional energy savings are not significantly effective unless the government takes action in legislating the issue, which would then result in energy savings as much as about 22% (see figure 5.7).

Table 5.2: Predicted Energy Savings within Privately Rented Tenure in the UK. (Generated 2003)

Sector	Energy (PJ)	Notes
Domestic Sector Energy Consumption	1974.3 *	30% of Total UK Energy Consumption
Privately Rented Sector (Current Status)	197.43	10% of Total Domestic Sector
After Improvements	193.1	22% Reduction Rate
Yorkshire and the Humber Region	19.743 *	10% of Total Privately Rented Sector
After Improvements	15.4	22% Reduction Rate
* Regional Energy Statistics taken from the Domestic Energy Fact File 2003 (Shorrock and Utley, 2003) and English House Conditions Survey 2001 (ODPM, 2003).		

Table 5.2 shows the latest total energy consumption recorded (2001) for the domestic sector, and estimated energy use for the privately rented sector, which is 10% of the total. Please also note that the privately rented regional stock for Yorkshire and the Humber is about 10% of the total private rented sector in the UK (ODPM, 2003).

If energy efficiency improvements were to be implemented within these privately rented properties analysed, in that case there would be energy savings as much as 22%. Please also note that the energy statistics for these properties are predicted analysis containing theoretical improvements undertaken (see figure 5.7).

Figure 5.7: Predicted Energy Consumption After Improvements within Privately Rented Tenure in the UK. (Generated 2003)

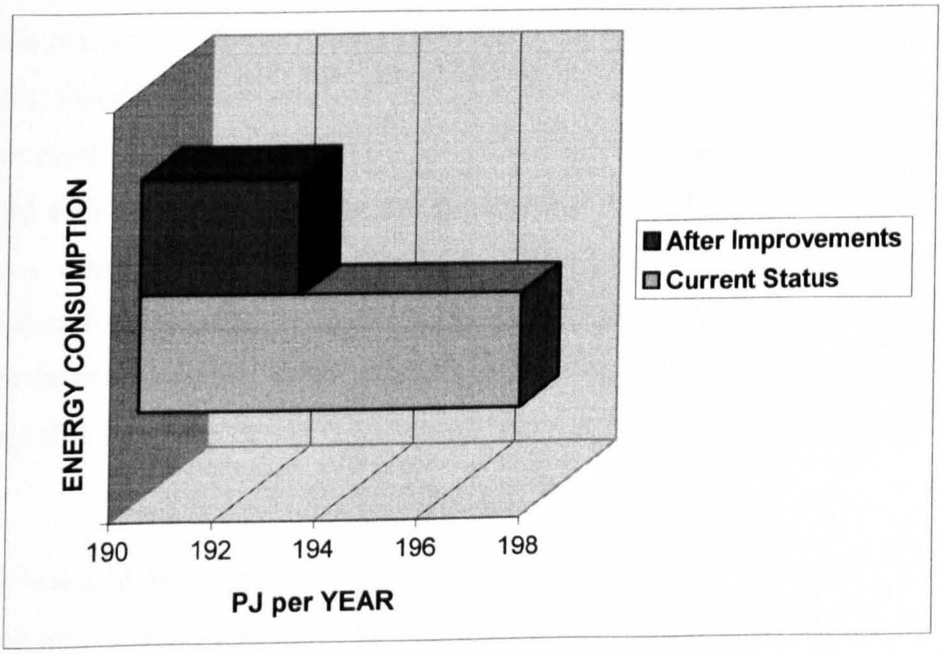


Figure 5.7 shows both current overall energy consumption in the privately rented sector in the UK and after the improvements undertaken through theoretical action

process within privately rented properties analysed. Rates on this chart are estimated figures; calculated using both data generated (see table 5.2) and obtained from the Domestic Energy Fact File 2003 (Shorrock and Utley, 2003) and English House Conditions Survey 2001 (ODPM, 2003) statistics.

Please also note that the privately rented sector accounts for about 10% of the total domestic sector in the UK (ODPM, 2003). Furthermore, due to the submission deadline of this thesis, the results for suggested improvements are still counting up (feedback is being received) and therefore the case study results only contain the most recent data received and analysed.

To conclude, considering today's housing standards reviewed in chapter 2, about 60% of privately rented dwellings examined can be considered as 'affordable and decent homes'. However if the government was to action in order to meet 20% reductions in CO_2 emissions, potential energy efficiency improvements in these particular sector (covering only the minority of the total UK housing stock) should therefore be implemented. Despite the fact that this sector only accounts for 15% of the total housing stock, it can significantly contribute to achieving targets both set nationally and internationally.

In this research, it should be emphasised that the methodology used can therefore guide for further developments within privately rented properties to help achieve effective results in energy efficiency improvement programme in the city. In addition, it should also be mentioned that the knowledge gap can be bridged and energy efficiency could be achieved generally in the private housing sector with close relationship developed through each housing community. This is again undoubtedly the right direction to guide policy makers prepare more effective policies to tackle the challenge that government and local authorities faced today, specifically in the private sector.

More detailed information on questionnaire-based survey and related results are shown in appendix A. The statistics for the first 55 property are shown in table 5.3. The table gives the existing conditions (with relevant SAP rating), cost of energy use (both for space and water heating), CO_2 emission, effective air change in the property (natural ventilation) and heat loss parameter.

Table 5.3: Current Conditions of the Properties Examined. (Generated 2002)

PRIVATE RENTED PROPERTIES REQUIRED SAP RATINGS = 80/81/82/83/84/85

PROPERTY NO	SAP	COSTS £ YEAR			CO_2	HEAT LOSS PARAMETER	AIR CHANGE RATE	PASS/FAIL P/F
		SPACE	WATER	TOTAL				
PROPERTY 1	54	263.01	150.04	413.05	4.54	2.81	0.77	F
PROPERTY 2	60	343.95	162.82	506.77	5.68	2.6	0.91	F
PROPERTY 3	58	319.03	158.68	477.71	5.33	2.7	0.9	F
PROPERTY 4	54	331.51	156.55	488.06	5.45	2.88	0.91	F
PROPERTY 5	50	324.27	152.29	476.56	5.31	3.17	0.86	F
PROPERTY 6	51	317.28	152.29	469.57	5.23	3.11	0.83	F
PROPERTY 7	51	292.58	150.04	442.62	4.9	3.11	0.77	F
PROPERTY 8	59	321.93	160.22	482.15	5.38	2.63	0.81	F
PROPERTY 9	58	361.72	162.82	524.54	5.9	2.76	0.83	F
PROPERTY 10	57	377.44	162.82	540.26	6.09	2.86	0.81	F
PROPERTY 11	65	291.64	162.82	454.46	5.04	2.3	0.77	F
PROPERTY 12	66	305.66	140.41	446.07	4.94	2.33	0.83	F
PROPERTY 13	56	380.5	162.82	543.32	6.13	2.86	0.83	F
PROPERTY 14	56	380.5	162.82	543.32	6.13	2.86	0.83	F
PROPERTY 15	56	386.81	162.82	549.63	6.21	2.92	0.83	F
PROPERTY 16	52	338.12	155.15	493.27	5.52	3.09	0.85	F
PROPERTY 17	66	294.03	164.39	458.42	5.09	2.27	0.83	F
PROPERTY 18	69	406.4	179.26	585.66	6.65	2.21	0.78	F
PROPERTY 19	69	408.87	179.26	588.13	6.68	2.23	0.78	F
PROPERTY 20	68	415.39	179.26	594.65	6.75	2.27	0.78	F
PROPERTY 21	68	415.39	179.26	594.65	6.75	2.27	0.78	F
PROPERTY 22	75	536.55	197.96	734.51	8.46	2.01	0.77	F
PROPERTY 23	53	835.54	195.77	1031.31	19.46	2.33	0.87	F
PROPERTY 24	52	278.14	150.04	428.18	4.72	2.95	0.86	F
PROPERTY 25	57	252.41	151.7	404.11	4.43	2.65	0.98	F
PROPERTY 26	60	342.76	162.82	505.58	5.67	2.61	0.88	F
PROPERTY 27	59	347.49	162.82	510.31	5.73	2.64	0.88	F
PROPERTY 28	56	272.85	112.76	385.61	4.2	2.85	0.98	F
PROPERTY 29	55	239.16	148.93	388.09	4.23	2.69	0.98	F
PROPERTY 30	71	332.88	174.23	507.11	5.69	2.05	0.88	F
PROPERTY 31	59	237.96	151.7	389.66	4.25	2.5	0.95	F
PROPERTY 32	55	273.71	151.7	425.41	4.69	2.82	0.98	F
PROPERTY 33	64	279.71	160.47	440.18	4.87	2.36	0.76	F
PROPERTY 34	67	253.56	160.86	414.42	4.55	2.2	0.83	F
PROPERTY 35	67	253.56	160.86	414.42	4.55	2.2	0.83	F
PROPERTY 36	67	253.56	160.86	414.42	4.55	2.2	0.83	F
PROPERTY 37	68	264.33	163.07	427.4	4.71	2.17	0.74	F
PROPERTY 38	70	270.68	166.31	436.99	4.83	2.09	0.74	F
PROPERTY 39	59	355.2	162.82	518.02	5.82	2.68	0.95	F
PROPERTY 40	62	309.36	161.96	471.32	5.25	2.43	0.86	F
PROPERTY 41	60	344.42	162.82	507.24	5.69	2.6	0.91	F
PROPERTY 42	60	371.98	165.63	537.61	6.06	2.62	0.83	F
PROPERTY 43	59	349.23	162.82	512.05	5.75	2.64	0.88	F
PROPERTY 44	59	355.88	162.82	518.7	5.83	2.71	0.91	F
PROPERTY 45	59	321.8	159.88	481.68	5.38	2.66	0.91	F
PROPERTY 46	51	272.04	148.93	420.97	4.63	2.99	0.85	F
PROPERTY 47	50	285.55	148.93	434.48	4.63	3.14	0.85	F

PRIVATE RENTED PROPERTIES REQUIRED SAP RATINGS = 80/81/82/83/84/85

PROPERTY NO	SAP	COSTS £ YEAR			CO_2	HEAT LOSS PARAMETER	AIR CHANGE RATE	PASS/FAIL P/F
		SPACE	WATER	TOTAL				
PROPERTY 48	54	329.09	156.13	485.22	4.8	2.94	0.92	F
PROPERTY 49	69	508.9	189.06	697.96	5.42	2.24	0.68	F
PROPERTY 50	66	378.93	173.13	552.06	8.02	2.35	0.85	F
PROPERTY 51	59	590.29	182.62	772.91	16.08	2.16	0.82	F
PROPERTY 52	73	456.59	189.06	645.65	7.38	2.1	0.85	F
PROPERTY 53	59	355.8	163.07	518.87	5.83	2.69	0.91	F
PROPERTY 54	65	352.09	169.04	521.13	5.86	2.34	0.97	F
PROPERTY 55	64	359.8	169.04	528.84	5.95	2.38	0.9	F

As it can be seen from the charts (figure 5.8, 5.9 and 5.10), properties 23 and 51 have shown extreme results on both carbon dioxide output and total energy use. This is due to the size of these properties being extensively larger dwellings compared to others in this case study. In contrast, SAP ratings for same dwellings remain below average energy rating (61) within these properties analysed.

Figure 5.8: Current SAP Ratings of the Properties Analysed. (Generated 2002)

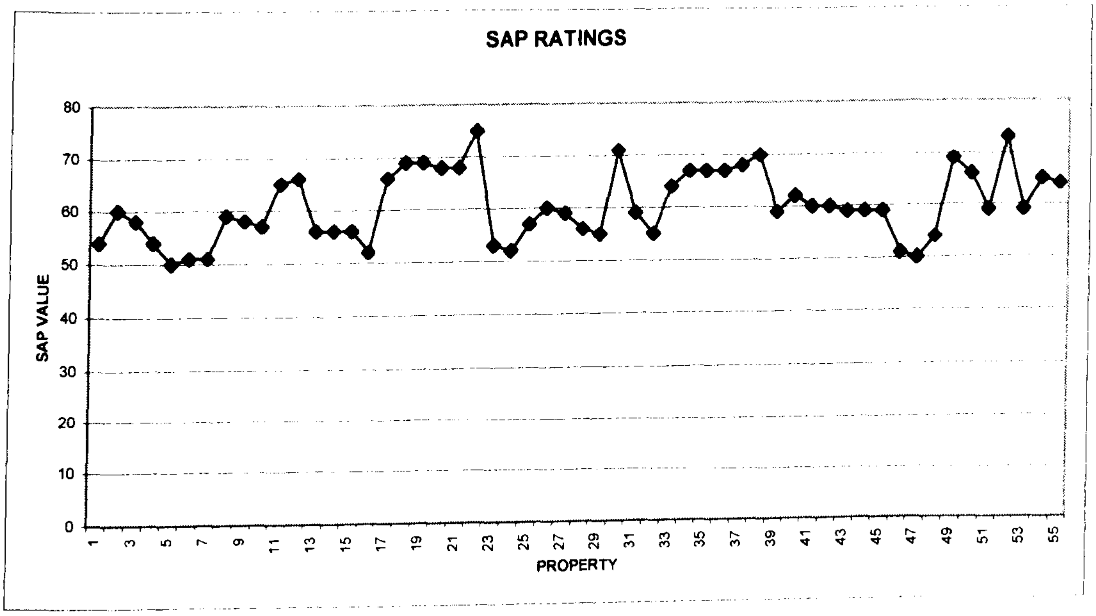


Figure 5.9: Predicted CO_2 Emissions in these Properties. (Generated 2002)

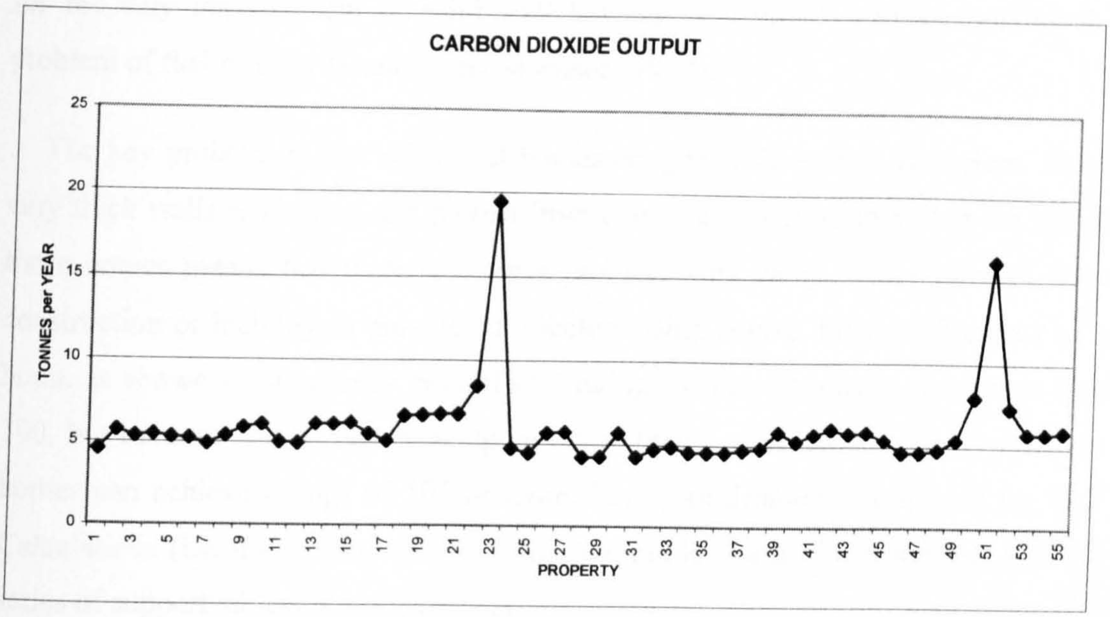
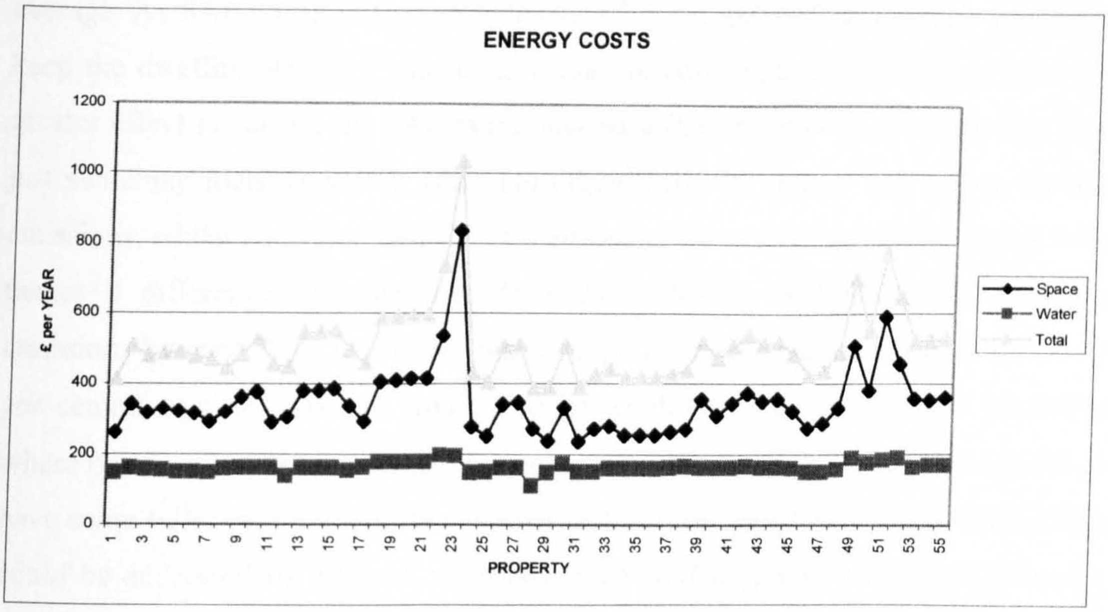


Figure 5.10: Estimated Energy Costs for Heating in these Properties. (Generated 2002)



This emphasises the predominance of SAP ratings, which is mainly between 50 - 70, due partly to the CO_2 emissions. Analysis of house conditions shows that, average SAP rating is 61, below required by the building regulations. In relation with the age of the property, it is estimated that during the Industrial Revolutions of the 18th and 19th centuries, there has been a massive increase in housing, which on average, 50% of private rented housing could be solid wall dwellings. It is also stated that around two thirds (66%) of solid wall dwellings are owner-occupied, with only 18% in the social rented sector, and 16% in the private rented sector. This has implications both for the way improvement of solid wall housing is marketed and for solving the problem of fuel poverty (Leather and Morrison, 1997).

The key problem is that solid wall homes are generally energy inefficient. Some very thick walls retain heat and protect from extremes of temperature, but the age of these homes means that there is often a problem with damp, either through floor construction or inability to provide an effective damp course. Energy efficiency of a house is shown by its energy rating (SAP rating), which nominally runs from 0 to 100, but because it is a calculated figure rather than a scale, highly energy efficient homes can achieve ratings of 105 or more. For more detailed information on SAP Calculations (i.e. the method of calculating the rating, form of a worksheet and the series of support tables), see appendix A.

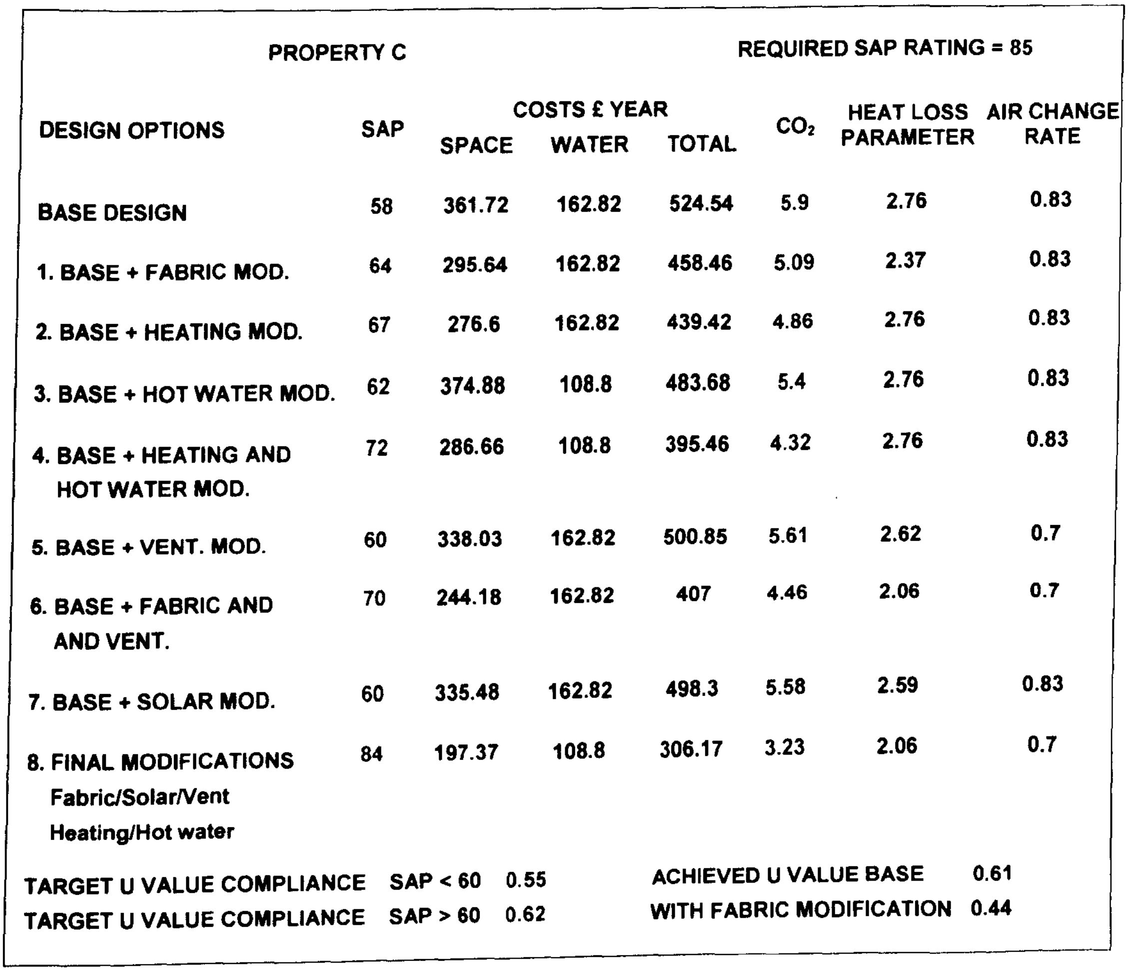
For the solid wall building, adding gas central heating leaves it below the national average. As SAP rating is also an indicator of the amount of expenditure needed to keep the dwelling warm, it can be seen that introducing better insulation has a far greater effect in raising the SAP rating and reducing the amount spent on fuel than just switching fuels. However, when considering climate change and carbon dioxide emissions, whilst insulation reduces CO_2 emissions by over 40%, just switching fuels makes a difference of more than 50%. Nevertheless, performing both reduces emissions by over 70%. It is likely that a programme that concentrated on installing gas central heating in homes would also be required to increase the loft insulation where possible and fit other measures such as draught proofing. It would be useful to have some fuller modelling of these scenarios based on actual numbers of homes that could be addressed by different measures, such as that carried out within privately rented dwellings in Sheffield.

Table 5.4: Comparison of SAP Ratings and CO_2 Emissions with respect to Double-Glazed and Central-Heated Properties. (Generated 2002)

Property A	SAP Ratings	CO_2 Emissions	Property B	SAP Ratings	CO_2 Emissions
No Insulation or Double Glazing; Gas Central Heating and Single Point Hot Water	50	5.31	No Insulation or Double Glazing; Electric Storage Heater	53	19.46
Fabric Modifications	58	4.43	Fabric Modifications	60	16.35
Heating and Hot Water Modifications	64	3.87	Heating and Hot Water Modifications	64	17.49
Full Modifications; Fabric, Solar, Vent, Heating and Hot Water	80	2.68	Full Modifications; Fabric, Solar, Vent, Heating and Hot Water	78	11.98

To summarise, properties with solid walls, of non-traditional construction types and/or off gas network are mostly have SAP ratings below average. There are insulating and/or heating solutions that can improve the SAP ratings and reduce the amount of CO_2 emitted through inefficient use of fuel. Sample dwellings in table 5.4 have been chosen from within privately rented properties examined.

Table 5.5: Example Details of Modifications to Original Base Design. (Generated 2002)



PROPERTY C REQUIRED SAP RATING = 85

DESIGN OPTIONS	SAP	COSTS £ YEAR SPACE	COSTS £ YEAR WATER	COSTS £ YEAR TOTAL	CO_2	HEAT LOSS PARAMETER	AIR CHANGE RATE
BASE DESIGN	58	361.72	162.82	524.54	5.9	2.76	0.83
1. BASE + FABRIC MOD.	64	295.64	162.82	458.46	5.09	2.37	0.83
2. BASE + HEATING MOD.	67	276.6	162.82	439.42	4.86	2.76	0.83
3. BASE + HOT WATER MOD.	62	374.88	108.8	483.68	5.4	2.76	0.83
4. BASE + HEATING AND HOT WATER MOD.	72	286.66	108.8	395.46	4.32	2.76	0.83
5. BASE + VENT. MOD.	60	338.03	162.82	500.85	5.61	2.62	0.7
6. BASE + FABRIC AND AND VENT.	70	244.18	162.82	407	4.46	2.06	0.7
7. BASE + SOLAR MOD.	60	335.48	162.82	498.3	5.58	2.59	0.83
8. FINAL MODIFICATIONS Fabric/Solar/Vent Heating/Hot water	84	197.37	108.8	306.17	3.23	2.06	0.7

TARGET U VALUE COMPLIANCE	SAP < 60	0.55	ACHIEVED U VALUE BASE	0.61
TARGET U VALUE COMPLIANCE	SAP > 60	0.62	WITH FABRIC MODIFICATION	0.44

Table 5.5 shows the various modifications undertaken to the base design (potential energy efficiency improvements) and the results on energy costs and ratings consequently. This sample base design is chosen from within privately rented properties examined. Design options shown on the following charts (figures 5.11, 5.12 and 5.13) are described on table 5.5 in more detail.

Figure 5.11: Change in SAP Ratings. (Generated 2002)

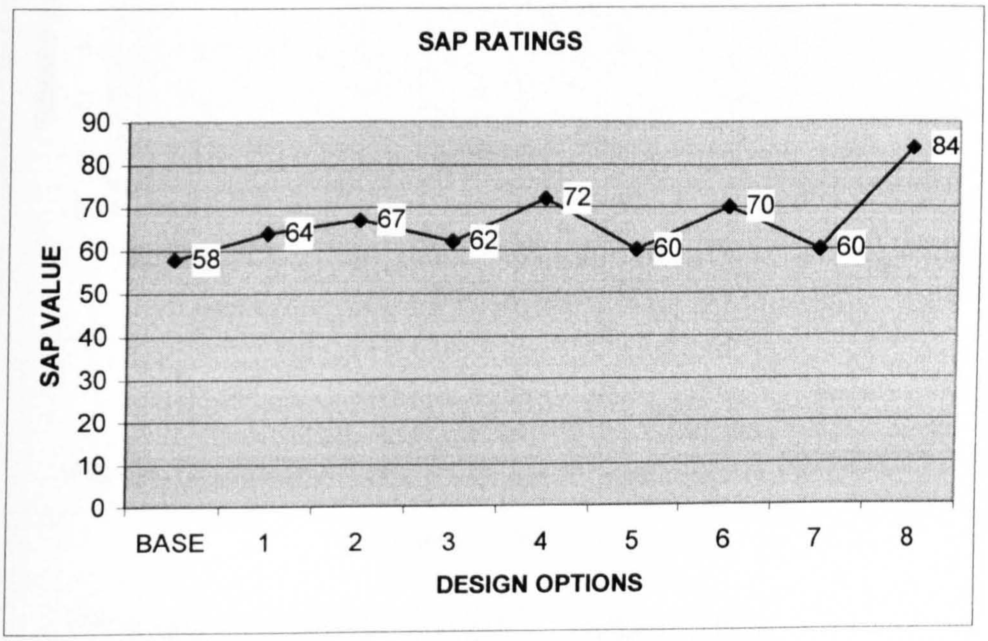


Figure 5.12: Change in CO_2 Emissions. (Generated 2002)

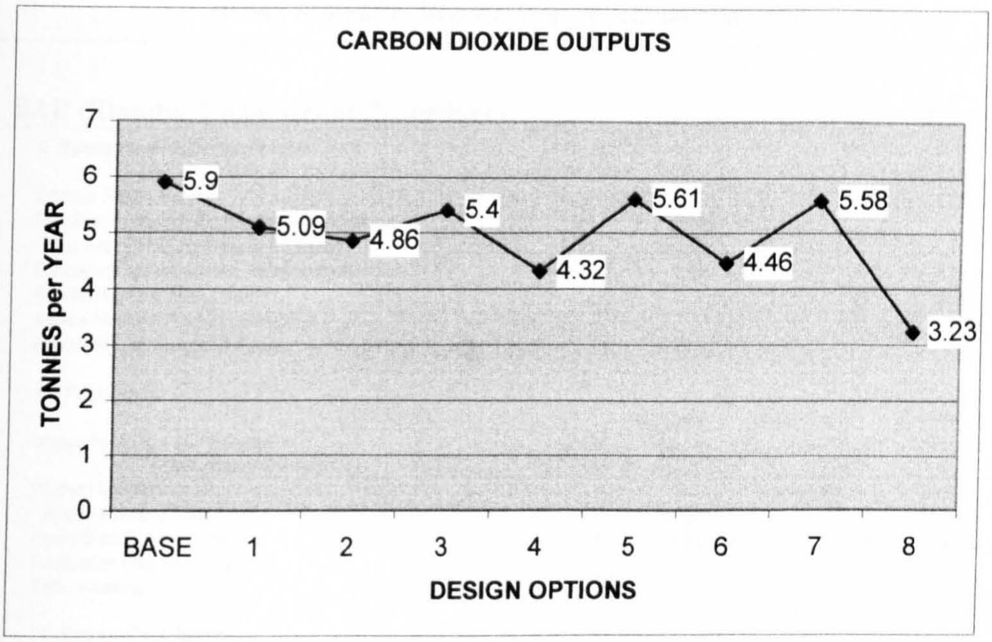
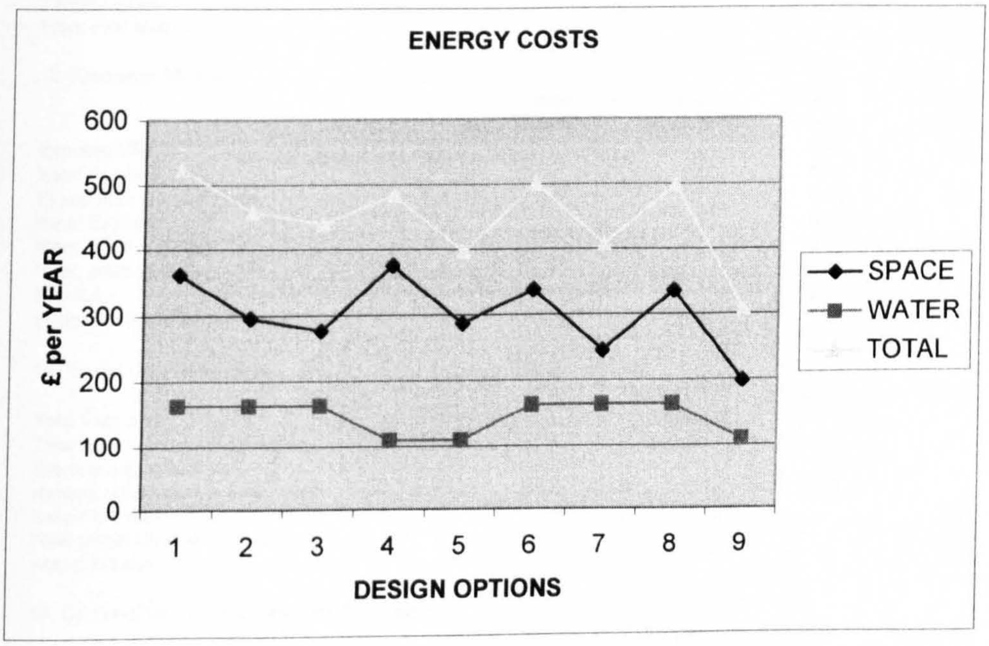
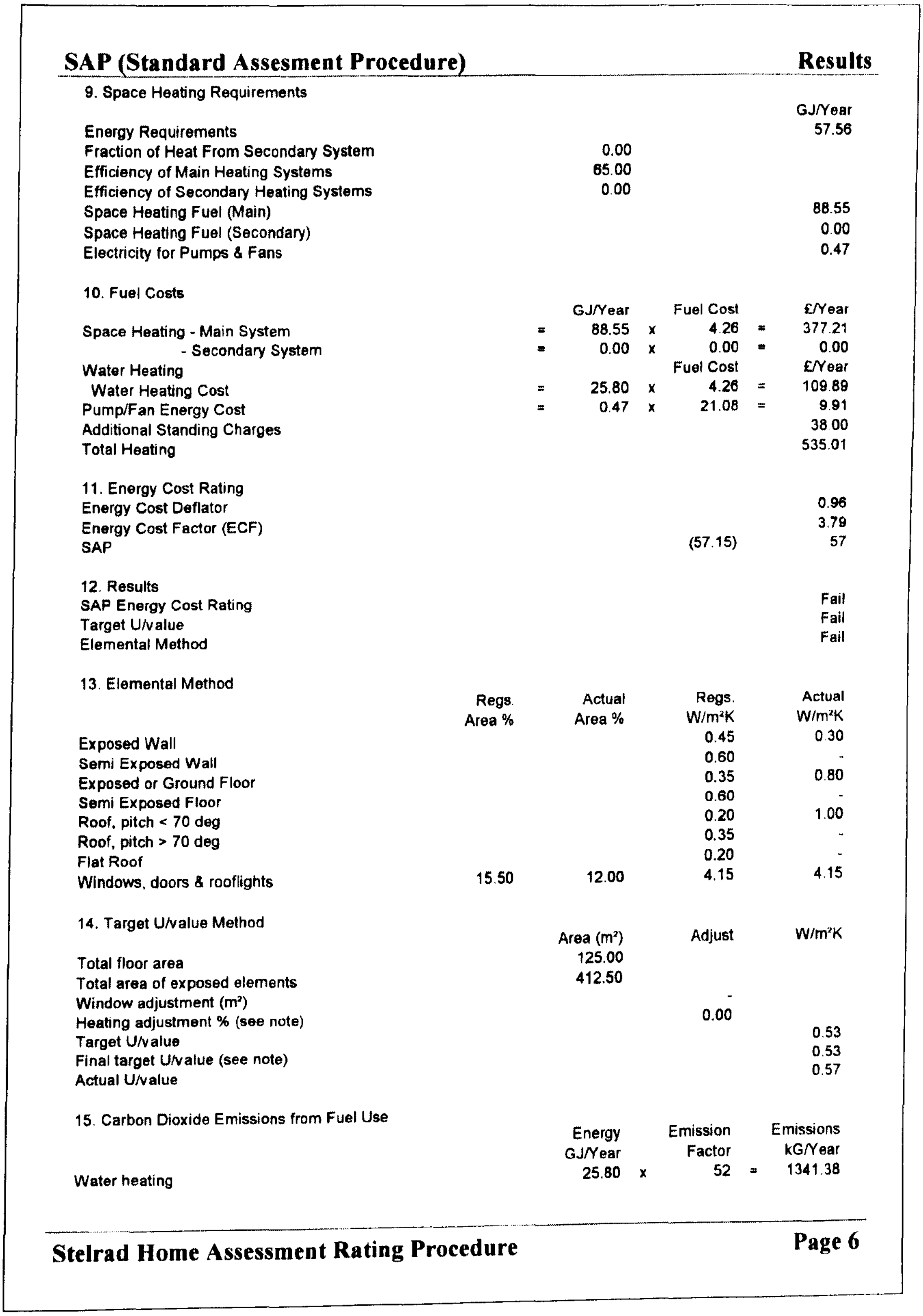


Figure 5.13: Change in Total Energy Costs for Heating. (Generated 2002)



The following figure 5.14 shows an example SAP worksheet (page 6) calculated by the use of Stelrad SAP calculation program. Within this worksheet, results of this sample calculation can be viewed in section 12 (see figure 5.14). Results presented include Energy Cost Rating (SAP rating) and Target U-Value.

Figure 5.14: Example of Stelrad Home Assessment Rating Procedure Results (Page 6). (Generated 2002)



SAP (Standard Assesment Procedure) — Results

9\. Space Heating Requirements

		GJ/Year
Energy Requirements		57.56
Fraction of Heat From Secondary System	0.00	
Efficiency of Main Heating Systems	65.00	
Efficiency of Secondary Heating Systems	0.00	
Space Heating Fuel (Main)		88.55
Space Heating Fuel (Secondary)		0.00
Electricity for Pumps & Fans		0.47

10\. Fuel Costs

		GJ/Year		Fuel Cost		£/Year
Space Heating - Main System	=	88.55	x	4.26	=	377.21
- Secondary System	=	0.00	x	0.00	=	0.00
Water Heating				Fuel Cost		£/Year
Water Heating Cost	=	25.80	x	4.26	=	109.89
Pump/Fan Energy Cost	=	0.47	x	21.08	=	9.91
Additional Standing Charges						38.00
Total Heating						535.01

11\. Energy Cost Rating

Energy Cost Deflator		0.96
Energy Cost Factor (ECF)		3.79
SAP	(57.15)	57

12\. Results

SAP Energy Cost Rating	Fail
Target U/value	Fail
Elemental Method	Fail

13\. Elemental Method

	Regs. Area %	Actual Area %	Regs. W/m²K	Actual W/m²K
Exposed Wall			0.45	0.30
Semi Exposed Wall			0.60	-
Exposed or Ground Floor			0.35	0.80
Semi Exposed Floor			0.60	-
Roof, pitch < 70 deg			0.20	1.00
Roof, pitch > 70 deg			0.35	-
Flat Roof			0.20	-
Windows, doors & rooflights	15.50	12.00	4.15	4.15

14\. Target U/value Method

	Area (m²)	Adjust	W/m²K
Total floor area	125.00		
Total area of exposed elements	412.50		
Window adjustment (m²)		-	
Heating adjustment % (see note)		0.00	
Target U/value			0.53
Final target U/value (see note)			0.53
Actual U/value			0.57

15\. Carbon Dioxide Emissions from Fuel Use

	Energy GJ/Year		Emission Factor		Emissions kG/Year
Water heating	25.80	x	52	=	1341.38

Stelrad Home Assessment Rating Procedure **Page 6**

5.5 Feedback Reports for Landlords/Landladies

Feedback reports have been compiled for each property owner to show the current conditions and energy standards of their property and determined to suggest potential energy efficiency improvements when considering refurbishments (see appendix A for more detailed information). In these summary reports, it is also stated that the government is determined to ensure that the thermal efficiency of housing (and also non domestic building) is improved and their intention is to introduce a 'Home Sellers/Buyers Pack' in which the energy efficiency of the dwelling would have to be given (see following section 5.6 for more information about the Home Information Report).

With the data compiled through case study analysis and property owners' contribution, the author has developed a database of the 'local' current situation and therefore can provide a benchmark figure against why potential improvements can be determined. This will not only help to encourage energy efficiency standards throughout the private housing sector, but also accelerate the necessity of improvements and consultancies in the domestic sector.

Furthermore, each feedback report compiled have been supplied with information on general recommendations for immediate savings in privately rented properties and questionnaire to find out how often they were informed about energy savings and whether they would act on it accordingly. By this, it was aimed to bring evidence to the case that there is still a knowledge gap between the energy efficiency technologies available and the property owners, which is considered as one of the main barriers in this research.

5.6 Home Information Pack

The UK government is committed to making it easier for people buying and selling homes in England and Wales through a new seller's pack proposed as the 'Home Information Pack'. Introducing the Home Information Pack (HIP) is a key part of a package of measures to reform the home buying and selling process. Legislation to introduce the pack was first introduced to the House of Commons on 12 December 2000 in the form of the Homes Bill 2001. However the Bill was unable to complete its passage before Parliament was dissolved for the 2001 General Election. Legislation is being reintroduced as part of the draft Housing Bill published on 31 March 2003 for consultation. The legislation will require homeowners or their selling agents to have a Home Information Pack when marketing homes for sale, and to make a copy of the pack available to prospective buyers on request (ODPM, 2003).

The HIP programme to improve the energy efficiency of the housing stock tends to be driven primarily either by the need to reduce carbon dioxide emissions or the need to improve living conditions for the health and well-being of the occupants. As part of the commitment to improve the home buying and selling process, the Lord Chancellors Department has brought in the Land Registration Act 2002, which will modernise the land registration system and prepare the way for electronic conveyancing. With electronic conveyancing brought forward, it is aimed to complement the proposals for Home Information Pack and therefore speed up the conveyancing process thereafter. Taken together, both of these measures will help create a faster and more efficient home buying and selling system (ODPM, 2003).

If the Home Information Pack legislation were to be introduced, it will require sellers of residential properties in England and Wales, or their agents, to make a Home Information Pack available before marketing homes for sale, and to make a copy of the pack available to prospective buyers on request. The Home Information Pack is likely to contain the following documents, most of which are currently provided later in the sale:

- Terms of sale.
- Evidence of title.
- Replies to standard preliminary enquiries made on behalf of buyers.
- Copies of any planning, listed building and building regulations consents and approvals.
- For new properties, copies of warranties and guarantees.
- Any guarantees for work carried out on the property.
- Replies to local searches.

- A home condition report based on a professional survey of the property, including an energy efficiency assessment.

Additionally, for leasehold properties, it will include a copy of the lease; most recent service charge accounts and receipts; building insurance policy details and payment receipts; regulations made by the landlord or management company; and memorandum and articles of the landlord or management company.

Furthermore, it has been also proposed in the Consultation Paper published on March 2003 that the Home Information Pack should contain an objective report on the condition of the property, which is the Home Condition Report (HCR) and should be prepared by the home inspector qualifying under a certification scheme approved by the Secretary of State. The report should also include an energy efficiency assessment compliant with EU Directive 2002/91/EC (Energy Performance of Buildings Directive) (ODPM, 2003).

The Home Condition Report would detail the current SAP rating of the dwelling and purpose the adoption of specific energy efficiency measures to increase this rating, potentially reducing fuel bills and CO_2 emissions. The aim of the HCR is to provide home sellers, buyers and lenders with an objective report on the condition and energy efficiency of the home that they can rely on. It will focus on communicating fuel costs and resulting financial savings as a means to motivate, with associated carbon savings presented as a secondary piece of information. The ultimate effect of the HCR is therefore to abate carbon dioxide emission and reduce effects of global warming. This report can be very effective as it has the benefits of creating more comfortable homes, which are affordable to heat, gives people a means for comparing homes in terms of energy efficiency and provides a benchmark figure with which to work.

5.7 Conclusion

As recent statistics stated the state of UK Housing, particularly the privately rented sector, the results of these case studies carried out in this research have once again shown that most of privately rented properties are in poor conditions (Revell and Leather, 2000) - below energy rating (SAP) required by the building regulations, and therefore there are potentials for energy efficiency improvements. This case study contains comprehensive reports compiled (feedback reports) for each property owner (landlord/landlady) participated in the survey on the condition of their property and potential energy efficiency improvements in their dwelling. These feedback reports put together also include current SAP ratings of the properties and other energy efficiency measures such as high-efficiency lighting, etc.

Privately rented properties targeted are university-registered properties with close links to the university housing community and operate under the control of the housing services department. In addition, majority of these properties registered to comply with the 'Responsible Landlord Scheme' provided by the City Council and therefore required to meet specified qualifying 'fit and proper' criteria. The results from property condition reports compiled in this survey have also been discussed with the university housing authorities and put forward for future references.

Having chosen university-controlled properties for this case study would therefore help to utilise the university authority to take action effectively and play a key role in guiding energy efficiency improvements within privately rented properties. With university authority, potential improvements in these properties can be encouraged and implemented much effectively, whilst existing legislation and policies are inoperative to enforce retrospective energy standards in existing dwellings. Moreover, this has a negative impact on the privately rented sector and can also be seen as a major barrier. Therefore, this is an opportunity that will not only increase energy standards of the housing stock in Sheffield, but also help to achieve the rate of improvement required by the Home Energy Conservation Act 1995 and reduce the overall energy consumption caused by the existing housing stock in the country accordingly.

As widely known, the technical expertise exists to enable energy efficiency improvements to be carried out, however success not only rests on the technical knowledge, but also demands political and governmental support. Moreover, a recent study indicates that the HECA 1995 is unlikely to achieve a 30% improvement in energy efficiency in homes by 2010 given that the progress has been slow and largely occurred in the public sector where this only constitute a dwindling minority of the stock (DETR, 1999).

On the other hand, local authorities can only have a little influence on the private sector, which accounts for the majority of the stock, and this therefore remains a great challenge for the government, whilst there is no enforced legislation of energy standards in the private sector. Thus, this research has focused on the privately rented properties that accounts for about 15% of the total housing stock and demonstrates one of the worst conditions of housing standards in the country (Revell and Leather, 2000).

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Conclusion

1. Introduction

The aim of this research has been to investigate one important aspect of the built environment, which is energy efficiency improvements and reduction of carbon dioxide emissions in the domestic sector. This research has reached the conclusion that there are great potentials for improving energy efficiency and reducing carbon dioxide emissions in existing housing in the UK, particularly in privately rented sector, such as the case studies carried out in Sheffield.

The results of this research has helped to develop a database of the 'local' current situation. By choosing university-controlled properties, this has assisted to utilise the university authority to take action effectively and play a key role in guiding energy efficiency improvements in these properties. This will not only help to encourage energy efficiency standards throughout the private housing sector, but also accelerate the necessity of improvements and consultancies in the domestic sector, particularly in privately rented sector.

2. Conclusion

To summarize some of the important conclusions defined from this research with response to the original research aims and objectives:

- To provide a database of the current conditions and energy standards of privately rented properties.

As explained in chapter 5, feedback reports have been compiled for each property owner to show the current conditions and energy standards of their property and therefore suggest potential energy efficiency improvements when considering refurbishments. The case study analysis and results have helped to develop a database of the 'local' current situation. They provide a benchmark figure of possible improvements which if carried out could contribute significantly to the overall improvement programme within privately rented sector in the UK.

- To investigate potentials for energy efficiency improvements and reduction of carbon dioxide emissions in the privately rented sector.

As one of the main aims, this research has investigated potentials for energy efficiency improvements and reduction of carbon dioxide emissions in the privately rented sector, and as a result, it has been concluded that there are great potentials for improvements particularly in this sector, such as the case studies undertaken in Sheffield.

- To evaluate and review energy and environmental assessment methods, and their applications in terms of energy efficiency and carbon index (CI).

As explained in chapters 3, existing building energy and environmental assessment methods have been evaluated and reviewed. Furthermore overall comparison was presented to be more familiar with these tools and techniques currently available and their applications concerning energy efficiency and carbon dioxide index.

- To identify a way of cost effective modifications to dwelling base designs which can improve energy efficiency within privately rented properties.

As described in chapter 5 in more detail, modifications were made to base designs to identify potential cost effective improvements in these properties. These have been analysed to estimate the full savings on the increased energy standards of these dwellings. The modifications identified as follows: Fabric (improve wall and roof insulation); solar gain (PVC-U frames and Low e glazing), ventilation (additional mechanical vents), space heating and water heating (new high-efficiency boiler and radiators).

- To develop case study results that can be used by landlords/landladies to encourage energy conservation.

This research is not only a reminder of energy conservation for those who were involved in the built environment, but also a database developed of the 'local' current situation providing checklist for both university housing services and property owners to help increase energy standards of these properties examined.

- To promote general recommendations for immediate energy savings throughout privately rented properties.

The research in a form of a comprehensive report will be submitted to the Sheffield City Housing Unit with an aim to help keeping up to date records of privately rented properties i.e. conditions and energy standards in Sheffield. This information can also be useful for HECA team to help tackle energy related problems in other existing dwellings in the city and meet its overall target.

3. Discussion

As chapter 5 stated, research results according to the research hypothesis indicates that privately rented properties in Sheffield have significant potentials for energy efficiency improvements.

In the UK, more than twenty-five years of research efforts have produced broad understanding of the implications of the energy use and developed energy strategies and technologies with significant potential for energy savings. These strategies and technologies have not been effectively transferred to the building design community and as a result, there has been a knowledge gap, which provided property developers designing without any energy-related considerations or environmental concerns. This again is one of the main reasons why the majority of domestic buildings in the UK are still designed with no further concerns to environmental issues or energy efficiency beyond those required by national building regulations.

According to the recently published English House Condition Survey, there is considerable scope for improvements in energy efficiency and thermal performance of the housing stock. The vast majority of the existing housing falls well below modern building regulations and standards with average SAP rating being 51. The housing stock is inefficient due to designing without any energy related considerations and other problems mentioned above. Many existing dwellings are not only physically capable of being made energy efficient, but also not physically capable of being brought up to a high SAP rating with heating and insulation measures available. Large number of households are lacking affordable warmth, especially households in council and privately rented housing across the country.

Energy efficiency programmes often form a core element of local strategies for sustainable development as they deliver social, economic and health benefits as well as reducing housing management costs and helping the environment. Looking at some of the energy efficiency design schemes carried out in the UK in the last ten years, it is anticipated that these low-energy houses will influence the design of housing in the near future. Domestic buildings will therefore have less impact on the environment, considering that sustainable green design issues are incorporated at the design stage. This should be also enforced by the building regulations and supported through existing energy and environmental assessment methods for buildings.

As sustainable design has become an important issue to achieve this there must be a significant reduction in carbon dioxide emissions and the amount of energy consumed in buildings. In this research, properties examined can be utilised to illustrate the potentials for energy efficiency improvements and by some means encourage property owners to increasing the energy standards of these dwellings.

4. Recommendations

An important incentive to the use of the building energy and environmental assessment methods more effectively is the need to improve energy efficiency and reduce carbon dioxide emissions in the country. In housing, this could contribute significant proportion of the total energy use and therefore help tackle crucial issues such as affordable warmth and fuel poverty in existing stock, as well as help the UK meeting its international target.

It is obvious from the case study results that the privately rented properties are below energy standards required by the building regulations and implementing energy efficiency improvements suggested within feedback reports compiled can therefore reduce the energy consumed in these dwellings. Overall, it should be emphasized that most of the energy efficiency improvements suggested are very cost effective and the payback time on these dwellings are significantly short. It is an important fact that if these improvements were to be implemented, both property occupiers and owners will benefit equally; especially when considering the forthcoming Government's

Home Information (Sellers/Buyers) Pack and EU's Energy Performance of Buildings Directive (EPBD).

On one hand, for occupier, since the property would be consuming less energy there will be significant energy savings, which would be beneficial for longer tenancy considering affordable warmth and utilities. On the other hand, for owners, the property energy rating would be higher. The higher the energy rating, the better the energy performance of the property, which is again lower carbon dioxide emission and therefore less impact on the environment; that could well be used as a marketing strategy in the near future.

Moreover, the government is determined to ensure that the thermal efficiency of housing (and also non domestic building) is improved and their intention is to introduce a Home Information (Sellers/Buyers) Pack in which the energy efficiency of the dwelling would have to be given. This can be therefore seen as boost for improvements in the private sector and against why potential improvements can be determined.

5. Further Research

It is evident from the previous discussions in this thesis that further work is necessary, particularly in the private sector where there is no legislation to enforce retrospective energy standards of housing. This is an exceptional opportunity which would not only increase overall energy standards of existing housing stock in the UK, but also help achieve targets set by the Home Energy Conservation Act 1995 and enhance the overall rate for energy efficiency improvements in the country accordingly. This will consequently contribute to reducing carbon dioxide emissions consumed by the domestic buildings.

Work in this area may be expanded in a number of different ways. Some suggestions for further research emerge from this research:

- The focus of this study was on privately rented housing sector. The extension of the study for improving energy standards and suggesting guidelines for other tenures of housing (owner occupied, local authority/housing association and council housing) are also important. Parameters such as housing conditions, both space and water heating and other issues can also be looked at in other tenures.

- Energy efficiency measures could be particularly included within presently undertaken schemes, such as Responsible Landlord and Accreditation Schemes to accelerate the energy efficiency improvements in the private sector and therefore help achieve national targets more rapidly. Similar case studies can also be carried out such as undertaken in this research in Sheffield within properties registered with similar schemes in the country.

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Terms and Definitions

Age of Dwelling	The age of the dwelling refers to the date of construction of the oldest part of the building.
Central Heating System	A heating system with a distribution system sufficient to provide heat in at least one room in addition to the room or space containing the boiler. This definition also includes electric storage heaters, which run on off-peak electricity, and programmable gas convector heaters.
Decent Homes	A decent home is one that satisfies all of the following four criteria: - It meets the current statutory minimum standard for housing – at present this is the fitness standard. - It is in a reasonable state of repair. - It has reasonably modern facilities and services. - It provides a reasonable degree of thermal comfort.
Double Glazing	Factory made sealed window units. Does not include windows with secondary glazing or external doors with double or secondary glazing (other than double glazed patio doors, which count as two windows).
Dwelling	A dwelling is a self-contained unit of accommodation where all rooms and facilities available for the use of the occupants are behind a front door. For the most part a dwelling will contain one household, but may contain none (vacant dwelling), or may contain more than one (HMO).

Energy Efficiency	The energy efficiency of an individual dwelling can be described in terms of an energy cost rating. Energy cost ratings in general gives a measure of the annual unit energy cost of space and water heating for the dwelling under a standard regime, assuming specific heating patterns and room temperatures. The energy cost rating used throughout this report is the Government's Standard Assessment Procedure (SAP). This is expressed on a scale of SAP ratings where the higher the number the better the standard. The energy cost rating (SAP) takes into account a range of factors that contribute to energy efficiency which include: - Thermal insulation of the building fabric. - Efficiency and control of the heating system. - The fuel used for space and water heating. - Ventilation and solar gain characteristics of the dwelling. It is not affected by the individual characteristics of the household occupying the dwelling or by the geographical location.
Fixed Heating	Heating that is physically fixed to the wall, connected via a gas point or fused spur. It also includes open fireplaces, which are capable of use with minimum effort (not permanently blocked), any heater that feeds a back boiler, 'Aga' type cookers or ranges, which also emit heat into the room, and large, heavy dimplex radiators, which are impossible for a single person to carry easily from room to room.

Floor Space	The usable internal floor area of the dwelling as measured by the surveyor, rounded to the nearest square metre. It excludes integral garages, balconies, stores accessed from the outside only and the area under partition walls.
Household	One person living alone or a group of people who have the address as their only or main residence and who either share one meal a day or share a living room.
Poor Housing	Poor housing refers to dwellings, which suffer from any one or more of the following problems: - Assessed as being statutorily unfit for human habitation in 'substantial disrepair', where 'urgent' repairs are required to bring them to a satisfactory condition. 'Urgent' repairs are those where the work needs to be undertaken to prevent further significant deterioration in the short term. - Requiring 'essential modernisation', where any one or more of the following apply: Kitchen facilities are more than 30 years old; electrics do not have all modern components; or there is no fixed space heating (i.e. the household relies on portable heaters only).
Poor Neighbourhoods	Poor neighbourhoods refer to local areas where the surveyor visually assessed whether any one or more of the following problems apply: - Over 10% of dwellings in the local area are visually assessed to be seriously defective. - The presence of serious problems related to any of the following: Vacant sites or derelict buildings; vacant or boarded up buildings; litter, rubbish or dumping; vandalism; graffiti or scruffy buildings, gardens or landscaping; neglected buildings.

	- Very poor visual quality of the local area.
Private Sector Housing	Housing occupied by private owners (with or without a mortgage) and privately rented housing.
Programmable Heating	Electric storage heaters, which run on off-peak electricity and programmable gas convector heaters. In practice, 98% of the heating covered by this term is overnight storage heating.

Abbreviations

BEPI	Building Energy Performance Index
BRE	Building Research Establishment
BRECSU	Building Research Establishment Conservation Support Unit
BREDEM	Building Research Establishment Domestic Energy Model
CCL	Climate Change Levy
CFCs	Chlorofluorocarbons
CH_4	Methane
CHP	Combined Heat and Power
CI	Carbon Index
CIBSE	Chartered Institution of Building Services Engineers
CO_2	Carbon Dioxide
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DOE	Department of the Environment
DTI	Department of Trade and Industry
EC	European Commission
ECAs	Energy Conservation Authorities
ECF	Energy Cost Factor
EDAS	Energy Design Advice Scheme
EDSL	Environmental Design Solutions Limited
EEC	Energy Efficiency Commitment
EEBPP	Energy Efficient Best Practice Programme
EEO	Energy Efficiency Office

EESoP	Energy Efficient Standards of Performance
EHCS	English House Condition Survey
EPBD	Energy Performance of Buildings Directive
EST	Energy Savings Trust
ETSU	Energy Technology Support Unit (A Part of the DTI)
EU	European Union
GJ	GigaJoules (= 1000 Million Joules)
GW	GigaWatt (= 1000 Mega Watts)
GWP	Global Warming Potential
GtC	Gigatonnes of Carbon
HA	Housing Association
HARP	Home Assessment Rating Procedure
HCR	Home Condition Report
HECA	Home Energy Conservation Act (1995)
HIP	Home Information Pack
HLP	Heat Loss Parameter
HMSO	Her Majesty's Stationery Office
HMO	Houses in Multiple Occupation
IEA	International Energy Agency
IES	Integrated Environmental Solutions
IPCC	Inter-Governmental Panel on Climate Change
J	Joule
KW	KiloWatt (= 1000 Watts)
KWh	KiloWatt hour: Unit of Electrical Energy - One Kilowatt of Electrical Power Provided for One Hour. The Basic Unit of Electrical Sales.
LA	Local Authority

LDCs	Less Developed Countries
LEACs	Local Energy Advice Centres
m	Million
mtoe	Million Tonnes of Oil Equivalent
N_2O	Nitrous Oxide
NHER	National Home Energy Rating
ODPM	Office of the Deputy Prime Minister Publications
OFGEM	Office of Gas and Electricity Markets
ONS	Office for National Statistics
OO	Owner Occupied
OPEC	Organisation of Petroleum Exporting Countries
PCTs	Primary Care Trusts
PIU	Performance and Innovation Unit
PJ	PetaJoules (= 10^{15} Joules)
PLEA	Passive and Low Energy Architecture
PR	Private Rented
PV	Photovoltaics
RCEP	Royal Commission on Environmental Pollution
RSL(s)	Registered Social Landlord(s)
SAP	Standard Assessment Procedure (for Measuring Energy - the Efficiency of Houses)
SO_2	Sulphur Dioxide
SRES	Special Report on Emission Scenarios
TAS	Thermal Analysis Software
toe	Tonnes of Oil Equivalent
TW	TerraWatt (= 1000 Giga Watts)
UN	United Nations

UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UK	United Kingdom
US	United States
VOCs	Volatile Organic Compounds
WCED	World Commission for Environment and Development
WMO	World Meteorological Organization

Appendixes

Appendix A

Questionnaire

This questionnaire is aimed to find out the conditions of 'Private Rented Accommodation' in Sheffield.

QUESTIONS	ANSWERS	PROPERTY 1	PROPERTY 2	PROPERTY 3	PROPERTY 4	PROPERTY 5
Q1: Address of the property?	*Please tick boxes for each property and write property's address below.*	Address 1	Address 2	Address 3	Address 4	Address 5
Q2: Type of the property?	House (e.g. detached, terraced, etc.)					
	Flat (e.g. purpose-built or converted)					
	Bungalow					
Q3: Bedroom number of the property?	One					
	Two					
	Three					
	Four					
	More than 'Four'					
Q4: What age is the property?	Pre 1900					
	1900-1944					
	1945-1964					
	1965-1990					
	Post 1990					
Q5: What type of heating is used in the property?	Gas Central					
	Local gas fire					
	Electric Storage heaters					
	Electric bar					
	Others					
Q6: If 'Gas Central Heating', which controls does it have?	Programmer and time switch					
	Room and cylinder thermostats					
	Zone controls					
	Thermostatic radiator valves					
Q7: Does this property have wall insulation?	Yes					
	No					
	Don't know					
Q8: Does this property have floor insulation?	Yes					
	No					
	Don't know					
Q9: Does this property have roof insulation?	Yes					
	No					
	Don't know					
Q10: Does this property have draught stripping?	Yes					
	No					
	Don't know					

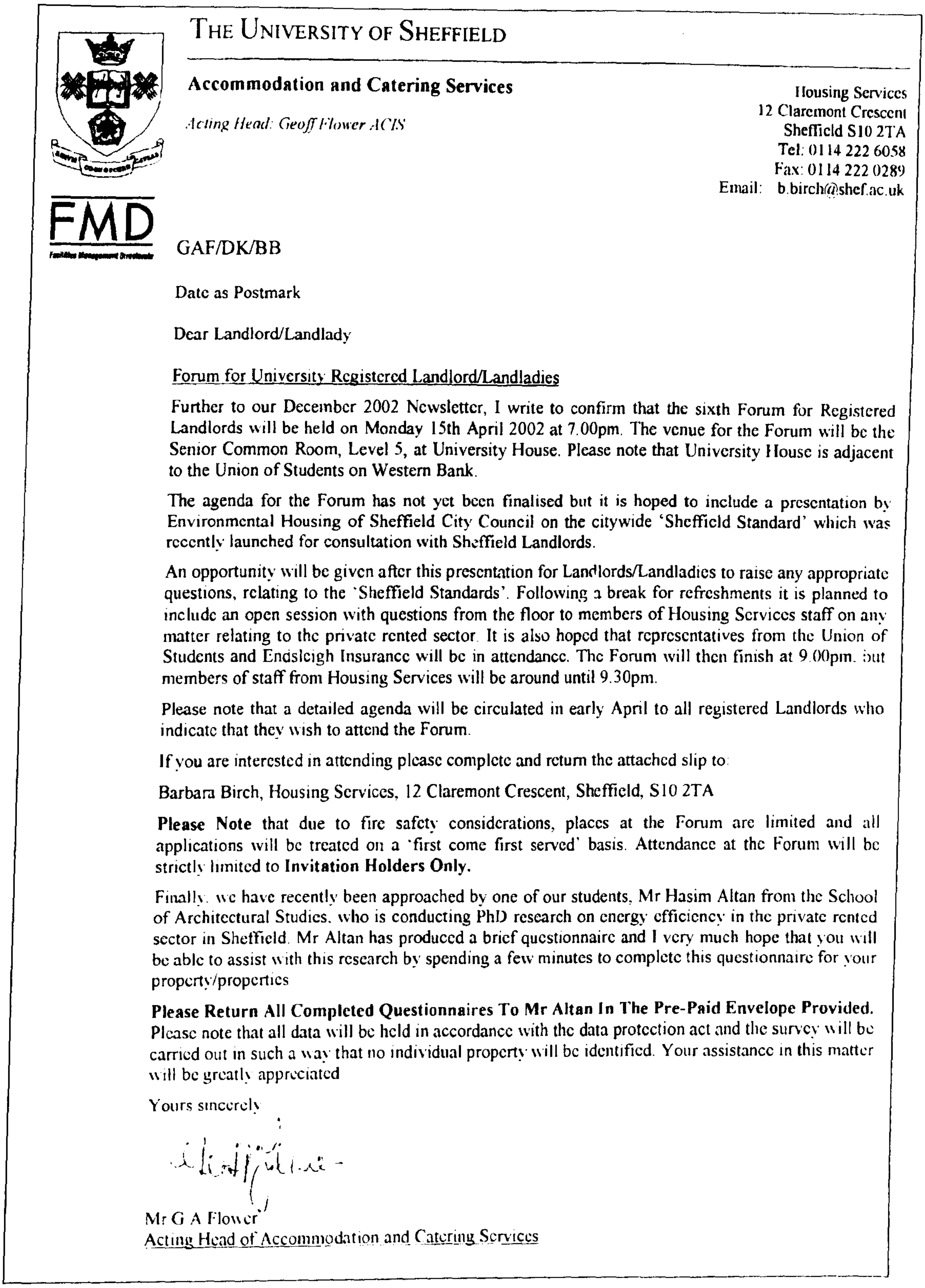
Q11: Does this property have double-glazing?	Full					
	Partial					
	None					
Q12: How is the hot water generated?	From gas central heating					
	Electric immersion heater					
	Individual gas fired units					
	Other					
Q13: Controls for hot water?	Time clock					
	Thermostat					
	None					
Q14: What does the property use for cooking?	Electricity					
	Gas					
	Other					
Q15: Does the property have low energy lighting?	Yes					
	No					
	Don't know					

ADDRESS	**PROPERTY 1**	
	PROPERTY 2	
	PROPERTY 3	
	PROPERTY 4	
	PROPERTY 5	

Would you like to receive a summary of the responses, please tick:	☐	***Address:***	

Thank you very much for your time. Please return this form to Mr H. Altan in the prepaid envelope provided.

Cover Letter (Housing Services Support)



THE UNIVERSITY OF SHEFFIELD

Accommodation and Catering Services

Acting Head: Geoff Flower ACIS

FMD

Housing Services
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Sheffield S10 2TA
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Email: b.birch@shef.ac.uk

GAF/DK/BB

Date as Postmark

Dear Landlord/Landlady

Forum for University Registered Landlord/Landladies

Further to our December 2002 Newsletter, I write to confirm that the sixth Forum for Registered Landlords will be held on Monday 15th April 2002 at 7.00pm. The venue for the Forum will be the Senior Common Room, Level 5, at University House. Please note that University House is adjacent to the Union of Students on Western Bank.

The agenda for the Forum has not yet been finalised but it is hoped to include a presentation by Environmental Housing of Sheffield City Council on the citywide 'Sheffield Standard' which was recently launched for consultation with Sheffield Landlords.

An opportunity will be given after this presentation for Landlords/Landladies to raise any appropriate questions, relating to the 'Sheffield Standards'. Following a break for refreshments it is planned to include an open session with questions from the floor to members of Housing Services staff on any matter relating to the private rented sector. It is also hoped that representatives from the Union of Students and Endsleigh Insurance will be in attendance. The Forum will then finish at 9.00pm. but members of staff from Housing Services will be around until 9.30pm.

Please note that a detailed agenda will be circulated in early April to all registered Landlords who indicate that they wish to attend the Forum.

If you are interested in attending please complete and return the attached slip to:

Barbara Birch, Housing Services, 12 Claremont Crescent, Sheffield, S10 2TA

Please Note that due to fire safety considerations, places at the Forum are limited and all applications will be treated on a 'first come first served' basis. Attendance at the Forum will be strictly limited to **Invitation Holders Only.**

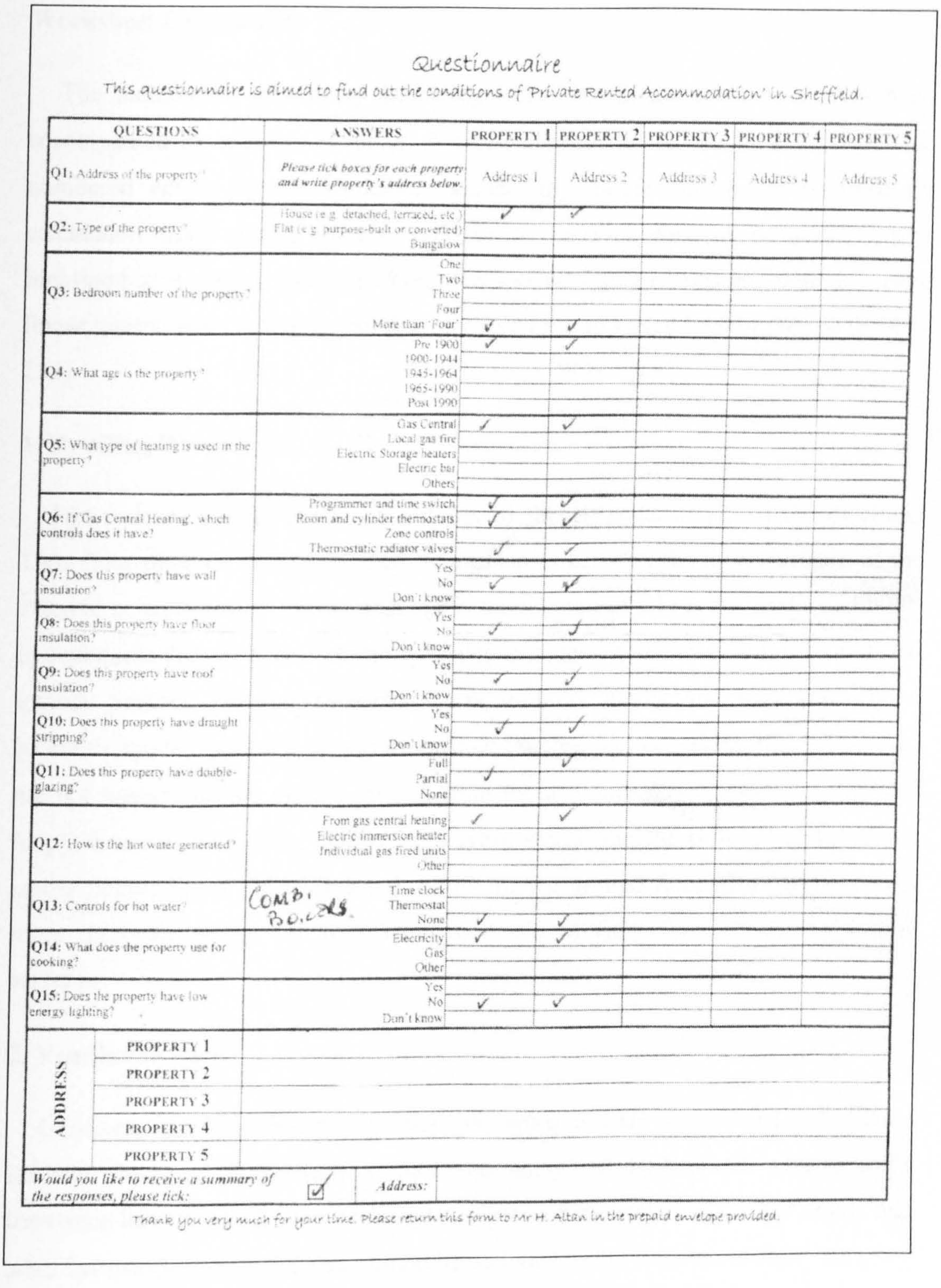
Finally, we have recently been approached by one of our students, Mr Hasim Altan from the School of Architectural Studies, who is conducting PhD research on energy efficiency in the private rented sector in Sheffield. Mr Altan has produced a brief questionnaire and I very much hope that you will be able to assist with this research by spending a few minutes to complete this questionnaire for your property/properties

Please Return All Completed Questionnaires To Mr Altan In The Pre-Paid Envelope Provided. Please note that all data will be held in accordance with the data protection act and the survey will be carried out in such a way that no individual property will be identified. Your assistance in this matter will be greatly appreciated

Yours sincerely

Mr G A Flower
Acting Head of Accommodation and Catering Services

Investigation Sample (Property No: 89/90)



Questionnaire

This questionnaire is aimed to find out the conditions of 'Private Rented Accommodation' in Sheffield.

QUESTIONS	ANSWERS	PROPERTY 1	PROPERTY 2	PROPERTY 3	PROPERTY 4	PROPERTY 5
Q1: Address of the property?	*Please tick boxes for each property and write property's address below.*	Address 1	Address 2	Address 3	Address 4	Address 5
Q2: Type of the property?	House (e.g. detached, terraced, etc.)	✓	✓			
	Flat (e.g. purpose-built or converted)					
	Bungalow					
Q3: Bedroom number of the property?	One					
	Two					
	Three					
	Four					
	More than 'Four'	✓	✓			
Q4: What age is the property?	Pre 1900	✓	✓			
	1900-1944					
	1945-1964					
	1965-1990					
	Post 1990					
Q5: What type of heating is used in the property?	Gas Central	✓	✓			
	Local gas fire					
	Electric Storage heaters					
	Electric bar					
	Others					
Q6: If 'Gas Central Heating', which controls does it have?	Programmer and time switch	✓	✓			
	Room and cylinder thermostats	✓	✓			
	Zone controls					
	Thermostatic radiator valves	✓	✓			
Q7: Does this property have wall insulation?	Yes					
	No	✓	✓			
	Don't know					
Q8: Does this property have floor insulation?	Yes					
	No	✓	✓			
	Don't know					
Q9: Does this property have roof insulation?	Yes					
	No	✓	✓			
	Don't know					
Q10: Does this property have draught stripping?	Yes					
	No	✓	✓			
	Don't know					
Q11: Does this property have double-glazing?	Full		✓			
	Partial	✓				
	None					
Q12: How is the hot water generated?	From gas central heating	✓	✓			
	Electric immersion heater					
	Individual gas fired units					
	Other					
Q13: Controls for hot water?	COMBI BOILERS Time clock					
	Thermostat					
	None	✓	✓			
Q14: What does the property use for cooking?	Electricity	✓	✓			
	Gas					
	Other					
Q15: Does the property have low energy lighting?	Yes					
	No	✓	✓			
	Don't know					

ADDRESS	PROPERTY 1	
	PROPERTY 2	
	PROPERTY 3	
	PROPERTY 4	
	PROPERTY 5	

Would you like to receive a summary of the responses, please tick: ☑ *Address:*

Thank you very much for your time. Please return this form to Mr H. Altan in the prepaid envelope provided.

SAP Calculations

Worksheet Calculations

The method of calculating the rating is set out in the form of a worksheet, accompanied by a series of tables. A calculation is carried out by completing the numbered entries in the worksheet sequentially. Some entries are obtained by calculation from entries already made or by carrying forward an earlier entry; highlighting is used to indicate where that applies. Other entries are obtained, using linear interpolation where appropriate, by reference to tables 1 to 14 (see page 149 - 153).

1. Dwelling Dimensions

Dimensions refer to the inner surfaces of the elements bounding the dwelling. Thus floor dimensions are obtained by measuring between the inner surfaces of the external or party walls. This measurement should include all internal walls and built-in cupboards that are accessible from the occupied area of the dwelling. It should also include porches and conservatories where they are heated and form part of the habitable space. It should, however, exclude porches and conservatories where they are not heated and are clearly divided from the dwelling. Storey height is the total height between the ceiling surface of a given storey and the ceiling surface of the storey below. For a single storey dwelling, or the ground floor of a dwelling with more than one storey, the measurement should be from floor surface to ceiling surface.

2. Ventilation Rate

Chimneys and flues should be entered only when they are unrestricted and suitable for use. Balanced flues, such as those on many gas boilers and wall-mounted convector heaters, should not be included. Extract fans, including cooker hoods and other independent extractor fans should be included in the 'number of fans' category, but those that form part of a whole-dwelling mechanical ventilation system should be excluded.

Mechanical ventilation should only be entered if the whole dwelling is served by a mechanical ventilation system. Many whole-dwelling mechanical ventilation systems have a heat exchanger to recover heat from the stale air being extracted from the dwelling. A warm-air heating system with flue heat recovery normally forms part of a full mechanical ventilation system with heat recovery.

In dwellings that have been subjected to a pressurisation test, steps (11) to (18) of the calculation may be by-passed. The air leakage at 50 Pa pressure difference, obtained from the test, is divided by 20 and the resulting value is entered in box (19).

When calculating for a new dwelling for Building Regulations purposes, enter 100% in box (16) for draught stripping of windows and doors. In the same context, it should be assumed that 2 sides of the dwelling are sheltered and hence the value 2 should be entered in box (20).

3. Heat Losses

The areas of building elements are derived using the same principles as set out in section 1, being based on the internal footnote dimensions of surfaces bounding the dwelling. Window area refers to the total area of the openings, including frames. Wall area is the net area of walls after allowing for windows and doors. Roof area is also net of any rooflights or windows set in the roof. The 'other' category is included principally to allow for the entry of heat losses to adjoining unheated areas, such as garages and conservatories. Box (35) can also be used to enter the sum of other heat losses calculated separately in those cases where there are several types of wall or roof. Losses or gains through party walls to spaces in other dwellings that are expected to be heated are assumed to be zero.

U-values for walls and roofs should be calculated using the proportional area method given in CIBSE Guide A3. U-values for floors should be calculated using the procedure described in BRE Information Papers IP3/90 and 1P7/93 and in Appendix C of the Building Regulations Approved Document L. U-values for windows should be obtained from Annex A unless certified manufacturer's data are available. This gives values appropriate for the whole window opening, including frames.

4. Water Heating Energy Requirements

Demand for hot water is derived from the floor area of the dwelling and is given in table 1 (see page 149). The energy required to produce that amount of hot water is then calculated, taking account of losses in generation, storage and distribution. The amount of heat released to the dwelling in the process of heating water is also estimated ('heat gains from water heating', box (52)) so that it can be taken into account in the calculation of space heating requirements.

A distinction is made between instantaneous water heating, which heats water when it is required, and water heating that relies on storage of hot water in a cylinder or tank. 'Primary' and 'cylinder' losses are not entered for instantaneous heaters. 'Single-point' heaters, which are located at the point of use and serve only one outlet, do not have distribution losses either. Gas 'multipoint' water heaters and 'combi' boilers are outlets, they arc assumed to have distribution losses.

Stored hot water systems can either be served by an electric immersion heater or obtain heat from a boiler through a primary circuit. In both cases, cylinder losses are incurred to an extent that depends on how well the storage cylinder is insulated. Table 2 (see page 149) gives factors for calculating cylinder loss for different thicknesses of insulation. For boiler systems, primary losses are incurred in transferring heat from the boiler to the cylinder; values for primary losses are obtained from table 3 (see page 149).

Water heating efficiency is obtained from table 4 (see page 150 – 151). Note that the efficiency is reduced by 5% for systems that do not have a means of shutting down the boiler when the hot water of cylinder reaches the required temperature. A thermostat on the hot water cylinder that controls the boiler via a relay or the auxiliary contacts on a motorised control valve normally carry out this function.

5. Internal Gains

Internal gains from lights, appliances, cooking and from the occupants of the dwelling arc estimated from floor area and obtained from table 5 (see page 151). Gains from central heating pumps located within the heated space are added to the value obtained from this table, using the values given in the footnote to that table. Gains from the fans in a whole-dwelling mechanical ventilation system are also included but no gains are assumed from individual extractor fans.

6. Solar Gains and Utilisation Factor

The solar gains entered are typical of the UK average and for dwellings where orientations are known should be obtained from table 6 (see page 151). Gains for a particular location not to be used for this purpose, even though they might be considered to be more accurate for a particular case.

The solar access factor, box (65), is assumed to be 0.4 for a building that has heavy overshading, 0.7 more than average, 1.0 for average and 1.3 for a building with very little overshading.

For new dwellings being assessed for Building Regulations, where orientations have not been fixed, glazed elements should be entered for East/West orientations and the solar access factor set to 1.

The solar gains are added to the internal gains to give total heat gains. A utilisation factor is then applied to the gains, which has the effect of reducing the contribution of gains where they are large in relation to the heat load. This factor calculated from the ratio of the total heat gains to the specific heat loss of the dwelling and is obtained from table 7 (see page 152).

7. Mean Internal Temperature

The calculated mean internal temperature is based on the heating requirements of a typical household, taking account of the degree to which the dwelling is insulated and how well the heating can be controlled. The average temperature of the living area is obtained from table 8 (see page 152), using the 'Heat loss parameter' (HLP), obtained from box (38) in the worksheet, and the type of heating system, obtained from the 'Heating' column of table 4a (see page 150). Note that the temperature obtained is raised in certain cases where the heating controls are poor; such cases are identified in table 4b (see page 151). This result is adjusted to take account of the level of heat gains previously calculated in sections 5 and 6 of the worksheet.

The temperature difference between the living area (zone 1) and the rest of the house is obtained from table 9 (see page 152), using the HLP and the 'Control' column of table 4b (see page 151).

Zone 1 is defined as all rooms in the dwelling that are accessible from the living room without having to open any doors or to go up or down stairs. The fraction (F) of the dwelling in Zone 1 may be measured or, where appropriate, can be estimated from the number of rooms in each zone, using the formula:

$$F = \frac{(1 + \text{number of rooms in Zone 1})}{(1 + \text{total number of rooms})}$$

For the purpose of this calculation, all rooms should be counted, but bathrooms and toilets should only count as half one room each. The hall and landing count as a single room.

8. Degree-Days

The degree-days depend on the 'base' temperature, which is calculated by adjusting the mean internal temperature to account of the heat provided by gains. Degree-days for different base temperatures are obtained from table 10 (see page 152), using linear interpolation for intermediate values

9. Space Heating Requirements

The 'useful' energy required from the heating system is calculated from degree-days and specific heat loss. The quantity of fuel or electric energy required to meet that demand is then calculated, taking account of the efficiency of the space heating system (obtained from table 4a – page 150). The procedure for dealing with dwellings that have more than one heating system is described in Annex B. Table 11 (see page

152) gives the combinations of heating systems that may be used in the SAP, together with the proportions of heat assumed to be supplied by main and secondary systems.

10. Fuel Costs

Fuel costs are calculated using the fuel and electricity requirements calculated earlier in the worksheet and prices obtained from table 12 (see page 153). The prices given in this table are averaged over the previous three years and across regions. Other prices must not be used for the purpose of this calculation.

11. Energy Cost Rating

An energy cost deflator term is applied before the rating is calculated. The purpose of the deflator is to ensure that the ratings do not, on average, change with fuel price changes. The energy cost deflator will be updated periodically, as will the fuel prices in table 12 (see page 153). The SAP rating is related to the energy cost factor by the equation:

$$SAP = 115 - 100 \times \log10 (ECF)$$

where: ECF = Energy Cost Factor

SAP ratings may also be obtained by using table 14 (see page 153).

The SAP rating scale was chosen to cover a wide spectrum of energy costs, rising by one unit as cost falls by a constant percentage. A SAP rating of 1 represents a poor standard of energy efficiency while a rating of 100 represents a very high standard. With respect to the Building Regulations 1991 (amended 1994), a SAP rating of 60 or below indicates the need for a higher standard of fabric insulation. A SAP rating of more than the target specified in table 4 in the Approved Document L is accepted as showing compliance with fabric insulation requirements, provided the guidance for limiting U-values and thermal bridging around openings is followed.

SAP Worksheet

Worksheet Page 1

SAP WORKSHEET (Version - 9.53)

1. Overall dwelling dimensions

	Area (m^2)		**Av. Room height(m)**		**Volume (m^3)**	
Ground floor		(1a) ×		=		(1b)
First floor		(2a) ×		=		(2b)
Second floor		(3a) ×		=		(3b)
Third and other floors		(4a) ×		=		(4b)
Total floor area (1a) + (2a) + (3a) + (4a) =		(5)				
Dwelling volume (m^3)	(1b) + (2b) + (3b) + (4b)			=		(6)

2. Ventilation rate

					m^3 per hour	
Number of chimneys		×	40	=		(7)
Number of flues		×	20	=		(8)
Number of fans and passive vents		×	10	=		(9)

Air changes per hour

Infiltration due to chimneys, fans and flues = ((7) + (8) + (9)) ÷ (6) = (10)

If a pressurisation test has been carried out, proceed to box (19)

Number of storeys (11)

Additional infiltration = ((11) – 1) × 0.1 = (12)

Structural infiltration 0.25 for timber frame 0.35 for masonry construction (13)

If suspended wooden floor, enter 0.2 (unsealed) 0.1 (sealed) (14)

If no draught lobby, enter 0.05 (15)

Percentage of windows and doors draught stripped (16)
Enter 100 for new dwellings which are to comply with Building Regulations

Window infiltration = 0.25 – (0.2 × (16) ÷ 100) = (17)

Infiltration rate = (10) + (12) + (13) + (14) + (15) + (17) = (18)

If pressurisation test done. (measured L_{50} ÷ 20) + (10) = (19)

else let (19) = (18)

Number of sides on which sheltered (20)
Enter 2 for new dwellings where location is not shown

Shelter factor = 1 – 0.075 × (20) = (21)

If mechanical ventilation with heat recovery,

effective air change rate = ((19) × (21) + 0.17) = (22)

(If no heat recovery, add 0.33 air changes per hour to value in box (22))

If natural ventilation, then air change rate = (19) × (21) = (23)

If (23) ≥ 1, then (24) = (23) (24)

else (24) = 0.5 + ((23)^2 × 0.5)

Effective air change rate (enter (22) or (24)) (25)

Worksheet Page 2

3. Heat losses and heat loss parameter

ELEMENT			Area (m²)		U-value (W/m²K)		A × U (W/K)	
Doors				×		=		(26)
Windows (single glazed)	0.9	×		×		=		(27)
Windows (double glazed)	0.9	×		×		=		(28)
Rooflights	0.9	×		×		=		(29)
Ground floor				×		=		(30)
Walls (type 1)				×		=		(31)
Walls (type 2)				×		=		(32)
Roof (type 1)				×		=		(33)
Roof (type 2)				×		=		(34)
Other				×		=		(35)

Ventilation heat loss = (25) × 0.33 × (6) = (36)

Specific heat loss = (26) + (27) + ... (35) + (36) = (37)

Heat loss parameter (HLP) = (37) ÷ (5) = (38)

4. Water heating energy requirements

GJ/year

Energy content of heated water (Table 1, column (a)) (39)

If instantaneous water heating at point of use, enter 0 in boxes (40), (43) and (48), and go to (49)

Distribution loss (Table 1, column (b)) (40)

If no hot water tank (ie combi or multipoint), go to (49)

Tank Volume (41)

Tank loss factor (Table 2) (42)

Energy lost from tank in GJ/year (41) × (42) = (43)

If no solar panel, enter 0 in box (47) and go to (48)

Area of solar panel (m²) (44)

Solar energy available = 1.3 × (44) (45)

Load ratio = (39) ÷ (45) = (46)

Solar input = (45) × (46) ÷ (1 + (46)) = (47)

Primary circuit loss (Table 3) (48)

Output from water heater = (39) + (40) + (43) + (48) − (47) = (49)

Efficiency of water heater (Table 4) % (50)

Energy required for water heating = (49) ÷ (50) × 100 = (51)

Heat gains from water heating = 0.8 × ((40) + (43) + (48)) + 0.25 × (39) = (52)

Worksheet Page 3

5. Internal gains

			Watts	
Lights, appliances, cooking and metabolic (Table 5)				(53)
Water heating	= 31.7 × (52)	=		(54)
Total internal gains	= (53) + (54)	=		(55)

6. Solar gains

Enter the area of the whole window including frames and the value for solar flux obtained from Table 6.
For Building Regulations assessment when orientations are not known, all vertical glazing should be entered as E/W.

Orientation	Area		Flux		Gains (W)	
North		×		=		(56)
Northeast		×		=		(57)
East		×		=		(58)
Southeast		×		=		(59)
South		×		=		(60)
Southwest		×		=		(61)
West		×		=		(62)
Northwest		×		=		(63)
Rooflights		×		=		(64)

Solar access factor *Enter 1 for new dwellings where overshading is not known*				(65)
Solar gains (UK average)	= ((56) + (57) + ... + (64)) × (65)	=		(66)
Total gains (W)	(55) + (66)	=		(67)
Gains/loss ratio (GLR)	= (67) ÷ (37) =			(68)
Utilisation factor (Table 7)				(69)
Useful gains (W)	= (67) × (69)	=		(70)

7. Mean internal temperature

			°C	
Mean internal temperature of the living area (Table 8)				(71)
Adjustment for gains	= 0.2 × *R* × ((70) ÷ (37) − 4.0)			(72)
R is obtained from the 'responsiveness' column of Table 4a				
Adjusted living room temperature	= (71) + (72)	=		(73)
Temperature difference between zones (Table 9)				(74)
Living area fraction (0 to 1.0)				(75)
Rest-of-house area fraction	= 1.0 − (75)	=		(76)
Mean internal temperature	= (73) − ((74) × (76))	=		(77)

Worksheet Page 4

8. Degree-days

Temperature rise from gains = (70) ÷ (37) = (78)

Base temperature = (77) − (78) = (79)

Degree days (use (79) and Table 10 to adjust base) (80)

9. Space heating requirement **GJ/year**

Energy requirement (useful) = 0.000 086 4 × (80) × (37) = (81)

Fraction of heat from secondary system (82)

Use value obtained from Table 11

Efficiency of main heating system (Table 4(a)) (83)

Efficiency of secondary heating system (Table 4(a)) (84)

} *Reduce by the amount shown in the 'efficiency' column of Table 4(b), where appropriate.*

Space heating fuel (main) = (1.0 − (82)) × (81) × 100 ÷ (83) = (85)

Space heating fuel (secondary) = (82) × (81) × 100 ÷ (84) = (86)

Electricity for pumps and fans
Enter 0.47 GJ for each central heating pump, 0.16 GJ for each boiler with a fan-assisted flue.
For warm air heating system fans, add 0.002 GJ × the volume of the dwelling, (given in box (6)).
For dwellings with whole-house mechanical ventilation, add 0.004 GJ × the volume of the dwelling. (87)

10. Fuel costs Fuel prices to be obtained from Table 12

			GJ/year	×	**Fuel price**	=	**£/year**	
Space heating	- main system	=	(85)	×		=		(88)
	- secondary system	=	(86)	×		=		(89)

Water heating **Fuel price** **£/year**

If off-peak electric water heating:

On-peak percentage (Table 13) (90)

Off-peak percentage 100 − (90) = (91)

On-peak cost = (51) × ((90) ÷ 100) × = (92)

Off-peak cost = (51) × ((91) ÷ 100) × = (93)

Else:

Water heating cost = (51) × = (94)

Pump/fan energy cost = (87) × = (95)

Additional standing charges (Table 12) (96)

Total heating (88) + (89) + (92) + (93) + (94) + (95) + (96) = (97)

11. SAP rating

Energy cost deflator (Table 12 footnote[3]) (98)

Energy cost factor (ECF) = ((97) × (98) − 40.0) ÷ (5) = (99)

SAP rating (Table 14)

SAP Tables

Tables Page 1

Table 1 : Hot water energy requirements

Floor area (m^2)	(a) Hot water usage GJ/year	(b) Distribution loss GJ/year
30	4.13	0.73
40	4.66	0.82
50	5.16	0.91
60	5.68	1.00
70	6.17	1.09
80	6.65	1.17
90	7.11	1.26
100	7.57	1.34
110	8.01	1.41
120	8.44	1.49
130	8.86	1.56
140	9.26	1.63
150	9.65	1.70
160	10.03	1.77
170	10.40	1.84
180	10.75	1.90
190	11.10	1.96
200	11.43	2.02
210	11.74	2.07
220	12.05	2.13
230	12.34	2.18
240	12.62	2.23
250	12.89	2.27
260	13.15	2.32
270	13.39	2.36
280	13.62	2.40
290	13.84	2.44
300	14.04	2.48

Alternatively, requirements and gains may be calculated from the total floor area of the dwelling (TFA), using the following steps:

(a) Calculate $N = 0.035 \times \text{TFA} - 0.000\,038 \times \text{TFA}^2$, if $\text{TFA} \leq 420$
$= 8.0$ if $\text{TFA} > 420$

(b) Hot water usage $= 0.85 \times (92 + 61 \times N) \div 31.71$

(c) Distribution loss $= 0.15 \times (92 + 61 \times N) \div 31.71$

Table 2 : Hot water cylinder loss factor (GJ/year/litre)
Multiply by cylinder volume in litres to get loss

Insulation thickness mm	Type: Foam	Type: Jacket
None	0.0945	0.0945
12.5	0.0315	0.0725
25	0.0157	0.0504
38	0.0104	0.0331
50*	0.0078	0.0252
80	0.0049	0.0157
100	0.0039	0.0126
150	0.0026	0.0084

** This is the minimum standard required by the Building Regulations.*

Table 3 : Primary circuit losses (GJ/year)

System loss	GJ/year
Electric immersion heater	0.0
Boiler with uninsulated primary pipework and no cylinder stat*	4.4
Boiler with insulated primary pipework and no cylinder stat*	2.2
Boiler with uninsulated primary pipework and with cylinder stat	2.2
Boiler with insulated primary pipework and with cylinder stat	1.3

** A cylinder stat is required by the Building Regulations in new dwellings*

Tables Page 2

Table 4a: Heating system efficiency

This table shows space heating efficiency. Water heating efficiency is also obtained from this table when hot water is from a boiler system. For independent electric water heating use 100%. Use 70% for single-point gas water heaters. For multi point gas water heaters and for heat exchangers built into gas warm air heaters, use 65%.

CENTRAL HEATING SYSTEMS WITH RADIATORS

1. 'Heating type' refers to the appropriate column in Table 8
2. Refer to Group 1 in Table 4b for control options
3. Check Table 4b for efficiency adjustment due to poor controls
4. Where two figures are given, the first is for space heating and the second is for water heating

	Efficiency (%)	Heating type	Responsive-ness
Gas boilers (including LPG) with fan-assisted flue			
1. Low thermal capacity	72	1	1.0
2. High or unknown thermal capacity	68	1	1.0
3. Condensing	85	1	1.0
4. Combi	71/69	1	1.0
5. Condensing combi	85/83	1	1.0
Gas boilers (including LPG) with balanced or open flue			
1. Wall mounted	65	1	1.0
2. Floor mounted, post 1979	65	1	1.0
3. Floor mounted, pre 1979	55	1	1.0
4. Combi	65	1	1.0
5. Room heater + back boiler	65	1	1.0
Oil boilers			
Standard oil boiler pre 1985	65	1	1.0
Standard oil boiler 1985 or later	70	1	1.0
Condensing boiler	85	1	1.0
Solid fuel boilers			
Manual feed (in heated space)	60	2	0.75
Manual feed (in unheated space)	55	2	0.75
Autofeed (in heated space)	65	2	0.75
Autofeed (in unheated space)	60	2	0.75
Open fire with back boiler to rads	55	3	0.50
Closed fire with back boiler to rads	65	3	0.50
Electric boilers			
Dry core boiler in heated space	100	2	0.75
Dry core boiler in unheated space	85	2	0.75
Economy 7 boiler in heated space	100	2	0.75
Economy 7 boiler in unheated space	85	2	0.75
On-peak heat pump	250	1	1.0
24 hour heat pump	240	1	1.0

STORAGE RADIATOR SYSTEMS

(Refer to Group 2 in Table 4b for control options)

	Efficiency (%)	Heating type	Responsive-ness
Old (large volume) storage heaters	100	5	0.0
Modern (slimline) storage heaters	100	4	0.25
Convector storage heaters	100	4	0.25
Fan-assisted storage heaters	100	3	0.5
Electric underfloor heating	100	5	0.0

WARM AIR SYSTEMS

1. Refer to Group 3 in Table 4b for control options

	Efficiency (%)	Heating type	Responsive-ness
Gas-fired warm air with fan-assisted flue			
Ducted, with gas-air modulation	80	1	1.0
Room heater, with in-floor ducts	77	1	1.0
Gas-fired warm air with balanced or open flue			
Ducted (on/off control)	70	1	1.0
Ducted (modulating control)	72	1	1.0
Stub ducted	70	1	1.0
Ducted with flue heat recovery	85	1	1.0
Stub ducted with flue heat recovery	82	1	1.0
Condensing	94	1	1.0
Oil-fired warm air			
Ducted output (on/off control)	70	1	1.0
Ducted output (modulating control)	72	1	1.0
Stub duct system	70	1	1.0
Electric warm air			
Electricaire system	100	2	0.75
Air to air heat pump	250	1	1.0

ROOM HEATER SYSTEMS

1. Refer to Group 4 in Table 4b for control options
2. Check Table 4b for efficiency adjustment due to poor control

	Efficiency (%)	Heating type	Responsive-ness
Gas			
Old style gas fire (open front)	50	1	1.0
Modern gas fire (glass enclosed front)	60	1	1.0
Modern gas fire with balanced flue	70	1	1.0
Modern gas fire with back boiler (no rads)	65	1	1.0
Condensing gas fire (fan assisted flue)	85	1	1.0
Gas fire or room heater with fan-assisted flue	79	1	1.0
Coal effect fire in fireplace	25	1	1.0
Coal effect fire in front of fireplace	60	1	1.0
Solid fuel			
Open fire in grate	32	3	0.5
Open fire in grate, with throat restrictor	42	3	0.5
Open fire with back boiler (no rads)	55	3	0.5
Closed room heater	60	3	0.5
Closed room heater with back boiler	65	3	0.5
Electric (direct acting)			
Panel, convector or radiant heaters	100	1	1.0
Portable electric heaters	100	1	1.0

OTHER SYSTEMS

Refer to group 5 for control options

	Efficiency (%)	Heating type	Responsive-ness
Gas underfloor heating	70	4	0.25
Gas underfloor heating, condensing boiler	87	4	0.25
Electric ceiling heating	100	2	0.75

Tables Page 3

Table 4b: Heating system controls

1. *Use Table 4a to select appropriate Group in this table.*
2. *'Control' refers to the appropriate column in Table 9*
3. *'Efficiency' is an adjustment that should be subtracted from the space heating efficiency obtained from Table 4a.*
4. *'Temp' is an adjustment that should be added to the temperature obtained from Table 8.*

Type of control	**Control**	**Efficiency** %	**Temp** °C
GROUP 1 : BOILER SYSTEMS WITH RADIATORS			
No thermostatic control* of room temperature	1	5	0.3
Programmer + roomstat	1	0	0
Prog + roomstat* (no boiler off)	1	5	0
Prog + roomstat + TRVs	2	0	0
Prog + roomstat + TRVs* (no boiler off)	2	5	0
TRVs + prog + bypass*	2	5	0
TRVs + prog + flow switch	2	0	0
TRVs + prog + boiler energy manager	2	0	0
Zone control	3	0	0
Zone control (no boiler off)*	3	5	0
GROUP 2 : STORAGE RADIATOR SYSTEMS			
Manual charge control	3	0	0.3
Automatic charge control	3	0	0
GROUP 3 : WARM AIR SYSTEMS			
No thermostatic control* of room temperature	1	0	0.3
Roomstat only*	1	0	0
Programmer + roomstat	1	0	0
Zone control	3	0	0
GROUP 4 : ROOM HEATER SYSTEMS			
No thermostatic control	2	0	0.3
Appliance stat	3	0	0
Appliance stat + prog	3	0	0
Programmer + roomstat	3	0	0
Roomstat only	3	0	0
GROUP 5 : OTHER SYSTEMS			
No thermostatic control of room temperature	1	0	0.3
Appliance stat only	1	0	0
Roomstat only	1	0	0
Programmer + roomstat	1	0	0
Programmer and zone control	3	0	0

* *These systems would not be acceptable in new dwellings*

Table 5 : Lighting, appliances, cooking and metabolic gains

Floor area (m^2)	Gains (W)	Floor area (m^2)	Gains (W)
30	230	170	893
40	282	180	935
50	332	190	978
60	382	200	1020
70	431	210	1061
80	480	220	1102
90	528	230	1142
100	576	240	1181
110	623	250	1220
120	669	260	1259
130	715	270	1297
140	760	280	1334
150	805	290	1349
160	849	300	1358

Alternatively, gains may be calculated from the total floor area of the dwelling (TFA), using the following steps:

(a) Calculate N $= 0.035 \times TFA - 0.000038 \times TFA^2$, if $TFA \leq 420$
$= 8.0$ if $TFA > 420$

(b) Gains (W) $= 74 + 2.66 \times TFA + 75.5 \times N$, if $TFA \leq 282$
$= 824 + 75.5 \times N$ if $TFA > 282$

Note:
Gains from the following equipment should be added to the totals given above:

Central heating pump	10 W
Mechanical ventilation system	25 W

Table 6 : Solar flux through glazing (W/m^2)

	Horizontal	Vertical				
		North	NE/NW	E/W	SE/SW	South
Single glazed	31	10	14	18	24	30
Double glazed	26	8	12	15	21	26
Double glazed with low E coating	24	8	11	14	19	24
Triple glazed	22	7	10	13	17	22

Note:
1. For a rooflight in a pitched roof with a pitch of up to 70°, use the value under 'Northerly' for orientations within 30° of North and the value under 'Horizontal' for all other orientations. (If the pitch is greater than 70°, then treat as if it were a vertical window.)
2. For Building Regulations assessment when orientations are not known, all vertical glazing should be entered as E/W.

Tables Page 4

Table 7 : Utilisation factor as a function of Gain/loss ratio (G/L)

G/L	Utilisation factor	G/L	Utilisation factor
1	1.00	16	0.68
2	1.00	17	0.65
3	1.00	18	0.63
4	0.99	19	0.61
5	0.97	20	0.59
6	0.95	21	0.58
7	0.92	22	0.56
8	0.89	23	0.54
9	0.86	24	0.53
10	0.83	25	0.51
11	0.81	30	0.45
12	0.78	35	0.40
13	0.75	40	0.36
14	0.72	45	0.33
15	0.70	50	0.30

Alternatively, the utilisation factor may be calculated by the formula:

Utilisation factor = 1 − exp (− 18 ÷ GLR),

where GLR = (total gains) ÷ (specific heat loss)

Table 8 : Mean internal temperature of living area

Number in brackets is from the 'heating' column of Table 4a. HLP is item 38 on the worksheet

HLP	(1)	(2)	(3)	(4)	(5)
1.0 (or lower)	18.88	19.32	19.76	20.21	20.66
1.5	18.88	19.31	19.76	20.20	20.64
2.0	18.85	19.30	19.75	20.19	20.63
2.5	18.81	19.26	19.71	20.17	20.61
3.0	18.74	19.19	19.66	20.13	20.59
3.5	18.62	19.10	19.59	20.08	20.57
4.0	18.48	18.99	19.51	20.03	20.54
4.5	18.33	18.86	19.42	19.97	20.51
5.0	18.16	18.73	19.32	19.90	20.48
5.5	17.98	18.59	19.21	19.82	20.45
6.0 (or higher)	17.78	18.44	19.08	19.73	20.40

Table 9 : Difference in temperatures between zones

Number in brackets is from the 'control' column of Table 4b. HLP is item 38 on the worksheet

HLP	(1)	(2)	(3)
1.0 (or lower)	0.40	1.41	1.75
1.5	0.60	1.49	1.92
2.0	0.79	1.57	2.08
2.5	0.97	1.65	2.22
3.0	1.15	1.72	2.35
3.5	1.32	1.79	2.48
4.0	1.48	1.85	2.61
4.5	1.63	1.90	2.72
5.0	1.76	1.94	2.83
5.5	1.89	1.97	2.92
6.0 (or higher)	2.00	2.00	3.00

Table 10 : Degree-days as a function of base temperature

Base temperature °C	Degree-days	Base temperature °C	Degree-days
1.0	0	11.0	1140
1.5	30	11.5	1240
2.0	60	12.0	1345
2.5	95	12.5	1450
3.0	125	13.0	1560
3.5	150	13.5	1670
4.0	185	14.0	1780
4.5	220	14.5	1900
5.0	265	15.0	2015
5.5	310	15.5	2130
6.0	360	16.0	2250
6.5	420	16.5	2370
7.0	480	17.0	2490
7.5	550	17.5	2610
8.0	620	18.0	2730
8.5	695	18.5	2850
9.0	775	19.0	2970
9.5	860	19.5	3090
10.0	950	20.0	3210
10.5	1045	20.5	3330

Table 11 : Fraction of heat supplied by secondary heating systems

Main heating system	Secondary system	Fraction
Central heating system with boiler and radiators, central warm-air system or other gas fired systems	gas fires coal fires electric heaters	0.15 0.10 0.05
Gas room heaters	gas fires coal fires electric heaters	0.30 0.15 0.10
Coal room heaters or electric room heaters	gas fires coal fires electric heaters	0.20 0.20 0.20
Electric storage heaters or other electric systems	gas fires coal fires electric heaters	0.15 0.10 0.10
Electric heat pump systems with heat storage or fan-assisted storage heaters	gas fires coal fires electric heaters	0.15 0.10 0.05

Tables Page 5

Table 12 : Fuel prices and additional standing charges

	Additional standing charge £	Unit price £/GJ
Gas (mains)	38	4.26
Bulk LPG	51	7.11
Bottled gas – propane 47 kg cylinder		13.26
Heating oil		3.68
House coal		3.87
Smokeless fuel		6.54
Anthracite nuts		5.04
Anthracite grains		4.53
Wood		4.20
Electricity (on-peak)		22.38
Electricity (off-peak)	14	7.60
Electricity (standard tariff)		21.08
Electricity (24-hr heating tariff)	45	8.57

Notes

1. The standing charge given for electricity is extra amount for the off peak tariff, over and above the amount for the standard domestic tariff, as it is assumed that the dwelling has a supply of electricity for reasons other than space and water heating. Standing charges for gas and for off-peak electricity are attributed to space and water heating costs where those fuels are used for heating.

2. The energy cost deflator term is currently set at 0.96. It will vary with the weighted average price of heating fuels in future, in such a way as to ensure that the SAP is not affected by the general rate of inflation. However, individual SAP ratings are affected by relative changes in the price of particular heating fuels.

Table 13 : On-peak fraction for electric water heating

Dwelling floor area m²	Cylinder size (litres) 110	160	210
40 or less	12 (56)	6 (18)	1
60	14 (58)	7 (21)	3
80	17 (60)	9 (24)	4
100	19 (62)	10 (27)	5
120	21 (63)	12 (30)	6
140	23 (65)	13 (33)	6
160	25 (66)	15 (35)	7
180	27 (68)	16 (37)	8
200	29 (69)	17 (40)	9
220	30 (70)	18 (42)	9
240	32 (71)	19 (44)	10
260	33 (72)	20 (45)	11
280	34 (73)	21 (45)	11
300	36 (74)	21 (45)	12
320	36 (75)	22 (46)	12
340	37 (75)	23 (47)	12
360	38 (76)	23 (48)	13
380	39 (76)	24 (49)	13
400	39 (76)	24 (49)	13
420 or more	39 (77)	24 (50)	13

Table 13 shows percentage of electricity required at on-peak rates for cylinders with dual immersion heaters. The figures in brackets are for cylinders with single immersion heaters.

Table 14 : SAP rating by energy cost factor

ECF £/m²	SAP rating	ECF £/m²	SAP rating
1.4	100	4	55
1.5	97	4.5	50
1.6	95	5	45
1.7	92	5.5	41
1.8	89	6	37
1.9	87	6.5	34
2	85	7	30
2.2	81	7.5	27
2.4	77	8	25
2.6	74	8.5	22
2.8	70	9	20
3	67	10	15
3.3	63	11	11
3.6	59	12	7
3.9	54	13	4
		14	1

The values in the above table may be obtained by using the formula:

$$\text{SAP Rating} = 115 - 100 \times \log_{10}(\text{ECF})$$

SAP Annexes

Annexes Page 1

ANNEX A : U-VALUES FOR GLAZING

Table A1: Indicative U-values [W/m²K] for windows, doors and rooflights

	Type of frame							
	Wood		Metal		Thermal break		PVC-U	
Air gap in sealed unit (mm)	6	12	6	12	6	12	6	12
Window, double-glazed	3.3	3.0	4.2	3.8	3.6	3.3	3.3	3.0
Window, double-glazed, low-E	2.9	2.4	3.7	3.2	3.1	2.6	2.9	2.4
Window, double-glazed, Argon fill	3.1	2.9	4.0	3.7	3.4	3.2	3.1	2.9
Window, double-glazed, low-E, Argon fill	2.6	2.2	3.4	2.9	2.8	2.4	2.6	2.2
Window, triple-glazed	2.6	2.4	3.4	3.2	2.9	2.6	2.6	2.4
Door, half double-glazed	3.1	3.0	3.6	3.4	3.3	3.2	3.1	3.0
Door, fully double-glazed	3.3	3.0	4.2	3.8	3.6	3.3	3.3	3.0
Rooflights, double-glazed at less than 70° from horizontal	3.6	3.4	4.6	4.4	4.0	3.8	3.6	3.4
Windows and doors, single-glazed	4.7		5.8		5.3		4.7	
Door, solid timber panel or similar	3.0		—		—		—	
Door, half single-glazed/half timber panel or similar	3.7				—		—	

Window U-values should be obtained from Table A1, regardless of building age. The values apply to the entire area of the window opening, including both frame and glass, and take account of the proportion of the area occupied by the frame and the heat conducted through it.

ANNEX B : DWELLINGS WITH MORE THAN ONE HEATING SYSTEM

General principles

The treatment of multiple forms of heating in SAP is based on the following principles:

(1) the decision to include a secondary heating system should be based on the characteristics of the dwelling and the systems installed and not on the heating practices of the occupying household;

(2) secondary systems should only be included if they are based on 'fixed' appliances, unless portable appliances are necessary to achieve adequate heating.

To avoid excessive complexity and to reduce the extent to which surveyor judgement can influence the rating, the SAP considers only one secondary heating system per dwelling. Furthermore, secondary heating systems are governed by a set of rules that restrict the allowable combinations of heating systems and stipulate the proportion of heat supplied by the secondary system. Those restrictions will inevitably mean that the rating is based on assumptions about use that, in some cases, diverge considerably from what is actually practised by the occupying household. This is in line with the general principle that SAP is a rating for the dwelling and does not depend on who happens to be living in that dwelling. That does not preclude further estimates of energy consumption being made to take account of actual usage. Such estimates would not be part of SAP but could form the basis of advice given to the occupying household on how to make best use of the systems at their disposal.

Procedure for dealing with secondary heating systems

(1) Identify the main heating system. If there is a central system that provides both space and water heating and it is capable of heating at least 30% of the dwelling, select that system. If there is no system that provides both space and water heating, then select the system that has the capability of heating the greatest part of the dwelling.

(2) If there is still doubt about which system should be selected as the primary, select the system that supplies useful heat to the dwelling at lowest cost, (obtained by dividing fuel cost by conversion efficiency).

(3) Use the responsiveness of the main heating system in calculating the mean internal temperature in Stage 7 of the SAP calculation.

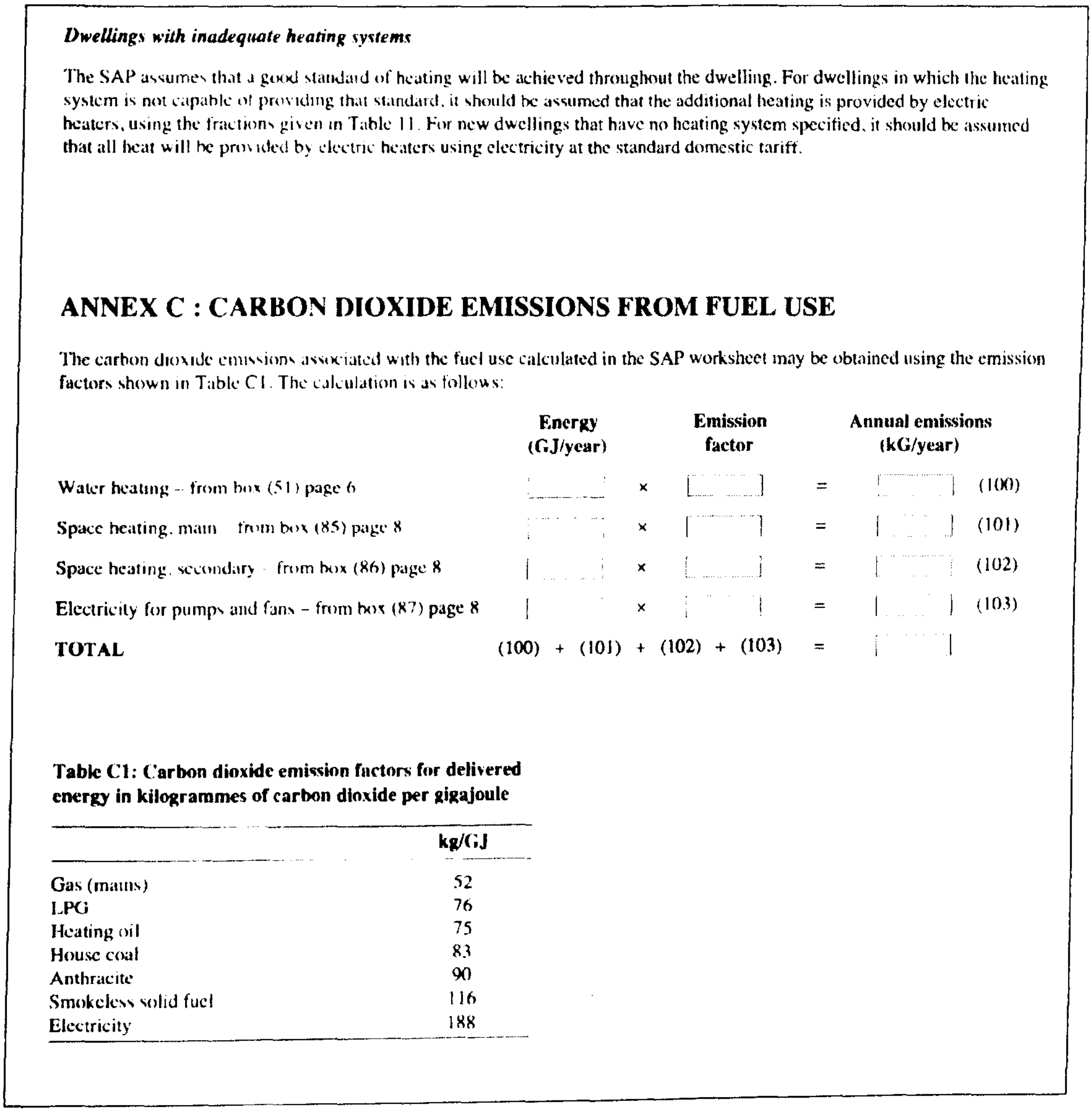
(4) Decide whether a secondary heating system needs to be specified, bearing in mind that systems based on stored heat produced from electricity generally require a secondary system for their successful operation. Ignore all portable heaters, such as plug-in electrical radiators and fan heaters or free-standing butane and paraffin heaters. If no secondary system is to be specified, enter zero in box (82).

(5) If a secondary heating system is to be specified, use Table 11 to select the most appropriate description of the primary/secondary combination. Obtain the proportion of use for the secondary heating system from Table 11 and enter in box (82).

(6) Obtain the efficiency of the secondary heating system from Table 4 and enter in box (84).

(7) Calculate the space heating fuel requirements for both main and secondary heating systems as specified for entry in boxes (85) and (86).

Annexes Page 2



Dwellings with inadequate heating systems

The SAP assumes that a good standard of heating will be achieved throughout the dwelling. For dwellings in which the heating system is not capable of providing that standard, it should be assumed that the additional heating is provided by electric heaters, using the fractions given in Table 11. For new dwellings that have no heating system specified, it should be assumed that all heat will be provided by electric heaters using electricity at the standard domestic tariff.

ANNEX C : CARBON DIOXIDE EMISSIONS FROM FUEL USE

The carbon dioxide emissions associated with the fuel use calculated in the SAP worksheet may be obtained using the emission factors shown in Table C1. The calculation is as follows:

	Energy (GJ/year)		**Emission factor**		**Annual emissions (kG/year)**	
Water heating – from box (51) page 6		×		=		(100)
Space heating, main – from box (85) page 8		×		=		(101)
Space heating, secondary – from box (86) page 8		×		=		(102)
Electricity for pumps and fans – from box (87) page 8		×		=		(103)
TOTAL	(100) + (101) + (102) + (103)			=		

Table C1: Carbon dioxide emission factors for delivered energy in kilogrammes of carbon dioxide per gigajoule

	kg/GJ
Gas (mains)	52
LPG	76
Heating oil	75
House coal	83
Anthracite	90
Smokeless solid fuel	116
Electricity	188

Source: BRECSU, 1994.

More detailed information about the Government's Standard Assessment Procedure for Energy Rating of Dwellings, see recent edition published by BRECSU on 2001.

Case Study Results

Properties 1 – 245

Property Type	house	terraced	detached	flat	bungalow
	81	104	15	44	1

Bedroom Number	one	two	three	four	more than four	five	six	seven	eight	nine	ten
	13	10	54	104	42	5	10	4	1	0	2

Property Age	pre-1900	1900-1944	1945-1964	1965-1990	post-1990	don't know
	80	133	4	15	7	6

Space Heating	gc	esh	gc/lgf	gc/eb	gc/lgf/o	gc/eb/o	esh/eb	o
	201	19	17	4	1	1	1	1

Controls	pts	pts/trv	pts/rct/trv	zc	pts/rct	n/a	trv	pts/zc	pts/rct/zc/trv	rct	pts/rct/zc
	115	49	21	1	29	16	4	3	1	5	1

Wall Insulation	yes	no	don't know
	173	27	45

Floor Insulation	yes	no	don't know
	176	35	34

Roof Insulation	yes	no	don't know
	31	180	34

Draught Stripping	yes	no	don't know
	138	79	28

Double Glazing	full	partial	none
	126	79	40

Hot Water Heating	gch	gch/eih	eih	o	igfu
	189	32	17	2	5

Controls	tc	tc/t	t	none	n/a
	99	78	44	23	1

Cooking	e	g	e/g	o
	103	101	41	0

Lighting	yes	no	don't know
	153	72	20

g: gas
e: electric
gc: gas central
esh: electric storage heater
lgf: local gas fire
gch: gas central heating
eih: electric immersion heater
igfu: individual gas fired units
pts: programmer and time switch
rct: room and cylinder thermostat
trv: thermostatic radiator valves

Improvement Checklist

Properties 1 – 55

Energy Efficiency Measures	Wall Insulations	Roof Insulation	Floor Insulation	Heating System	Hot Water System	Controls	Draught-Stripping	Controlled Ventilation	Double Glazing	Energy Efficient Lighting	SAP
PROPERTY 1	✓	✓	✓	gc	gch	pts	✓	-	✓	-	54
PROPERTY 2	-	✓	-	gc/lgf	gch	pts	-	-	✓	-	60
PROPERTY 3	-	-	-	gc	gch	pts/trv	-	-	✓	-	58
PROPERTY 4	-	-	-	gc	gch	pts	-	-	-	-	54
PROPERTY 5	-	✓	-	gc	gch	pts/trv	-	-	-	-	50
PROPERTY 6	-	-	-	gc	gch	pts/rct	-	-	-	-	51
PROPERTY 7	-	✓	-	gc/lgf	gch	pts/trv	-	-	-	-	51
PROPERTY 8	-	-	-	gc	gch	pts	-	-	-	-	59
PROPERTY 9	-	✓	-	gc	gch	pts	-	-	-	-	58
PROPERTY 10	-	✓	-	gc	gch	pts/trv	-	-	-	-	57
PROPERTY 11	-	✓	✓	gc	gch	pts/rct/trv	✓	-	✓	-	65
PROPERTY 12	-	✓	✓	gc/eb	gch	pts/rct	-	-	✓	-	66
PROPERTY 13	-	✓	-	gc	gch	pts	-	-	-	-	56
PROPERTY 14	-	✓	-	gc	gch	pts	-	-	-	-	56
PROPERTY 15	-	✓	-	gc	gch	pts	-	-	-	-	52
PROPERTY 16	-	✓	-	gc/lgf	gch	pts/zc	✓	-	-	-	66
PROPERTY 17	-	✓	-	gc/lgf	gch	pts/zc	✓	-	-	-	69
PROPERTY 18	-	✓	-	gc	gch/eih	pts/rct/trv	-	-	✓	-	69
PROPERTY 19	-	✓	-	gc	gch	pts/rct/trv	-	-	✓	-	68
PROPERTY 20	-	-	-	gc	gch	pts/rct	-	-	✓	-	68
PROPERTY 21	-	✓	-	gc	gch	pts/rct/trv	-	-	✓	-	75
PROPERTY 22	-	-	-	gc	gch	pts/rct/trv	-	-	✓	-	53
PROPERTY 23	-	✓	-	esh	eih	n/a	-	-	-	-	52
PROPERTY 24	-	✓	-	gc	gch	pts	-	-	✓	-	52
PROPERTY 25	-	✓	✓	gc	gch	pts	-	-	-	-	57
PROPERTY 26	✓	✓	-	gc	gch	pts	-	-	✓	-	60
PROPERTY 27	-	✓	✓	gc	gch	pts/rct/trv	✓	-	✓	-	59
PROPERTY 28	-	✓	-	gc	igfu	pts	✓	-	-	-	56
PROPERTY 29	-	✓	-	gc	gch/eih	pts	✓	-	✓	-	55
PROPERTY 30	✓	✓	-	gc	gch	pts	-	-	✓	-	71

Energy Efficiency Measures	Wall Insulations	Roof Insulation	Floor Insulation	Heating System	Hot Water System	Controls	Draught-Stripping	Controlled Ventilation	Double Glazing	Energy Efficient Lighting	SAP
PROPERTY 31	-	✔	-	gc	gch	pts/rct	-	-	✔	-	59
PROPERTY 32	-	✔	-	gc/lgf	gch/eih	pts	✔	-	-	-	55
PROPERTY 33	-	✔	-	gc	gch	pts/rct	-	-	-	-	64
PROPERTY 34	-	-	-	gc	gch	pts	-	-	-	-	67
PROPERTY 35	-	-	✔	gc	gch	pts	-	-	-	-	67
PROPERTY 36	-	-	✔	gc	gch	pts	-	-	-	-	67
PROPERTY 37	-	✔	-	gc	gch	pts	✔	-	✔	-	68
PROPERTY 38	-	✔	-	gc	gch	pts	✔	-	✔	-	70
PROPERTY 39	-	-	-	gc	gch	pts	✔	-	✔	-	59
PROPERTY 40	-	✔	-	gc	gch	pts	-	-	-	-	62
PROPERTY 41	-	-	-	gc	gch	pts	✔	-	✔	-	60
PROPERTY 42	-	-	-	gc	gch	pts	-	-	✔	-	60
PROPERTY 43	-	✔	-	gc	gch	pts	-	-	✔	-	59
PROPERTY 44	-	-	-	gc	gch	pts/rct	-	-	-	-	59
PROPERTY 45	-	-	-	gc	gch	pts	-	-	-	-	59
PROPERTY 46	-	✔	-	gc	gch/eih	pts/trv	-	-	✔	-	51
PROPERTY 47	-	✔	-	gc	gch/eih	pts/trv	-	-	✔	-	50
PROPERTY 48	-	✔	-	gc	gch	pts	-	-	-	-	54
PROPERTY 49	✔	✔	-	gc	gch	pts/trv	-	-	✔	-	69
PROPERTY 50	-	-	-	gc	gch	pts/trv	-	-	✔	-	66
PROPERTY 51	-	-	-	esh	eih	n/a	✔	-	-	-	59
PROPERTY 52	-	✔	-	gc	gch/eih	pts/rct/trv	-	-	✔	-	73
PROPERTY 53	-	-	-	gc	gch	rct	-	-	-	-	59
PROPERTY 54	-	-	-	gc	gch	pts	-	-	✔	-	65
PROPERTY 55	-	-	-	gc	gch	pts	-	-	-	-	64

gc: gas central
esh: electric storage heater
lgf: local gas fire
gch: gas central heating
eih: electric immersion heater
igfu: individual gas fired units
pts: programmer and time switch
rct: room and cylinder thermostat
trv: thermostatic radiator valves

Feedback Report

Feedback Cover Letter and Short Questionnaire

Dear Landlord/Landlady,

As you may remember, you have filled in and returned a questionnaire regarding the conditions of your property, which was presented by Mr. Hasim ALTAN from School of Architecture, the University of Sheffield, under a research project on energy efficiency in the private rented sector in Sheffield, and distributed by the housing services at the end of 2002.

The enclosed report has been compiled for your property and I hope that it will be of some benefit to you when you are considering refurbishment. You may also be aware that the government is determined to ensure that the thermal efficiency of housing (and also non domestic building) is improved. It is their intention to introduce a 'Home Sellers/Buyers Pack' in which the energy efficiency of the dwelling would have to be given. Your participation in this recent target will help to develop a database of the 'local' current situation and therefore provide a benchmark figure against why potential improvements can be determined. The current thinking of an appropriate benchmark for an energy efficient house is a SAP rating of 80 - 85.

I would like to inform you that the database will not be holding any personal information and all data will be held in accordance with **the Data Protection Act**. Furthermore, the survey will be carried out in such a way that no individual property will be identified and/or passed on to third parties.

I would like to kindly thank you for participating in this research and also like to ask you to complete the following short questionnaire and return it to Mr. H ALTAN in the pre-paid envelope provided.

Kindest Regards and Many Thanks.

Yours Sincerely,

Hasim Altan

After completion, tear it through here and send it in the pre-paid envelope provided.

--✂------------

Please circle the appropriate answer to you as follows:

Do you get information on energy savings through the post – circulars or telephone	Yes	No
If Yes;		
Do you bin it?	Yes	No
Do you read it?	Yes	No
Do you do anything about it?	Yes	No

From the feedback report enclosed; would you act on it?	Yes	No
If Yes; which one will you consider?		
1- Likely to implement. 2- Possibly to implement. 3- Not likely to implement.		

If you have any further thoughts or comments regarding these issues, please feel free to write in the space provided below:

Thanks again.

H. Altan

Feedback Report Template/Sample

Private Rented Property Feedback

| Property Address |

Current Conditions:

Property Energy Efficiency Measures

Energy Efficiency Measures	Wall Insulation	Roof Insulation	Floor Insulation	Heating System	Hot Water System	Controls	Draught Stripping	Controlled Ventilation	Double Glazing	Energy Efficient Lighting	SAP
PROPERTY	n	y	n	gc	gch	pts	n	n	y	n	62
gc: gas central / **esh**: electric storage heater / **lgf**: local gas fire / **gch**: gas central heating / **eih**: electric immersion heater / **igfu**: individual gas fired units / **pts**: programmer and time switch / **rct**: room and cylinder thermostat / **trv**: thermostatic radiator valves / **y**: yes / **n**: no / **p**: partial											

Total Energy Use, CO_2 Emission & SAP Rating Analysis

PRIVATE RENTED PROPERTY		REQUIRED SAP RATING = 85						CURRENT REGULATIONS PASS/FAIL
PROPERTY	SAP	COSTS £ YEAR			CO_2	HEAT LOSS PARAMETER	AIR CHANGE RATE	
		SPACE	WATER	TOTAL				P/F
PROPERTY ADDRESS	62	366.45	167.46	533.91	6.01	2.63	0.89	F

Suggested Improvements:

Considering the analysis carried out and presented above, there are potential improvements to the following energy efficiency measures:

- ☐ Draught-stripping
- ☐ Wall/floor insulation
- ☐ Energy efficient lighting
- ☐ Heating system
- ☐ Hot water system
- ☐ Controls for heating and hot water

If you were to implement the following energy efficiency measures, the SAP rating of the property could be increased from 62 to 76, which again is a significant improvement in energy efficiency.

- ☐ Heating system
- ☐ Hot water system
- ☐ Controls for heating and hot water

The following chart is to give you an idea about estimated cost figures that could be spent if suggested improvements were to be implemented.

Estimated Cost Analysis for Property Improvements (2001 – 2003)

Measures	Saving (£/yr)	Cost (£)	Payback (yr)
Cavity Wall Insulation	75-150 INST	450 INST	4-6 INST
Solid Wall Insulation (external)	85-120 INST	1500 INST	12-13 INST
Solid Wall Insulation (Internal)	75-100 INST	650 INST	6-7 INST
Roof Insulation (Loft Insulation)	35-50 DIY/INST	75-110 DIY 200-230 INST	1-3 DIY 4-6 INST
Floor Insulation	20-40 DIY/INST	75-110 DIY 200-300 INST	1-2 DIY 7-10 INST
Replacing Condensing Boiler	150 INST	300 INST	2 INST
Hot Water Insulation Package	15-25 DIY/INST	20-25 DIY 30-40 INST	1 DIY 2 INST
Fuel Heating Control Package	25-120 INST	80-400 INST	3 INST
Draught Stripping	15-25 DIY/INST	50 DIY 150 INST	2 DIY 6 INST
Double Glazing (standard)	25-30 INST	170 INST	5-6 INST
Double Glazing (low-emissivity)	30-40 INST	275 INST	7-8 INST
Lighting (x4 Lamps)	40-50 INST	20-25 INST	0.5 INST

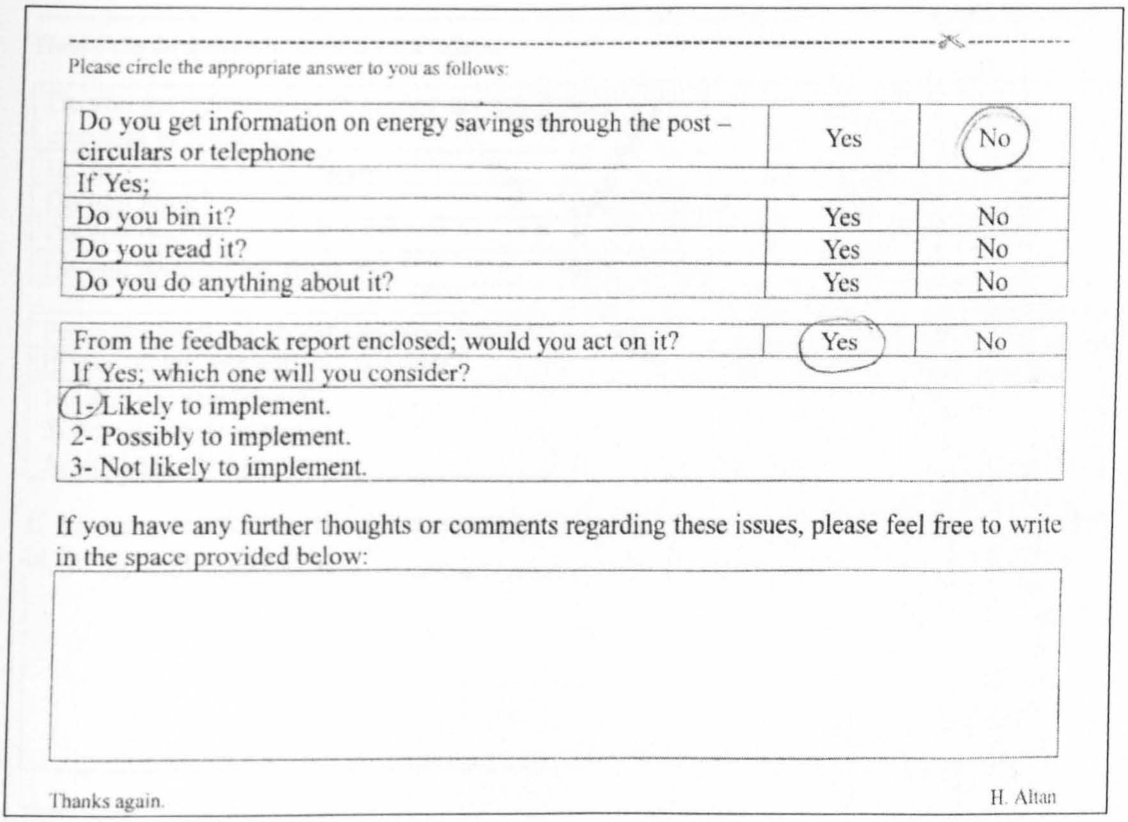
INST: Professional Installer / **DIY:** Do It Yourself

NOTE: The cost and savings figures will vary according to the property size, its location, the measures (if appropriate), fuel, heating system and the material used. Energy savings are estimated from a range of standard house type with gas central heating and standard occupancy. Actual savings depend on individual circumstances.

General Recommendations for Immediate Savings

1. Increase the depth of loft insulation to at least six inches (150mm).
2. If the property was built after 1940, installing cavity wall insulation will reduce heat loss through the wall by up to 60%.
3. Change to energy saving light bulbs, especially in areas where lights are used most - it will use around a quarter of the electricity, and will last eight times longer than an ordinary bulb.
4. If the boiler is 10 years old or unreliable, replace it - you could save 10 - 15% on your fuel bill.
5. Add heating controls to your central heating system and cut your costs by up to 20%.
6. Fit a good insulating jacket to your hot water tank if it is not foam covered.
7. If the property is too warm, turn the thermostat down by 1°C; this can cut up to 10% off your fuel bills.
8. Invest in draught stripping for letterboxes and for doors and windows opening onto the outside to reduce the amount of warm air escaping.
9. A shower uses only 2/5th of the hot water needed for a bath. Shower attachments for bath taps can be bought from many local stores.
10. Water does not need to be heated to a scalding temperature. Setting the thermostat at 60°C /140°F is usually quite adequate.
11. Don't put really wet clothes into a tumble dryer, ring them out or spin-dry them first. It's much faster and will save money as well.
12. Close curtains at dusk to stop heat escaping through the windows.
13. Always wait until you have a full load before using your washing machine. If this isn't possible, use a half-load or an economy programme if your machine has one.
14. Always remember to put the plug in the basin or sink. Leaving hot water taps running without the plug is both wasteful and expensive.
15. Use the microwave, rather than the conventional oven to heat up food (always make sure the food is piping hot before eating).

Sample Investigation (Short Questionnaire No: 02): 'Yes – Likely to Implement'



Please circle the appropriate answer to you as follows:

Do you get information on energy savings through the post – circulars or telephone	Yes	[✓ No]
If Yes;		
Do you bin it?	Yes	No
Do you read it?	Yes	No
Do you do anything about it?	Yes	No

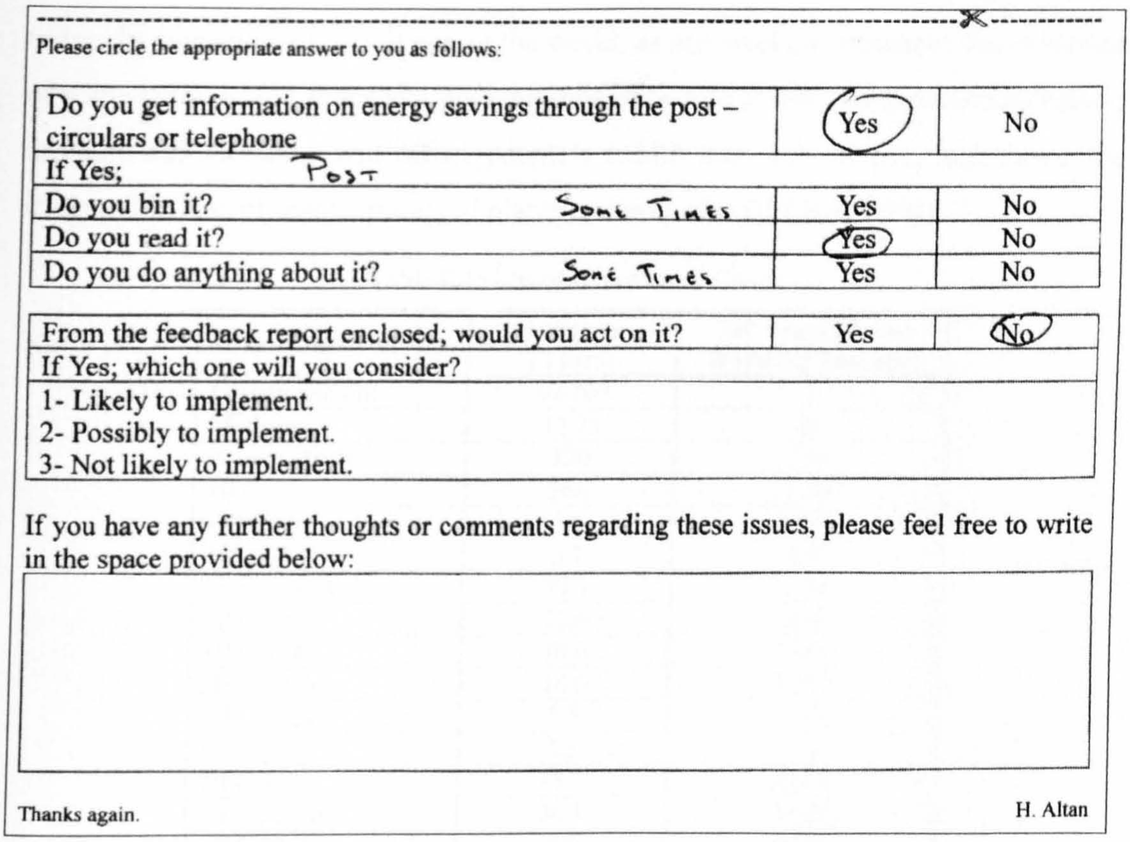
From the feedback report enclosed; would you act on it?	[✓ Yes]	No
If Yes; which one will you consider?		

[✓ 1-] Likely to implement.
2- Possibly to implement.
3- Not likely to implement.

If you have any further thoughts or comments regarding these issues, please feel free to write in the space provided below:

Thanks again. H. Altan

Sample Investigation (Short Questionnaire No: 04): 'No – Not Likely to Implement'



Please circle the appropriate answer to you as follows:

Do you get information on energy savings through the post – circulars or telephone	[✓ Yes]	No
If Yes; Post		
Do you bin it? Some Times	Yes	No
Do you read it?	[✓ Yes]	No
Do you do anything about it? Some Times	Yes	No

From the feedback report enclosed; would you act on it?	Yes	[✓ No]
If Yes; which one will you consider?		
1- Likely to implement. 2- Possibly to implement. 3- Not likely to implement.		

If you have any further thoughts or comments regarding these issues, please feel free to write in the space provided below:

Thanks again.

H. Altan

Appendix B

List of Greenhouse Gases

Climate change is one of the most serious environmental threats facing the world today. Its impacts will be felt across the world, as sea level rise threatens the existence of some small island states and puts millions of people at risk. Temperature increases; drought and flooding will affect people's health and way of life, and cause the irreversible loss of many species of plants and animals (DEFRA, 2000).

Table B.1: List of Greenhouse Gases.

Greenhouse Gas	Lifetime (Years)	100 Years Global Warming Potential
Carbon Dioxide	50-200	1
Methane	12.23	21
Nitrous oxide	120	310
HFC-23	264	11,700
HFC-32	5.6	650
HFC-41	3.7	150
HFC-43-10mee	17.1	1,300
HFC-125	32.6	2,800
HFC-134	10.6	1,000
HFC-134a	14.6	1,300
HFC-152a	1.5	140
HFC-143	3.8	300
HFC-143a	48.3	3,800
HFC-227ea	36.5	2,900
HFC-236fa	209	6,300
HFC-245ca	6.6	560
Chloroform	0.51	4
Methylene chloride	0.46	9
Sulphur hexafluoride	3,200	23,900
Perfluoromethane	50,000	6,500
Perfluorethane	10,000	9,200
Perfluoropropane	2,600	7,000
Perfluorobutane	2,600	7,000
Perfluoropentane	4,100	7,500
Perfluorohexane	3,200	7,400
Perfluorocyclobutane	3,200	8,700
Trifluoroiodomethane	<0.005	<1

Source: DEFRA, 2000.

How to Compare the Relative Climate Effects of Greenhouse Gases

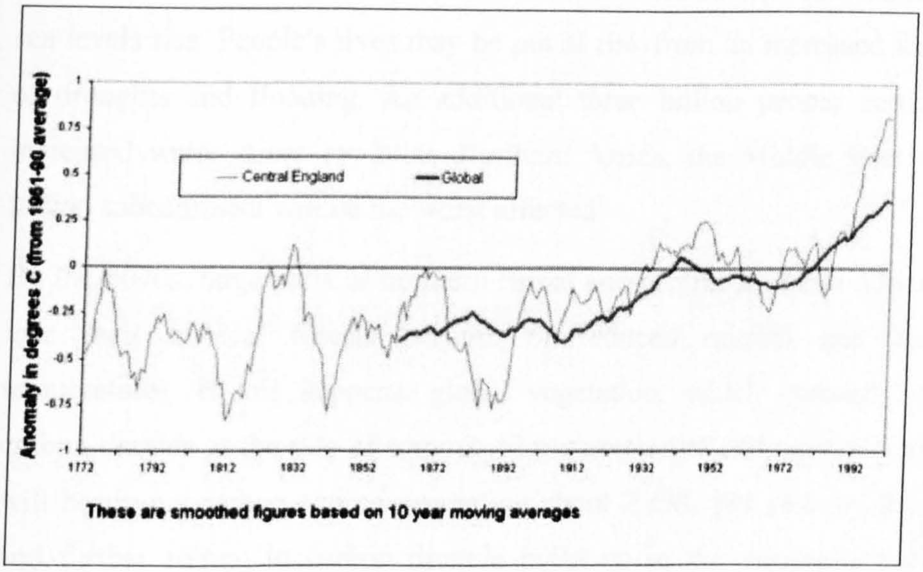
1. To compare the relative climate effects of greenhouse gases, it is necessary to assess their contribution to changes in the net downward infra-red radiation flux at the tropopause (the top of the lower atmosphere) over a period of time. Ultimately the best way to do this is by comparing different emission scenarios in climate models, but a simple working method has been derived for use by Parties to the UNFCCC. This provides the relative contribution of a unit emission of each gas, relative to the effect of a unit emission of carbon dioxide integrated over a fixed time period. A 100-year time horizon has been chosen by the Convention in view of the relatively long time scale for addressing climate change.
2. The factor is known as a global warming potential (GWP). It means for example, that 1 tonne of HFC-134 emitted to the atmosphere has 1,000 times the warming potential over 100 years of 1 tonne of carbon dioxide.
3. To compute the carbon dioxide equivalent of the emission of any gas, multiply its emission by the GWP. This is often expressed as the carbon equivalent so then multiply by 12/44, the ratio of the atomic weights of carbon and carbon dioxide. Thus, for example, an emission of 1 tonne of HFC-134 is equivalent to 1 x 1000 x 12/44 = 273 tonnes of carbon.

How the World's Climate may Change in the Future

Climate change is one of the most serious environmental threats facing the world today. Its impacts will be felt across the world, as sea level rise threatens the existence of some small island states and puts millions of people at risk. Temperature increases; drought and flooding will affect people's health and way of life, and cause the irreversible loss of many species of plants and animals.

Average global surface temperatures have increased by 0.6°C over the 20th century (see figure B.1). Nine out of the ten hottest years on record have been during the period 1990 - 2002. According to the Inter-Governmental Panel on Climate Change (IPCC) the strong warming of the last 50 years cannot be explained by natural climate variations alone, but requires the inclusion of the effects of human emissions. Much of the observed rise in sea-level (10 - 20 cm) during the 20th century may be related to this increase in global mean temperatures. Current climate models predict that global temperatures will rise by a further 1.4 to 5.8°C by the end of the 21st century. Global mean sea levels are also predicted to rise by 9 to 88 cm by 2100 (DEFRA, 2000).

Figure B.1: Global and Central England Surface Temperature Anomalies: 1772 - 2000.



These are smoothed figures based on 10 year moving averages

Source: Met Office, 2001.

Key Impacts

Nevertheless effective policies are to reduce emissions of greenhouse gases; the world will now experience a significant degree of climate change. This is likely to have far-reaching effects on all aspects of the world's environment, economy and society including:

- Sea level is expected to rise by over 40 centimetres by the 2080s because of thermal expansion of the oceans as temperatures rise and because of melting of land ice. This will threaten the existence of some small island states and put millions of people at risk;
- The poorest countries are likely to be the most vulnerable to the effects of climate change. 60% of the additional 80 million people projected to be at risk of flooding are expected to be in Southern Asia (Pakistan, India, Sri Lanka, Bangladesh and Myanmar) and 20% in South East Asia (from Thailand to Vietnam, including Indonesia and the Philippines);

- Africa is expected to experience significant reductions in cereal yields, as are the Middle East and India. And an additional 290 million people could be exposed to malaria by the 2080s, with China and Central Asia likely to see the largest increase in risk;
- In some areas, water resources for drinking and irrigation will be affected by reduced rainfall or as ground water in coastal zones suffers from salination as sea levels rise. People's lives may be put at risk from an increased frequency of droughts and flooding. An additional three billion people could suffer increased water stress by 2080. Northern Africa, the Middle East and the Indian subcontinent will be the worst affected;
- By the 2070s, large parts of northern Brazil and central southern Africa could lose their tropical forests because of reduced rainfall and increased temperatures. If this happens, global vegetation, which currently absorbs carbon dioxide at the rate of some 2 - 3 gigatonnes of carbon (GtC) per year will become a carbon source generating about 2 GtC per year by the 2070s and further adding to carbon dioxide build up in the atmosphere (current global man-made emissions are about 6 - 7 GtC per year).

How the UK could be Affected

Climate change could have significant affects on the UK. Average temperatures could rise by a further 3°C by 2100 and rainfall could increase by as much as 10% over England and Wales and 20% over Scotland by the 2080s, according to national climate change scenarios from the UK Climate Impacts Programme. Climate-induced sea level rise, together with natural vertical land movements, could be 41cm in East Anglia and 21cm in the west of Scotland by the 2050s. Seasonal changes are also expected, with UK winters and autumns getting wetter, and spring and summer rainfall patterns changing so that the north west of England will be wetter and the southeast will be drier. Higher temperatures in the UK may lead to poorer air quality in the summer months. Gradual changes in climate and sea level will also be accompanied by changes in the frequency of extreme events (DEFRA, 2000).

Importance of Energy Conservation

Economic Importance: Energy is a commodity, which people cannot afford to waste. Even though fuel costs have fallen, people still spend around £50 billion a year on fuel in the UK, of which 20% could be saved cost-effectively by investing in energy conservation. This would yield savings of over £10 billion a year, money that would boost the economy when spent on other goods and services.

Environmental Importance: Saving energy makes environmental sense. It is universally recognised that human kind are changing the climate in ways they cannot predict, by altering the composition of the earth's atmosphere as a result of burning fossil fuels for heat and electricity. The more efficiently people can use energy, the less they need of it to maintain their lifestyle, and the less carbon dioxide will be released into the atmosphere.

Social Importance: Social benefits of investment in energy conservation include creating significant numbers of jobs in energy-related services such as manufacturing and installation of energy saving equipment. Moreover, homes and workplaces would be made easier and cheaper to heat, greatly improving standards of living and comfort. This is especially important for people on low incomes, whose homes are often the hardest and most expensive to heat, and for people who are at home all day or who have higher heating needs because of illness or disability.

Energy Conservation in Domestic Buildings

Depending on the level of industrial activity, a country uses about 30 to 35 percent of its total energy consumption in buildings. Of this amount, about 60% is used for heating and air conditioning. This means that of the total energy consumption, about 20% is used in building space heating and air conditioning. Burning fossil fuel is the most important source of providing energy in a building. One of the most serious complications of burning fossil fuel is the release of carbon dioxide. The last seventy years have seen a 10% rise in atmospheric levels of CO_2 and at the same time global temperatures have risen by 0.2°C. The burning of fossil fuels is thought to account for half the global warming in the world through the greenhouse effect.

Appendix C

Paper Title: The Applications of Solar Energy and Solar Radiation Data in Renewable Energy Resource Planning

Conference Name: Architecture City Environment

Date: 2nd – 5th July 2000

Location: Cambridge, England

Source: Conference Proceeding

The Applications of Solar Energy and Solar Radiation Data in Renewable Energy Resource Planning

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ABSTRACT

This paper discusses the importance of solar energy use in buildings, as a building energy supply for space heating, cooling and lighting, for the future of Iran. It examines the solar radiation data calculated on an hourly and a monthly basis by using two individual calculation methods and presents the comparison between them. Furthermore, certain positive suggestions about solar energy applications in buildings and solar radiation data use in renewable energy resource planning are also presented regarding the future of solar energy use in Iran. Moreover, in this study, crucial points in renewable energy resource planning are discussed and necessary suggestions are also made concerning environmental issues.

INTRODUCTION

Since the 1970s, over a thirty-year period, the interest in renewable energy has been growing steadily all around the world. Today, there are very few countries, which would perceive a future without renewable energy resources contributing to their energy provision.

The energy crisis has been the cause of many governments searching for new ways of increasing the diversity of their energy supplies. It mainly affected the countries outside OPEC (Organization of Petroleum Exporting Countries). The countries like

Iran and the rest of the OPEC world were carried into a completely opposite situation. Their role was to export more oil and make a profit out of it; especially from countries that would not have any other option in finding new ways of supplying their energy needs.

In addition to these changes all around the world, there were also huge developments in the technologies in the renewable energy world. Today, renewable energy resources have become the most important consideration in energy provision in the world. Generally, in the last ten years, concern about the environment has increased, and in particular the environmental impacts of conventional energy systems such as global warming, acid rain, etc., have revitalised the interest in renewables. Concerning the environment, renewables are often considered to be environmentally friendly resources and they will make a substantial contribution to our world energy supply.

Like many developing countries, today Iran is beset with serious energy supply difficulties. The main issues are the rapid increase in energy demand/cost, air pollution caused by over use of fossil fuel (usually used in buildings for heating purposes), the limitation of fossil fuel resources and the high cost/difficulty of transporting fossil fuel around the country (specially in winter). Moreover, there is the need for careful planning and strategy as well as the development of a decision support model for the future of Iran.

GENERAL DEFINITIONS

Renewable Energy

"Renewable energy is the term used to cover energy flows, which are occurred frequently in the environment and can be harnessed for human benefit." [1] The ultimate sources of this energy are the Sun, gravity and the earth's rotation.

Solar Energy

The Sun is the source of solar energy. Solar energy is one of the most important renewable energy sources and can be derived from the Sun's solar radiation to cover most of the world's energy supplies.

Solar radiation can be converted to energy use directly via certain technologies such as those given below:

- Solar collectors to provide solar space or water heating during the cold seasons can absorb the energy needed from the Sun.
- Buildings can be designed with passive solar design strategies, which will allow solar energy to contribute to their space heating requirements. Furthermore, in buildings, small solar collectors are extensively used to supply domestic hot water in several countries such as Australia, Cyprus, Israel, Japan, etc.
- Parabolic mirrors to provide heat at up to several thousand degrees Celsius can convert solar radiation, and this high temperature may then be used either for heating purposes or to generate electricity.
- Photovoltaic devices (solar cells) can also be used to convert solar radiation directly into electrical energy.

Solar radiation can also be converted to useful energy indirectly via other energy forms, such as wind, wave, and hydropower.

Solar Radiation Data

Solar radiation data are the best source of information that is related to solar energy besides other meteorological measurements. Solar radiation data can be available in numerous forms, but they should include specific information such as:

- information about; whether the measurements are direct measurements or values integrated over some period of time (usually hour or day).
- information about; the time or time period of the measurements.
- information about; whether the measurements are of beam, diffuse or total radiation, and the instruments used.
- information about; the receiving-surface orientation; usually horizontal, sometimes inclined at a fixed slope, or normal orientation.
- information about; if averaged, the period over which they are averaged (e.g. monthly averages of daily radiation).

The Use of Solar Radiation Data

There are several approaches to the use of solar radiation data such as given below:

- to use the average solar energy available, for instance for a month, to estimate the average performance of a process.
- to use the past hourly or daily data performance of a process that would have been relevant under those past conditions, and on this basis project future performance.
- to reduce the radiation data to a more manageable form by using statistical methods, and use the resulting time distributions in process performance predictions, such as, for example, the statistical treatment of radiation available, which is based in part on collector performance.

Iranian Solar Radiation Data

These data are calculated for each city, such as Tehran, Mashhad, etc. by using Islamic Republic of Iran Meteorological Organisation (IRIMO)'s statistics. The solar radiation data reflect direct beam irradiance on a surface normal to solar beam, direct irradiance on surfaces horizontal to and vertical to solar beam.

OVERALL DATA RESULTS

The examination of the preceding tables and graphs clearly shows that the solar radiation data can be used confidently in renewable energy resource planning in Iran.

First of all, the manually calculated data are prepared by use of IRIMO statistics and are specific to every city in Iran. On the other hand, Meteonorm was designed for European use and is generally generated to cover the world cities.

When calculating the solar radiation for certain cities, for example, Tehran and Chalos (which are on same the longitude, slightly different latitudes but also at the same altitude) the manual calculation method displays incompatible results for both cities, whereas meteonorm shows exactly the same data for both.

In this case, it can be assumed that the manually calculated data are more useful in that they are more precise and much more reliable compared to meteonorm data for Iran.

Although, there are small differences in the tables and graphs shown above, the results are relatively similar. In addition, they support the calculations done manually and show that the results are dependable.

Due to the fact that the country has 8 different climate zones and the human settlements are located variously among these zones, solar radiation differs and should be estimated as precisely as possible.

CONCLUSION

Solar energy is one of the most significant and technically exploitable renewable energy resources available in Iran. This needs to be taken into account seriously, regarding both economical and environmental problems in that country.

This study restates and emphasises the importance of solar radiation data in renewable energy resource planning. Therefore, in Iran, there is the need for the precise calculation of solar radiation for each and every city in order to better exploit the benefits of solar energy for the future of this country.

The overall data results show that there is sufficient solar radiation for the application of solar design strategies in buildings. Solar technology applications in buildings such as photovoltaics, active solar and thermal solar power and passive solar design will provide a positive solution for the country's air-pollution, especially in the city of Tehran. Designing buildings with solar features will reduce the oil use in the country and at the same time, will reduce CO_2 production, which is one of the principal causes of global warming. Reduction in oil use in buildings also increases the exportation of oil to other countries. As a result, Iran's economy will be supported and will benefit. Adapting new technologies into buildings will help Iran to become an environmentally friendly country with a positive impact on the environment.

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Paper Title: Analysis of Existing Environmental Assessment Methods for Buildings in the UK

Conference Name: Renewable Energy for a Sustainable Development of the Built Environment

Date: 7th – 9th November 2001

Location: Florianopolis, Brazil

Source: Conference Proceeding

ANALYSIS OF EXISTING ENVIRONMENTAL ASSESSMENT METHODS FOR BUILDINGS WITHIN THE UK

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ABSTRACT

This paper, once again, states the importance of environmental issues and good building design. It reviews existing building environmental assessment methods developed in the UK in the last twenty-five years and provides the benefits of using energy efficient strategies and technologies with significant potential for energy savings. This study also refers to existing methods added to the building regulations and therefore, discusses whether they have been effectively transferred to the building design community and worked as successful solutions. Furthermore, a comparison study of five main building environmental assessment methods is carried out and certain suggestions are made regarding the housing conditions. Moreover, crucial points are also mentioned concerning global environmental.

Conference Topic: 3.2 Building Energy Analysis and Design Support Tool

1. INTRODUCTION

As a global matter, environmental issues and good building design have also been increasingly important in the UK for the last twenty-five years. Additionally, building environmental assessment methods have been developed with the intention of accomplishing good building design, which could contribute considerably to reducing pollution and improving the environment. These methods identify criteria for a range of issues also concerning the global, national and indoor environments and carry out key objectives, such as:

- To raise awareness of the dominant role which buildings play in global warming and reduce their long-term impact on the global environment.
- To provide a common set of targets and standards, which would not only provide recognition for buildings, that is friendlier to the global environment than normal practice, but also help to simulate a market for them.
- To improve the indoor environment quality and occupants' health.
- To encourage designers to achieve environmentally friendly building designs.

2. REVIEW OF BUILDING ENVIRONMENTAL ASSESSMENT METHODS

In the UK, there are five main building environmental assessment methods that have been developed since early eighties and moreover added to the building regulations to improve the building energy usage and increase the efficiency:

1. **BREDEM-** The BRE's Domestic Energy Model is developed in 1980s by the Building Research Establishment (BRE) and the Department of the Environment (DOE). This method measures the energy use in occupied dwellings and shows that the physical characteristics of a dwelling and the lifestyles of the occupants are about equally important in determining energy consumption. BREDEM exists in a number of standardised versions, which differs in technical detail and in the precise requirements for data related to particular application. Some versions are designed to be implemented as computer programs while others are defined in such a way that do not require the use of a computer.

2. **SAP-** Standard Assessment Procedure is the Government's standard system for home energy rating, which was published in 1993 and used to calculate the rating based on the BREDEM. It is included as one means to satisfy the Building Regulations Part L domestic buildings since July 1995. The SAP rating is normalised for floor area and set out in the form of a worksheet, accompanied by series of tables. Results are presented on a scale of 1–100: the higher the number, the better the

standard. In addition, there is a computer program approved for SAP calculations by the BRE that could also be used.

3. **Environmental Standard ~ BREEAM-** Environmental Standard is the first revision of BREEAM Version 3/91 for new homes, which replaces and reflects the increase in knowledge and understanding of early issues since it launched in 1991. BREEAM/New Homes is one of the series of five assessment methods developed by BRE and Municipal Mutual Insurance Ltd for different type of buildings. BREEAM, the BRE's Environmental Assessment Method, is developed in 1990 by ECD Energy & Environment with the BRE. This method is based on readily available and generally accepted information. As it is stated in one of BRE's Reports [1], the method identifies and credits designs where specific targets are met. Since its launch, BREEAM has become the UK industry standard for specifying and benchmarking the environmental performance of buildings.

4. **NHER-** National Home Energy Rating is a policy tool for Authorities and Housing Associations, which calculates the energy performance of dwellings and the first scheme to receive full governmental approval for the delivery of SAP. It is designed in 1990 by the BRE in the function of a comprehensive system for evaluating the energy efficiency of housing stock. The NHER has three steps towards establishing and implementing an energy policy, which are: A Stock Profile; Priorities and Targets; and Implementation. The software delivers many useful indices and ratings including; the Government's SAP, the NHER on a scale of 1-10, the Building Energy Performance Index (BEPI), the total CO2 Emissions produced by a house.

5. **MNV STARPOINT-** This Home Energy Labelling model is an essential aid to achieving the needs and requirements set by the Government and the Housing Corporation, which is launched in 1990. It aims to assess existing energy efficient standards in housing, identify priority action areas and cost-effective improvements and tests the extent to which these improvements can raise the rating and reduce CO2 emissions and heating bills. MNV STARPOINT is a computer software and its products and consultancy services are based on the Government's SAP. It has been given to issue Home Energy Labels on a scale of ONE STAR being poor and FIVE STAR excellent.

Table I: A comparison study of five main building environmental assessment methods (Y:Yes, N:No).

GENERAL CRITERIA	1	2	3	4	5
Produces an energy rating/Is a software based program/Offers greater flexibility in benchmarking building portfolios	N	Y	Y	Y	Y
Suitable for calculating SAP ratings/Provides simple means of reliably estimating the energy efficiency performance	Y	Y	N	Y	Y
Provides a framework for calculation of energy use in buildings	Y	N	Y	N	Y
Thermal insulation of the building envelope; the efficiency and control of the heating and hot water systems; and the ventilation characteristics of the dwelling are included when calculating energy costs	N	Y	N	Y	N
Estimates the energy used for space and water heating/Consists of worksheets/Enables the levels of energy efficiency in buildings to be compared	N	Y	N	Y	Y
Additionally takes into account CO2, CFC and HCFC emissions; renewable resources and recycled materials; lighting; etc.	N	N	Y	Y	Y
Provides guidance and covers issues such as global, local and indoor	N	N	Y	N	Y
Encourages the use of public transport and cycling/Provides the environmental assessment of materials and rating for recyclability	N	N	Y	N	N

3. CONCLUSION

In the UK, more than twenty-five years of research background has produced broad understanding of the implications of the energy use and helped increasing the number of building environmental assessment methods with significant potential for energy savings. These methods are not only covering a large part in the research background achieved in the country, but also playing an essential role in increasing awareness of the importance of energy efficiency and encouraging energy conscious building design throughout the country. Moreover, they have been added to the building regulations to improve the building energy usage and increase the efficiency of building stock. However these methods have not been effectively transferred to the building design community. Yet these schemes aimed to assess the building stock could be more effective solutions. In fact, recent studies suggest that the UK building stock is in poor conditions [3], [5].

Against this background, my research advocates that more emphasis should be paid to encouraging property developers to design energy conscious buildings as opposed to previous studies that have mainly focused on tool developments and ratings. Today, as being one of the most important issues, sustainable development is forever on the agenda. Therefore, the knowledge gap between the developed building environmental assessment methods and the building design community, should be bridged rapidly. Additionally, the building regulations and associated policies could be more effective and efficient. Moreover, the use of energy ratings should enable decision makers to take energy efficiency into account on a rational basis when designing new dwellings or refurbishing existing ones. For building professionals, ratings can be used as a design tool to optimise energy efficient design.

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Paper Title: Home Energy Use and the Environment: Housing Conditions and Potential Energy-Efficiency Improvements in Sheffield, UK

Conference Name: Design with the Environment

Date: 22nd – 24th July 2002

Location: Toulouse, France

Source: Conference Proceeding

HOME ENERGY USE AND THE ENVIRONMENT

Housing Conditions and Potential Energy-Efficiency Improvements in Sheffield, UK

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ABSTRACT

Today, global warming is one of the most dangerous instabilities that we are introducing into our ecosystem. Accordingly, the relationship between global warming and the way we use energy in our homes is becoming increasingly related and crucial. Energy used in the home is responsible for significant amount of the UK's CO_2 emissions. It is a major contributor to 'Global Warming' and therefore, improved energy efficiency is a key element of necessary changes. This study is aimed to introduce the importance of energy efficiency improvements in housing. Improvements in this sector will therefore help significantly to the whole improvement programme in housing in the country.

Conference Topic: Case Study

Keywords: Climate Change, Home Energy Use, Environment, Energy-Efficiency Housing

INTRODUCTION

Global Warming and Energy Use

Global warming today is one of the most dangerous instabilities that are being introduced into our ecosystem. Consequently, the relationship between global warming and the way we use energy in our homes is becoming increasingly related and crucial. Energy used in the home is responsible for about 30% of the UK's CO_2 emissions. This is a major contributor to '*Global Warming*' and therefore, improved energy efficiency is a key element of necessary changes.

As a contribution to global efforts to prevent *Climate Change* running out of control, the United Kingdom should plan for a reduction of 60% over the next 50 years in the amounts of carbon dioxide it produces by burning fossil fuels. This is again one of the key conclusions of a major report published in the year 2000 [1].

Furthermore, information also published by the Department of Trade and Industry shows that in the UK almost 50% of the total energy used by the country is accounted for the building sector [2]. This supports the idea of why the government is given the commitment to reduce the emissions of ozone depleting gasses by 20% and ensure that the building sector is playing its fair role in helping to meet these standards.

In this study, it is aimed to introduce the importance of potential energy efficiency improvements in housing in Sheffield. Improvements in this sector will therefore help significantly to the whole improvement programme in housing in the country.

Households and Energy Consumption

In the UK, household's share of total energy consumption stands at 29%; higher than the shares of the industrial and service sectors, lower than the share of transport's [3]. Additionally, total energy consumption in the domestic sector rose by just under a quarter between 1973 and 1998 (see figure 1).

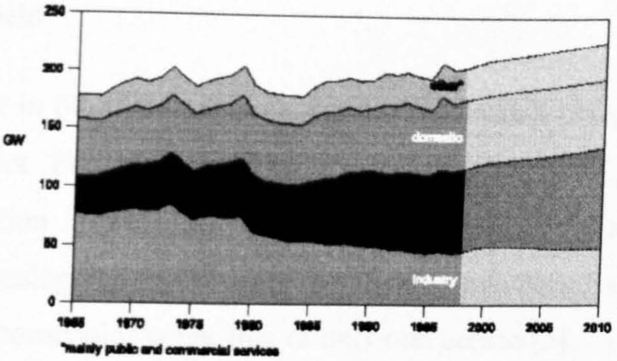
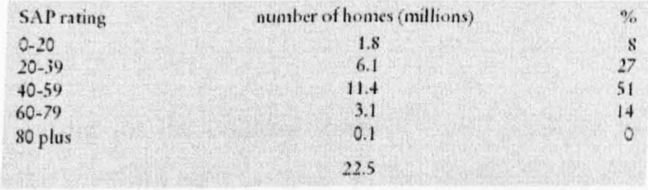


Figure 1. UK energy consumption rate by sector 1965-2010.

As the report states, over the 25 years period (1973 -1998), despite the increase mentioned above, the total energy consumed within the home by the average UK household fell by about a tenth. Now this fall is mostly attributable to a decline in the average number of people per household, to an increase in insulation and draught proofing as new homes are built and existing dwellings are improved, and to the introduction of more energy efficient heating systems.

Moreover, it is stated that, a single household's total energy consumption depends heavily on levels of insulation and draught proofing and the heating system it uses. The government's *Standard Assessment Procedure* (SAP) for the energy costs rating of dwellings is currently extensively used to measure the basic energy efficiency of UK homes (see figure 2) for space heating and hot water [4]. Although the existing housing stock has steadily improved, most of it is still far from having cost-effective levels of insulation.



SAP rating	number of homes (millions)	%
0-20	1.8	8
20-39	6.1	27
40-59	11.4	51
60-79	3.1	14
80 plus	0.1	0
	22.5	

Figure 2. SAP ratings.

Analysis of SAP ratings from these surveys demonstrates that lower income households are those who can least afford to waste energy and live in the most inefficient property that are hardest to heat. In the country, generally the privately rented sector has a lower rating than owner-occupied, council and housing association homes, which is reported by the Department of Energy's *Energy Report* [3].

Housing in Sheffield

Over 1 in 5 people in Sheffield are over pension age, which is higher than any other metropolitan district. People over 85 ages are rising by 2.9% per year. Although Sheffield's population is projected to fall over the next ten years, the number of households is increasing and this reflects the growing number of smaller households, with almost 1 in 3 households consisting of only one person [5].

Large number of households contains someone who has problems coping with their accommodation because of disability, health problems or long-term illness. These households are often most at risk from fuel poverty. Although Sheffield has a low proportion of households with children (26.7%), it is expected to increase.

Sheffield has a large number of terraced properties, which were constructed before 1919 (mainly owner-occupied, some privately rented) and are in poor state of repair. 15% of terraced homes are unfit, with the main reasons dampness and disrepair. There are high proportions of purpose built flats, which have large number of one and two bedroom properties compared to other metropolitan districts and very small proportion of large family houses (seven or more rooms – less than 20,000 homes) [5].

Large number of council houses is in need of modernisation including improved heating and insulation. Additionally, over 14,000 properties are without central heating, the vast majority of the stock is lacking the insulation required by building standards.

The average energy rating for the council stock is 4 and 5 on the NHER scale. Over 27,000 properties have a rating of 3 or less. In the private sector, 30,000 properties have a SAP energy rating of 30 or less [5].

Over 20,000 private sector properties (15%) have no insulation and the rest 23,000 (17%) have less than current building standards. 16% of properties rely on individual room heaters as their main source of heating. Over half of households (51%) in unfurnished tenancies lack central heating. 46% of private sector properties are estimated as having solid walls, which restricts the option for insulation.

According to the report published by Sheffield Housing, overall 17% (37,719) households had difficulty paying their fuel bills. This was most severe for council tenants (22%) and for tenants of private sector landlords (28%). 34% of households did not heat all their rooms in winter due to the following reasons; too expensive to heat all the rooms (22%), had no heating in some rooms (22%) [5].

Table 1. Total energy use by tenure (1996).

Council	Tjoules p.a.	Percentage	£million p.a.
Space heating	5,210	66	22.5
Water heating	1,760	23	10.6
Cooking	334	4	1.3
Lights and appliances	564	7	10.4
Standing charges	n/a	n/a	5.6
Total	7,868		50.4
Owner occupied	Tjoules p.a.	Percentage	£million p.a.
Space heating	13,000	72	54.7
Water heating	2,970	16.5	15.1
Cooking	661	4	2.6
Lights and appliances	1,350	7.5	25.2
Standing charges	n/a	n/a	9.9
Total	17,981		107.5

These calculations give an average weekly energy bill of £13.55 for council tenants and £16.18 for owner-occupiers.

Table 2. Total energy consumption by tenure (1996).

Tenure	Energy (Tjoules p.a.)	CO2 Emissions (ktonnes p.a.)	Average Rating (NHER)
Owner occupied	18,000	1,423	4.6
Council	7,880	657	4.5
Private rented	2,056	159	*
Hosing Association	651	53	*
Total	28,587	2,292	

* Data was calculated using the Building Research Establishment software, which generates a less accurate energy consumption figure.

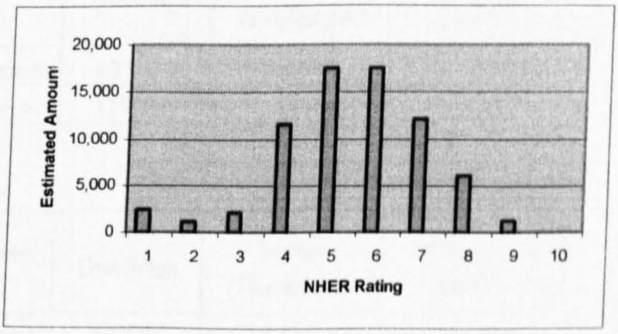


Figure 3. NHER ratings for council housing.

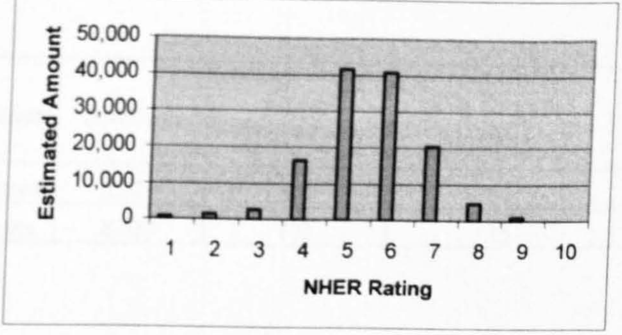


Figure 4. NHER ratings for owner occupied housing.

RESULTS AND DISCUSSIONS

In the UK, the replacement rate of old homes by new, more energy-efficient ones is extremely slow; less than one tenth of 1% of the UK housing stock is demolished each year [6]. This means that there have to be major improvements to the energy efficiency of the existing stock if household energy consumption is to be reduced.

The Home Energy Conservation Act 1995 requires UK local housing authorities to draw up strategies for cost-effectively raising the energy efficiency of private and public sector homes in their area. Also, a recent study indicates that the Act is unlikely to achieve such an improvement [8].

Table 3. Energy efficiency improvements, Sheffield 1996.

Council Housing	Dwellings	Energy (Tjoules p.a.)	CO_2 Emissions (ktonnes p.a.)	Average Rating (NHER)
Before improvements	71,510	7,880	657	4.5
After improvements	71,510	3,117	309	6.3

Owner occupied Housing	Dwellings	Energy (Tjoules p.a.)	CO_2 Emissions (ktonnes p.a.)	Average Rating (NHER)
Before improvements	127,730	18,000	1,423	4.6
After improvements	127,730	5,310	457	5.7

Private rented sector Housing	Dwellings	Energy (Tjoules p.a.)	CO_2 Emissions (ktonnes p.a.)	Average Rating (NHER)
Before improvements	17,380	2,056	159	n/a
After improvements	17,380	601	49	n/a

Housing Association	Dwellings	Energy (*Tjoules p.a.*)	CO_2 Emissions (ktonnes p.a.)	Average Rating (NHER)
Before improvements	8,020	651	53	*N/a*
After improvements	8,020	172	15	n/a

Above tables show the energy efficiency improvements, which can achieve the 30% target set by Sheffield's Home Energy Conservation Act (HECA) programme [5].

Furthermore, Sheffield's HECA Strategy's full report stated that the measures to achieve these savings are estimated at £383.42 million and the time scale is at to over 10 years.

Table 4. Overall results by tenure, Sheffield Housing 1996.

Tenure	CO_2 Reduction (%)	Energy Savings (%)
Council Housing	53	60
Owner occupied Housing	68	70
Private rented sector Housing	69	71
Housing Association	72	74

According to the overall results given above, Sheffield's HECA programme can achieve an average overall 65% savings. This can show that all the other cities can achieve similar percentage savings and therefore, we could say that the UK, as an individual country, can achieve overall 50% CO_2 reduction and total energy savings by the year 2010, which is also the deadline for Kyoto Protocol.

CONCLUSION

The results of this study will not only help us in our aim to improve energy efficiency in our homes and increase standards and performance of the properties, but also help the potential for future improvements and energy savings in the UK. Additionally, the study will assist to develop a strategy for energy efficiency improvements in housing sector in this field. Presented data will also accelerate the necessity of improvements and consultancies in private sector within the country.

Overall, it will help to make a small-but significant-contribution to the well being of the global environment; live in a healthier environment; save energy.

This survey is again a reminder for all architects, engineers, project managers, consultants and other professionals involved in energy efficiency improvements to comprehend the importance of home energy use in our environment.

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Paper Title: Improving Energy Efficiency and Reducing Carbon Dioxide Emission within Private Housing Sector in Sheffield, UK

Conference Name: Rethinking Development

Date: 9th – 12th November 2003

Location: Santiago, Chile

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Improving Energy Efficiency and Reducing Carbon Dioxide Emission within Private Housing Sector in Sheffield, UK

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ABSTRACT

Along with the UN Framework Convention on Climate Change signed in 1992, UK government has committed to reducing the emission of six greenhouse gases with carbon dioxide being the most significant to 12.5% lower than the 1990 levels. The government has also indicated that it has an aim of further reducing the emissions with an eventual target of 20% below the 1990 levels by 2010. Today, the housing stock is responsible for about 30% of overall emissions, which is a major contributor to global warming and therefore, improving energy efficiency and reducing carbon dioxide emission within housing stock is a key factor for long-term sustainability in the built environment.

Conference Topic: Case Studies

Keywords: Sustainable Development, CO_2 Emission, Energy Conservation

1. BACKGROUND

The UK Government has signed the UN Framework Convention on Climate Change in Rio de Janeiro in 1992 and is therefore committed to reducing the emission of six greenhouse gases with carbon dioxide being the most significant to 12.5% lower than the 1990 levels. The government has also indicated that it has an aim of further reducing the emissions with an eventual target of 20% below the 1990 levels by 2010 [1].

In the UK, energy consumed by the building stock approaches 50% of the total while transport is responsible for 28% and predicted to rise significantly. Moreover, energy used in housing sector is responsible for about 30% of overall CO_2 emission and considerably is a major contributor to global warming [2]. Today, home energy consumption has become one of the key elements of improving energy efficiency and reducing carbon dioxide emission in the country.

2. AIMS AND OBJECTIVES

- Increasing standards in private housing sector in order to contribute the overall improvement programme in the UK.
- Analysing energy efficient housing strategies and current technologies to examine the delivery of required standards.
- Performing modifications to dwelling base designs to improve energy-efficiency within studied properties.
- Introducing case study results to landlords/landladies to encourage energy conservation.
- Encouraging the use of low energy (high-efficiency) lighting, such as compact fluorescent bulbs, to help energy savings in buildings.
- Promoting energy savings throughout the housing sector in Sheffield and ultimately in the entire UK.

3. METHODOLOGY

For the determination of energy efficiency potentials in studied properties and analysed areas, it is necessary to have information on the following:

- The current condition of the property, including the efficiency of space and water heating systems in use.
- The SAP rating of the dwelling with respect to CO_2 emission.
- The reduction analysis of the property CO_2 emission due to the modification carried out to base designs.

Work carried out in this study at the University of Sheffield, has demonstrated quite clearly that the importance of energy efficiency in private housing sector within Sheffield will therefore help significantly to the whole improvement programme in the UK.

The main factors examined are:

- House Conditions (Energy rating with SAP).
- Cost of Energy Use (Both for Space and Water Heating).
- CO_2 Emissions.
- Effective Air Change in the Property (Natural Ventilation).
- Heat Loss Parameters (HLP).

Over 600 questionnaires were distributed to obtain the initial information about the conditions of privately rented properties within Sheffield. With the feedback gained, analysis have been carried out and recorded. Moreover, SAP calculations, layout plans and current photos of these properties have also been verified and attained for future references to help the improvement programme for energy efficiency. The information produced in this study relates to properties mainly rented by the university students, staff and other professionals within areas such as S3, S10, etc.

4. CASE STUDY RESULTS

More than 200 properties have been examined; existing conditions (with relevant SAP rating), cost of energy use (both for space and water heating), CO_2 emissions, effective air change in the property (natural ventilation) and heat loss parameters have been calculated.

Case study has also been followed up by the comparison between results obtained from Stelrad software (Home Assessment Rating Procedure) and SAP (Standard Assessment Procedure) rating version 9.53.

Table I: Comparison of Property Base Designs.

STUDIED PROPERTIES REQUIRED SAP RATINGS = 80/81/82/83/84/85						
PROP. NO	SPACE	WATER	TOTAL	CO_2	SAP	P/F
PROP. 1	263.01	150.04	413.05	4.54	54	F
PROP. 2	265.82	150.04	415.86	4.57	54	F
PROP. 3	297.99	158.68	456.67	5.07	60	F
PROP. 4	312.81	156.55	469.36	5.23	56	F
PROP. 5	314.86	152.42	467.28	5.2	51	F
PROP. 6	307.91	152.42	460.33	5.12	52	F
PROP. 7	292.58	150.04	442.62	4.9	51	F
PROP. 8	321.93	160.22	482.15	5.38	59	F
PROP. 9	294.79	155.87	450.66	5	57	F
PROP. 10	310.04	155.87	465.91	5.18	56	F
PROP. 11	246.31	148.8	395.11	4.32	54	F
PROP. 12	259.6	126.35	385.95	4.21	56	F
PROP. 13	313.62	155.87	469.49	5.23	55	F
PROP. 14	313.62	155.87	469.49	5.23	55	F
PROP. 15	396.31	166.31	562.62	6.36	58	F
PROP. 16	338.12	155.15	493.27	5.52	52	F
PROP. 17	294.03	164.39	458.42	5.09	66	F
PROP. 18	406.4	179.26	585.66	6.65	69	F
PROP. 19	408.87	179.26	588.13	6.68	69	F
PROP. 20	415.39	179.26	594.65	6.75	68	F
PROP. 21	415.39	179.26	594.65	6.75	68	F
PROP. 22	481.29	190.76	672.05	7.7	73	F
PROP. 23	835.54	195.77	1031.31	19.46	53	F
PROP. 24	278.14	150.04	428.18	4.72	52	F
PROP. 25	252.41	151.7	404.11	4.43	57	F
PROP. 26	290.19	152.42	442.61	4.9	54	F
PROP. 27	296.75	154.51	451.26	5	56	F
PROP. 28	268	114.98	382.98	4.17	59	F
PROP. 29	233.79	151.27	385.06	4.2	59	F
PROP. 30	321.08	173.76	494.84	5.54	72	F
PROP. 31	237.96	151.7	389.66	4.25	59	F
PROP. 32	273.71	151.7	425.41	4.69	55	F
PROP. 33	279.71	160.47	440.18	4.87	64	F
PROP. 34	253.56	160.86	414.42	4.55	67	F
PROP. 35	253.56	160.86	414.42	4.55	67	F
PROP. 36	253.56	160.86	414.42	4.55	67	F
PROP. 37	264.33	163.07	427.4	4.71	68	F
PROP. 38	270.68	166.31	436.99	4.83	70	F
SPACE/WATER/TOTAL: COSTS £ YEAR, P/F: PASS/FAIL						

Figure 1: Property SAP Rating within Sheffield.

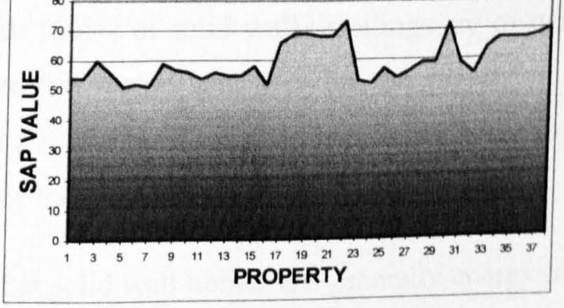


Figure 2: Property CO_2 Emission within Sheffield.

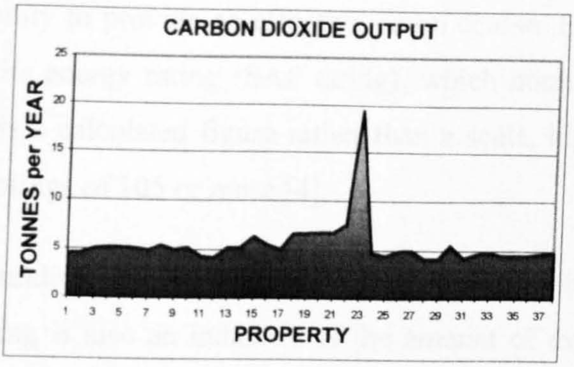
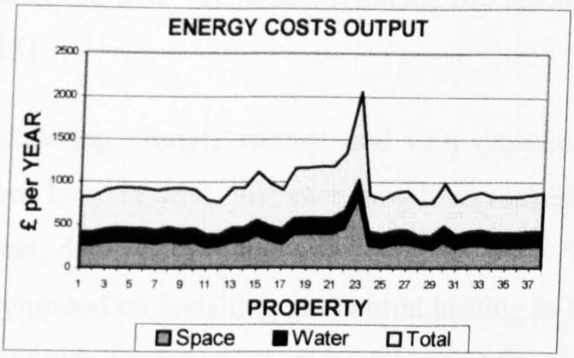


Figure 3: Property Energy Costs within Sheffield.



5. ANALYSIS AND OUTCOME

Table I shows different category of property base designs in respect to SAP rating, CO_2 emission and total energy consumption in studied properties within Sheffield.

This emphasises the predominance of SAP rating output, which is mainly between 50-60, due partly to CO_2 emissions. Analysis of house conditions show that, average SAP rating is 56, which is again below required building regulations. In relation with the age of the property, it is estimated that during the Industrial Revolutions of the 18th and 19th centuries, there has been a massive increase in housing, which on average, 50% of private rented housing could be solid wall dwellings. It is also stated that around two thirds (66%) of solid wall dwellings are owner-occupied, with only 18% in the social rented sector, and 16% in the private rented sector. This has implications both for the way improvement of solid wall housing is marketed and for solving the problem of fuel poverty [3].

The key problem is that solid wall homes are generally energy inefficient. Some very thick walls retain heat and protect from extremes of temperature, but the age of these homes means that there is often a problem with damp, either through floor construction or inability to provide an effective damp course. Energy efficiency of a house is shown by its energy rating (SAP rating), which nominally runs from 0 to 100, but because it is a calculated figure rather than a scale, highly energy efficient homes can achieve ratings of 105 or more [4].

For the solid wall building, adding gas central heating leaves it below the national average. As SAP rating is also an indicator of the amount of expenditure needed to keep the dwelling warm, it can be seen that introducing better insulation has a far greater effect in raising the SAP rating and reducing the amount spent on fuel than just switching fuels [5].

However, when considering climate change and CO_2 emissions, whilst insulation reduces CO2 emissions by over 40%, just switching fuels makes a difference of more than 50%. Nevertheless, doing both reduces emissions by over 70%. It is likely that a programme that concentrated on installing gas central heating in homes would also be required to increase the loft insulation where possible and fit other measures such as draught proofing. It would be useful to have some fuller modelling of these scenarios based on actual numbers of homes that could be addressed by different measures, such as that carried out for housing stock in Sheffield (see table II and III).

Table II: Comparison of SAP Ratings and CO_2 Emissions between Double-Glazed and Central-Heated Properties within Sheffield.

Property A	SAP Rating	CO_2 Emission
No Insulation or Double Glazing; Gas Central Heating & Single Point Hot Water	51	5.2
Fabric Modifications	59	4.31
Heating & Hot Water Modifications	65	3.79
Full Modifications; Fabric, Solar, Vent., Heating & Hot Water	81	2.62

Property B	SAP Rating	CO_2 Emission
No Insulation or Double Glazing; Electric Storage Heater	53	19.46
Fabric Modifications	60	16.35
Heating & Hot Water Modifications	64	17.49
Full Modifications; Fabric, Solar, Vent., Heating & Hot Water	78	11.98

To summarise, properties with solid walls, of non-traditional construction types and/or off gas network are mostly have SAP ratings below average. There are insulating and/or heating solutions that can improve the SAP ratings and reduce the amount of CO_2 emitted through inefficient use of fuel.

Table III: Performed Sample Details of Modifications to Original Base Design.

PROPERTY C	REQUIRED SAP RATING = 83				
DESIGN OPTIONS	SPACE	WATER	TOTAL	CO_2	SAP
BASE DESIGN	294.79	155.87	450.66	5	57
1. BASE + FABRIC MOD.	234.43	155.87	390.3	4.26	64
2. BASE + HEATING MOD.	225.44	155.87	381.31	4.15	65
3. BASE + HOT WATER MOD.	309.02	103.47	412.49	4.53	62
4. BASE + HEATING AND HOT WATER MOD.	236.3	103.47	339.77	3.64	71
5. BASE + VENT. MOD.	272.64	155.87	428.51	4.73	60
6. BASE + FABRIC AND VENT. MOD.	184.16	155.87	340.03	3.65	71
7. BASE + SOLAR MOD.	267.87	155.87	423.74	4.67	60
8. FINAL MODIFICATIONS Fabric/Solar/Vent. Heating/Hot Water	151.1	103.47	254.57	2.6	86
SPACE/WATER/TOTAL: COSTS £ YEAR					

Figure 4: SAP Rating Chart for Property C.

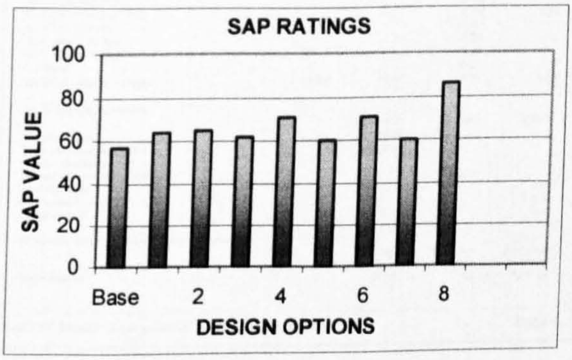


Figure 5: CO_2 Emission Chart for Property C.

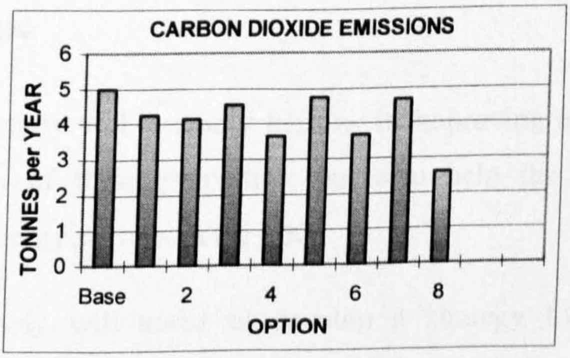


Figure 6: Total Energy Costs Chart for Property C.

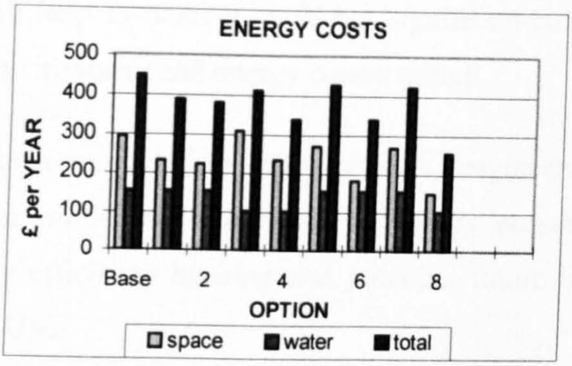
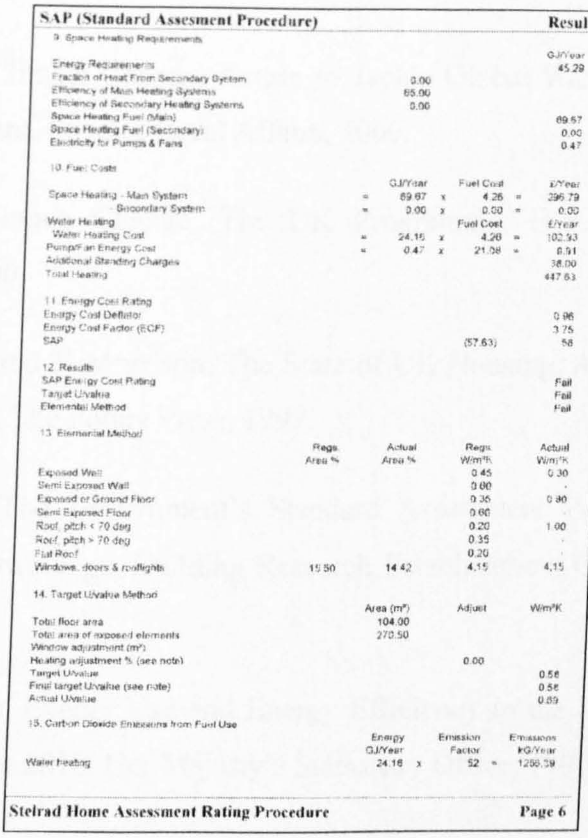


Figure 7: Sample Sheet of Stelrad Home Assessment Rating Procedure Results.



SAP (Standard Assesment Procedure) **Results**

9. Space Heating Requirements

		GJ/Year
Energy Requirements		45.29
Fraction of Heat From Secondary System	0.00	
Efficiency of Main Heating Systems	65.00	
Efficiency of Secondary Heating Systems	0.00	
Space Heating Fuel (Main)		69.57
Space Heating Fuel (Secondary)		0.00
Electricity for Pumps & Fans		0.47

10. Fuel Costs

		GJ/Year		Fuel Cost		£/Year
Space Heating - Main System	=	69.67	x	4.26	=	296.79
- Secondary System	=	0.00	x	0.00	=	0.00
Water Heating				Fuel Cost		£/Year
Water Heating Cost	=	24.15	x	4.26	=	102.93
Pump/Fan Energy Cost	=	0.47	x	21.08	=	9.91
Additional Standing Charges						38.00
Total Heating						447.63

11. Energy Cost Rating

Energy Cost Deflator		0.96
Energy Cost Factor (ECF)		3.75
SAP	(57.63)	58

12. Results

SAP Energy Cost Rating	Fail
Target U/value	Fail
Elemental Method	Fail

13. Elemental Method

	Regs. Area %	Actual Area %	Regs. W/m²K	Actual W/m²K
Exposed Wall			0.45	0.30
Semi Exposed Wall			0.60	-
Exposed or Ground Floor			0.35	0.80
Semi Exposed Floor			0.60	-
Roof, pitch < 70 deg			0.20	1.00
Roof, pitch > 70 deg			0.35	-
Flat Roof			0.20	-
Windows, doors & rooflights	15.50	14.42	4.15	4.15

14. Target U/value Method

	Area (m²)	Adjust	W/m²K
Total floor area	104.00		
Total area of exposed elements	270.50		
Window adjustment (m²)			
Heating adjustment % (see note)		0.00	
Target U/value			0.58
Final target U/value (see note)			0.58
Actual U/value			0.89

15. Carbon Dioxide Emissions from Fuel Use

	Energy GJ/Year		Emission Factor		Emissions KG/Year
Water heating	24.16	x	52	=	1256.39

Stelrad Home Assessment Rating Procedure **Page 6**

6. CONCLUSION

The results of this study will not only help us in improving energy efficiency and increasing standards of these properties, but also help the potential for future improvements and energy savings in the UK.

Furthermore, the study will assist to develop a strategy for energy efficiency improvements in private housing sector in Sheffield and therefore accelerate the necessity of improvements and consultancies in housing sector within the country.

On the whole, it will help to make a small-but significant-contribution to the well being of the global environment and energy conservation.

This survey is again a reminder for all architects, engineers, project managers, consultants and other professionals involved in energy conservation to grasp the importance of energy efficiency housing and potential future improvements within housing sector in the UK.

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